Chapter 7
A Bibliometric Review of AI-Driven Green Education Using the Four-in-Balance Framework for Sustainable Learning Environments

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ABSTRACT

This chapter provides a thematic and bibliometric review of the use of artificial intelligence (AI) in education to promote green learning environments and sustainability. We used VOSviewer to map research trends and collaborative clusters in accordance with SDG 4.7 under the Four-in-Balance model: Vision, Infrastructure, Digital Content, and Competencies. The literature showed rapid expansion in

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learning analytics and e-learning; sustainability and the SDGs; higher education's institutional reform and digital adoption; and emerging technologies, including big data, generative AI, and Industry 4.0. The results show uneven progress: Vision and Competencies lag, leading to fragmented, reactive adoption, while Infrastructure and Digital Content have improved, including intelligent tutoring, IoT-enabled classrooms, and adaptable resources. Few institutions incorporate environmental goals into strategy, and persistent gaps in AI literacy and sustainability skills limit responsible use.

INTRODUCTION

21st-century skills are crucial, along with traditional academic knowledge, for preparing children for a competitive future(Rehman, Huang, Mahmood, AlGerafi, et al., 2024). Artificial intelligence (AI) is reshaping education by enabling personalized learning and data-driven decision-making (S. Javed, Y. Rong, & B. N. Abbasi, 2024). At the same time, growing environmental crises underscore the urgency of sustainability education, which seeks to foster knowledge, skills, and values for a more equitable future (Unesco, 2020). While AI is widely recognized as a transformative force, its role in advancing sustainability within education remains underexplored (Kalim et al., 2025; Vinuesa et al., 2020; Zafeer et al., 2021). This chapter positions AI not merely as a technological tool but as a potential catalyst for integrating ecological responsibility into teaching, learning, and institutional practices.

There has never been a more urgent moment to align technological modernization with environmental sustainability. As systems pursue SDG 4.7 inclusive, equitable education that fosters sustainable development, global citizenship, and environmental awareness, recent work shows AI's potential is still underused for ecological goals (Akinsemolu, 2025; Vinuesa et al., 2020; Zafeer, Maqbool, et al., 2022). This chapter argues that AI can redefine environmental education by integrating sustainability into infrastructure, pedagogy, content, and capacity building, transforming not only what we teach but how institutions operate and how learners engage. Realizing this promise requires a policy and evaluation approach that goes beyond isolated pilots (Maqbool, Sarwar, et al., 2020; Zafeer et al., 2020).

In this sense, the Four-in-Balance model originally developed to analyze ICT integration (Sufyan Maqbool et al., 2024), offers a structured lens to evaluate whether AI advances inclusive and sustainable learning environments. Yet few studies examine the AI-environmental literacy intersection through such an evaluative frame; most treat AI integration and green education as separate paradigms, leading to fragmented implementations and policy guidance. By conducting a bibliometric +