THE CONVERGENCE OF INDUSTRY 4.0 AND 5.0 WITH ENVIRONMENTAL EDUCATION THROUGH ARTIFICIAL INTELLIGENCE: A REVIEW

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Abstract: The escalating ecological challenges confronting our planet necessitate innovative approaches to education and problem-solving. Environmental Education (EE) has become a paramount concern, engendering a deeper realization of the impact human actions exert on the natural world. At the same time as, artificial intelligence (AI) emerges as a transformative technology with the potential to revolutionize myriad sectors, including education. This article delves into the synthesis of environmental education and AI, exploring how the latter can amplify the former's efficacy and reach, thereby fostering a more sustainable future. The incursion of Industry 4.0 has given rise to a transformational period distinct by automation and data exchange in manufacturing technologies. Following to this, Industry 5.0 emerges, reintroducing human ingenuity alongside smart systems. This paper conducts a widespread literature review to elucidate the roles of AI and EE within these industrial shifts for fostering sustainable practices. The connection of these domains holds the potential for innovation in preserving our natural tradition.

Keywords: Industry 4.0 and 5.0; Artificial Intelligence; Environmental Education; Sustainability; Innovation.

Resumo: Os crescentes desafios ecológicos que nosso planeta enfrenta exigem abordagens inovadoras para a educação e a resolução de problemas. A Educação Ambiental (EA) tornou-se uma preocupação primordial, gerando uma compreensão mais profunda do impacto que as ações humanas exercem sobre o mundo natural. Ao mesmo tempo, a inteligência artificial (IA) emerge como uma tecnologia transformadora com potencial para revolucionar inúmeros setores, incluindo a educação. Este artigo analisa a síntese entre Educação Ambiental e IA, explorando como esta última pode ampliar a eficácia e o alcance da primeira, promovendo assim um futuro mais sustentável. A incursão da Indústria 4.0 deu origem a um período de transformação caracterizado pela automação e pela troca de dados nas tecnologias de manufatura. Em seguida, surge a Indústria 5.0, reintroduzindo a engenhosidade humana juntamente com os sistemas inteligentes. Este artigo realiza uma ampla revisão bibliográfica para elucidar os papéis da IA e da EA nessas mudanças industriais para o fomento de práticas sustentáveis. A conexão entre esses domínios possui potencial para inovação na preservação de nossa tradição natural.

Palavras-chave: Indústria 4.0 e 5.0; Inteligência Artificial; Educação Ambiental; Sustentabilidade; Inovação.

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Introduction

As the world grapples with pressing environmental issues such as climate change, biodiversity loss, and resource diminution, the role of education in cultivating an informed and conscientious community cannot be overstated. EE aims to equip individuals with the knowledge, skills, attitudes, and values necessary to act as agents of change for environmental development and protection. In this scenario, AI has the opportunity to serve as a influential collaborator, providing innovative tools and methodologies to enrich educational experiences and outcome.

Environmental concerns are at the pinnacle of global priorities, necessitating immediate and innovative approaches to ensure sustainability and preservation. As we stand on the brink of the Fourth and Fifth Industrial Revolutions, the integration of environmental education within these paradigms has become crucial. This article reviews the literature to explore how artificial intelligence can act as a conduit for environmental awareness and practices, culminating in a sustainable industrial future

In the contemporary landscape of technological advancements, innovation serves as the cornerstone of progress across various industries. A highly influential domain within this sphere is the recognition of EE, which are a form of intellectual property rights that designate products with qualities or reputations stemming. The integration of AI into this sector has the potential to enhance the materialization of innovations and effectively supervise GI-protected products.

By align education with the advent of advanced technologies; individuals can develop a deeper understanding of how to engage with these technologies responsibly and sustainably. Education programs must evolve to incorporate information on new technologies, sustainability, and environmental principles, equipping people with the knowledge to make environmentally beneficial decision.

Ultimately, the challenge lies in fostering an environmental realization and sustainable development attitude from the early stages of education. This must then translate into practical solutions that not only cater to economic growth and technological advancements but also prioritize the health of our planet. Implementing well-read policy, investing in education that bridges the space between innovation and environmental stewardship, and promoting cross-sector collaborations are fundamental stepladder towards a harmonious and sustainable future.

Environmental concerns are at the summit of global priorities, necessitating immediate and innovative approaches to ensure sustainability and preservation. As we stand on the brink of the Fourth and Fifth Industrial Revolutions, the integration of environmental education within these paradigms has become decisive. This article reviews the literature to explore how artificial intelligence can act as a conduit for environmental awareness and practices, culminating in a sustainable industrial future.

Materials and Methods

The approach to intertwine innovation, geographical indication, and AI begins by collecting expansive datasets relating to EE products. AI algorithms are then employed to analyze these data sets, identifying patterns and insights that human analysis might overlook. The methodology includes utilizing machine learning techniques to predict market trends for GI products, assessing consumer sentiment, and optimizing supply chain logistics to protect the integrity of these unique items.

Advanced data analytics tools are used to scrutinize the complex relationships between geographical location, environmental factors, and the distinctive characteristics of EE products. EE mapping technology is also integrated to visually represent the connections between EE products and their origin, providing a comprehensive view of their environmental relevance.

The Role of AI in Environmental Education

Artificial intelligence can revolutionize environmental education in several ways. Firstly, AI-driven analytics can facilitate personalized learning experiences by adapting content to meet the unique needs and learning paces of individuals. AI can identify patterns in a student's interaction with educational materials, providing modified resources that reinforce strengths and address weaknesses.

Secondly, AI can assist in creating immersive educational ecosystems using virtual and augmented reality. Such technologies can simulate real-world environmental scenarios, allowing learners to witness the consequences of certain actions or policies without any real-world risk. This experiential learning can foster empathy and a profound understanding of environmental issues, potentially triggering more substantial and persistent behavioral changes.

Moreover, AI contributions to research in environmental sciences can provide up-to-date, accurate information for educational content, ensuring that what is taught reflects the latest scientific consensus and discoveries. Access to cutting-edge AI tools for data analysis and modeling can also inspire innovative problem-solving approaches within the field, which can be integrated into curriculum design.

The AI fast growth and its broad impact on various sectors need an evaluation of its effect on the accomplishment of the sustainable development goals (SDGs). AI is the biggest influence on the global economy. AI plays a very important role in achieving environmental sustainability-from ending hunger and poverty to achieving sustainable energy and gender equality for the protection and preservation of biodiversity. The SDGs are divided into three categories namely society, economy, and environment (Kumari e Pandey, 2023). This division allows us to come up with an overview of the general impact areas of AI. AI finds application in a wide array of environmental sectors, which include natural resource conservation, energy management, wildlife

protection, pollution control and agriculture, clean energy, and waste management (Figure 1).

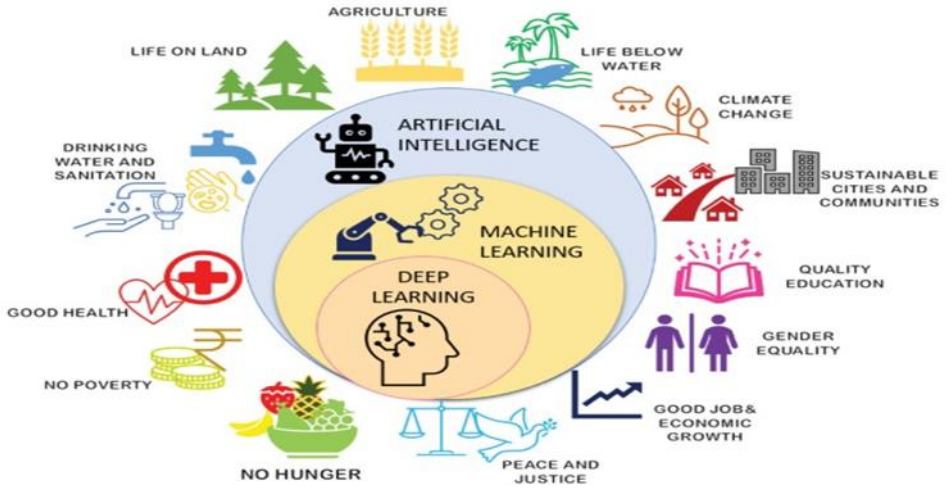

Figure 1: Artificial Intelligence (AI) fast growth and its broad impact on various sectors need an evaluation of its effect on the accomplishment of the sustainable.
Source: (Kumari e Pandey, 2023).

Challenges and Reproduction

The integration of AI into environmental education does not come without its challenges. There is a pressing need to address issues related to accessibility and equity, particularly in underfunded and marginalized communities that may lack the requisite technology and infrastructure. Additionally, educators must receive proper training to utilize AI tools effectively and ethically, ensuring that the technology is a means of enhancing human-led instruction, not replacing it.

Furthermore, as we meld AI with environmental education, we must uphold data security and privacy principles, especially when it comes to the personal information of students. Transparent algorithms are critical to prevent biases in educational AI systems which could perpetuate inequalities (Kumari e Pandey, 2023).

As big data, machine learning, and artificial intelligence continue to gain prominence in information technology, experts are raising concerns about the environmental costs of computation - primarily data and AI's carbon footprint and greenhouse gas emissions (Figure 2). The problem is showing no signs of slowing down. As a result of the Covid-19 pandemic, data and AI deployment increased exponentially as the demand for digital transformation increased (Marr, 2023).

Figure 2: Green Intelligence: why data and AI must become more sustainable.
Source: Marr (2023).

Industry 4.0 and Environmental Consciousness

Industry 4.0 marks the onset of cyber-physical systems and the Internet of Things (IoT), encouraging smart manufacturing. An extensive review of the literature reveals that AI's role in Industry 4.0 extends to optimizing source consumption and reducing waste, significant for environmental preservation (Ghobakhloo et al., 2024). However, merely employing technology does not suffice. Integrating environmental education within Industry 4.0 becomes imperative to fortify the workforce with the skills necessary to leverage these technologies for sustainable out comes (Mangla et al., 2024).

Industry 4.0, also identified as the Fourth Industrial Revolution, encompasses a broad system of advanced technologies such as artificial intelligence, robotics, etc (Ghobakhloo et al., 2024). As of July 13, 2023, these innovations continue to permeate various sectors such as education, technology, services, and, of course, the domains of environmental, economic, and social impact. Augmented Reality and Artificial Intelligence are now being applied within these fields to further enhance efficiency and engagement (Figure 3).

Sustainable manufacturing transcends the goal of merely reducing carbon footprints, embodying a holistic approach to production. This paradigm shift incorporates energy-efficient processes and the integration of renewable energy sources like solar and wind, significantly cutting greenhouse gas emissions while also reducing operational costs (Ghobakhloo et al., 2024). The adoption of eco-friendly materials is also paramount, with a focus on biodegradable, recycled, or sustainably sourced inputs, reflecting a commitment to minimizing environmental

impact across product life cycles (Mangla et al., 2024). Recycling and reusing materials are crucial, with closed-loop systems reprocessing dissipate back into production, enhancing resource efficiency. This extends to responsible supply chain management, where manufacturers select supplier based on their environmental practices, promoting broader ecological responsibility (Figure 4). This comprehensive approach to sustainability is not just environmentally driven but also an economic and ethical strategy. It aligns with increasing consumer demand for responsible products and prepares businesses for future environmental regulations, thus securing their long-term viability and commitment to protecting future generation (Mangla et al., 2024).

Figure 3: Industry 4.0. Overcoming workforce challenges with technology.
Source: (Mangla et al., 2024); (Ghobakhloo et al., 2024).

Figure 4: Sustainable manufacturing, not only net zero.
Source: (Mangla et al., 2024); (Ghobakhloo et al., 2024); (Kkumar, 2024).

The digital manufacturing landscape is witnessing a significant trend: the rise of Generative AI. This cutting-edge technology is revolutionize how products are designed, developed, and deliver (Kumar, 2024). Generative AI refers to algorithms that can generate new data similar to the data they were trained on, enabling them to create everything from optimized product designs to efficient manufacturing processes. In the realm of digital manufacturing, this translates to AI systems that can design parts, predict optimal material combinations, and even simulate entire production processes before a single physical prototype is made (Kumar, 2024). This not only accelerates the product development cycle but also reduces costs and waste, as manufacturers can foresee and rectify potential issues in the virtual realm. Generative AI is fostering a new era of customization.

Transition to Industry 5.0: a Synergy of Automation and Human Expertise

While Industry 4.0 focuses on technological advances, Industry 5.0 is heralded by its human-centric approach. Literature indicates that Industry 5.0 caters to personalization and societal well-being. It is here that AI, combined with human creativity and environmental ethics, is set to play a pivotal role (Kar; Choudhary; Singh, 2022). The knowledge from environmental education can inform AI systems to recognize, adapt, and innovate for environmental preservation amidst industrial activities.

Industry 5.0, with its focus on human-centric production, highlights the significance of collaboration between humans and machines. It advocates for a tailored approach to production that embraces digital craft smart ship and leverages technology to protect the environment (Figure 5).

The major requirement for full adoption of any industrial revolution is law and regulations. Although standards for automation, innovation policy and industry policies are available in general, the more specific standard for this new era must been forced (Maddikunta et al., 2022). As Industry 5.0 a bring back the human work force to share and work to get the mart machines, various regulations pertaining to both the human and cobot must be devised (Kar; Choudhary; Singh, 2022). Several issues may arise without proper regulation saddle gal policies inthisco-production environment. Regulations ford sting gushing cobot from other machines like drones must be enforced. Also, regulations which will inculcate use of AI, cobots, other machines in manufacturingindustry should be devised for better predictions and sophistication co-production (Maddikunta et al., 2022).The better standards, laws, guide line sand stand adds will make the adoption faster, complete and moor emanate able (Figure 5).

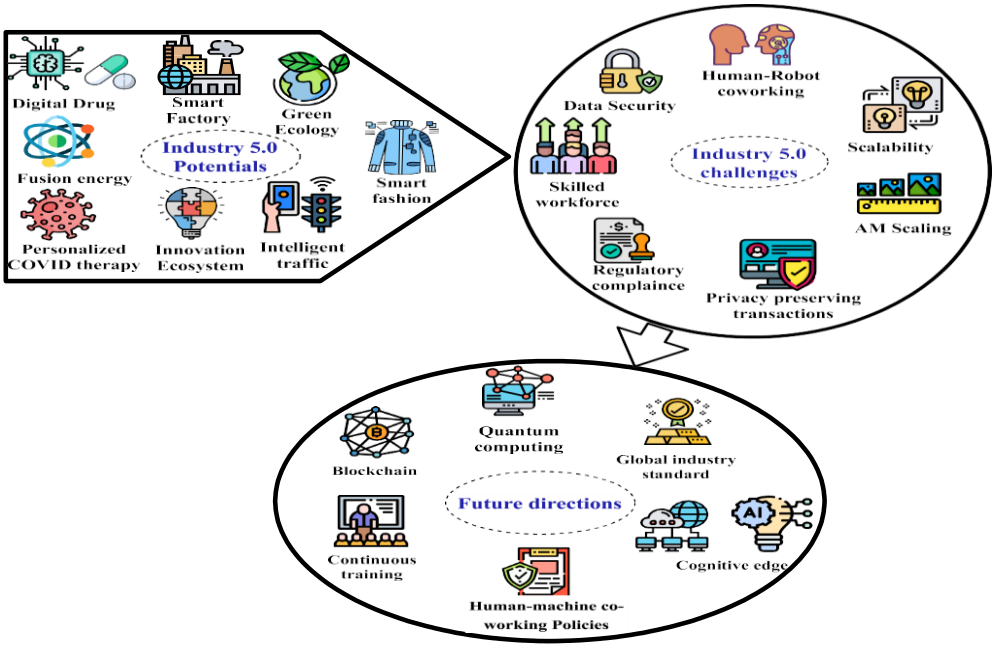

Figure 5: Industry 5.0 potentials, challenges and future directions.
Source: (Maddikunta et al., 2022).

Innovation in Environmental Preservation through AI

AI's capability for large data analysis and predictive analytics opens vast opportunities in environmental management. The literature points to innovative applications such as smart energy grids, precision agriculture, and sustainable supply chains, all underpinned by AI's prowess (Pham, et al., 2024). These innovations are instrumental for ensuring compliance with environmental standards and fostering a culture of conservation within industries (Xu et al., 2021).

Our literature review suggests that the harmonization of environmental education with artificial intelligence in the context of Industry 4.0 and 5.0 sparks a new era of eco-innovation (Kar; Choudhary; Singh, 2022). Such innovation is not merely a technological infiltrate but a paradigm shift that encapsulates human intellect, ethical considerations, and the relentless pursuit of environmental preservation. Therefore, it is essential for policymakers, educational institutions, and industry stakeholders to collaboratively cultivate a framework that intertwines these critical elements for a sustainable opportunity (Abulibdeh; Zaidan; Abulibdeh, 2024).

By March 19, 2024, it has become evident that these technological advancements bring valuable contributions to the industrial sector by minimizing environmental impacts and optimizing resource utilization (Kar; Choudhary; Singh, 2022). Artificial Intelligence and Big Data analysis, particularly, facilitate real-time data examination; enable smarter and more sustainable decision-making processes (Pham, et al., 2024).

AI models can be difficult to interpret and explain which can make it difficult for organizations to understand how decisions are made. It is important to ensure that AI and EE models are transparent and explainable (Abulibdeh; Zaidan; Abulibdeh, 2024). To address this challenge, organizations should implement interpretability and explainability controls such as feature importance analysis and model visualization tools. Figure 6 shows the challenging elements of interpretability and explainability.

Artificial intelligence has become an integral part of modern society, with its influence seen in various domains, including healthcare, finance, transportation, EE and many othersManikandan et al., 2024). The rise of AI has been largely driven by advances in machine learning and deep learning techniques, which have demonstrated impressive results in solving complex problems. However, these techniques have also given rise to black-box models, characterized by their lack of interpretability and explainability (Pham, et al., 2024), (Figure 6).

Figure 6: “black-box” models, characterized by their lack of interpretability and explainability
Source: Aldoseri; Al-Khalifa; Hamouda (2023).

The computer vision system scans each berry on the plant and determines the ripeness and health before harvesting. Plantix, the crop damage diagnosis mobile application (Plantix) developed by German startup PEAT (Progressive Environmental and Agricultural Technologies), uses deep learning and computer vision to help farmers to combat pests and diseases (Kar; Choudhary; Singh, 2022). The application’s functionality enables the end-user to upload crop images and get guidance on the disease affected, symptom descriptions, treatment information, preventive measures, EE etc. With the same objective of identifying a large number of plant diseases, other applications. Scholarship farming senteringaf ou revolution, term agriculture 4.0 ors mart agriculture, benefiting from the arrival of the big data era swell asteroid progress flotsof advanced technologies (Xu et al. 2021), in particular Machine (ML), modern information, and communication technologies. Application Sof Deep Learning (DL), information, and sensing technologies in agriculture covert hew stage Sof agricultural production, including breeding, cultivation, and harvesting (Figure 7).

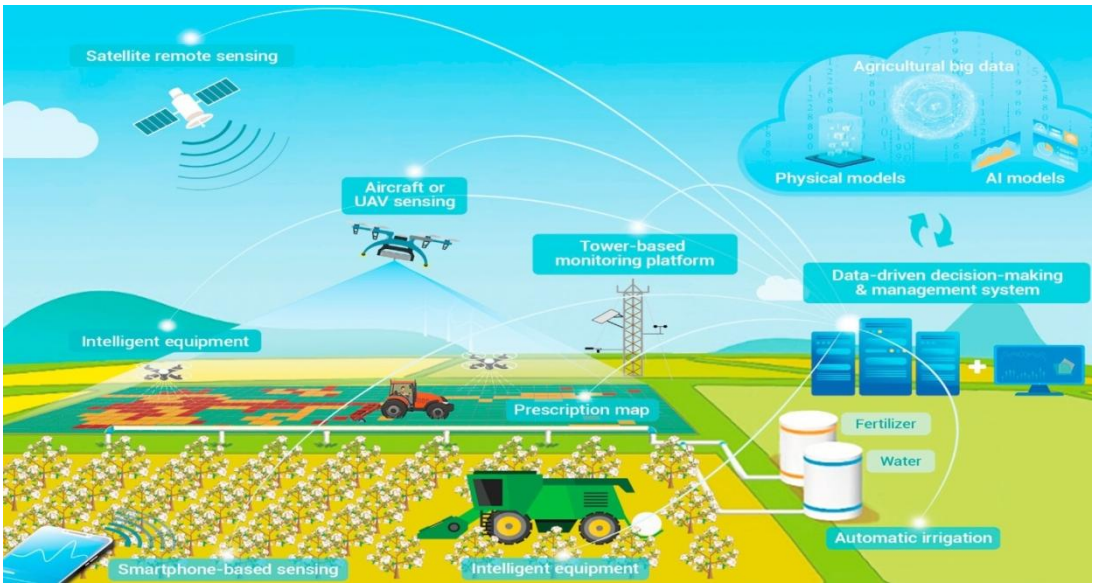

Figure 7: Artificial intelligence in Environmental Management and Agricultural.
Source: (Xu et al. 2021).

Environmental Education as the Catalyst for Change

A profound understanding of the challenges facing our environment is needed to navigate through the technological advancements of Industry 4.0 and 5.0. EE emerges as a fundamental strategy to empower individuals with knowledge and ethics (Singh, Goyal, 2023). The literature advocates for comprehensive environmental curriculum that can be integrated into industrial training program, thereby creating a skilled workforce committed to sustainable practices (Meng; Xu; Zhang, 2022).

The Figure 8 show an overview of the evolution of Industrial 5.0.The development time for the firs three revolutions was around 100 years, and 40 year store ach the fourth from the third (Maddikunta et al., 2022). In1800s, Industry 1.0 evolved through the development of mechanical production infrastructures for water and steam-powered machines (Meng; Xu; Zhang, 2022).There is a massive gain in the economy as production capacity has increased. Industry 2.0 evolved in the year of 1870 with the concept electric power and assembly line production. Industry 2.0 focused primarily on mass production and is distribution of workloads, which better the productivity of manufacturing companies (Maddikunta et al., 2022). Industry 3.0 evolved in 1969 with the concept of electronics, partial automation and information technologies. Industry 4.0 evolved in 2011 with the concept of smart manufacturing for the future (Maddikunta et al., 2022). The main objective is to maximize productivity and achieve mass production using emerging technologies. Industry 5.0 is future evolution designed to use the creativity of human expertsworking together with efficient, intelligent and accurate machines with presents a summary of important survey son Industry 5.0 (Singh; Goyal, 2023).

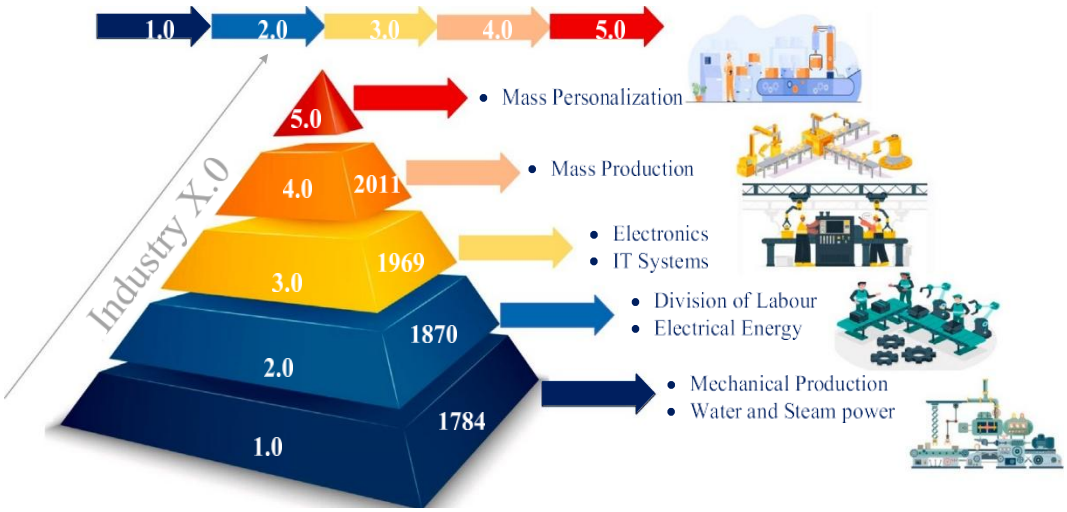

Figure 8: Illustration of industrial evolution.
Source: (Maddikunta et al., 2022).

In summary, the integration of EE with the innovations of Industry 4.0 and 5.0 has the potential to lead to a more sustainable development model. However, achieving this requires policies that encourage sustainable practices, investment in quality education, and collaboration between the technological and environmental sectors (David et al., 2022). This collaboration promotes innovation while preserving the environment for future generations. The confluence of EE and AI holds immense potential for educating future generations about the significance of sustainable living and environmental stewardship (Bao; Xie, 2022). As we harness the power of AI to personalize learning and present complex environmental concepts in accessible formats, we step closer to a society deeply attuned to the rhythms of the natural world and committed to its preservation (Meng, Xu, Zhang, 2022). By approaching this intersection with care, foresight, and a commitment to equity, we can unlock ground breaking educational paradigms that foster a harmonious coexistence with our planet (Marques e Nikolodi, 2021).

EE and AI can be connected in many ways

EE and AI can be connected in many ways to promote sustainability and understanding of environmental issues. Below are some ways in which AI can be applied in EE (Table 1).

Table 1: EE and AI can be connected in many ways to promote sustainability.

Artificial Intelligence method	EE
Adaptive Learning Platform. AI can be used to create educational platforms that adapt to the user's learning style.	Students receive personalized content that helps them better understand environmental topics.
Simulações Realistas. estudantes podem experienciar simulações ambientais altamente interativas,	Mudanças climáticas e seus impactos em diferentes ecossistemas, o que seria impraticável na realidade.

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