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Mapping the Global Research Landscape of Problem-Based Learning in Digital Learning Environments: A Bibliometric Analysis Toward Achieving SDG 4

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ABSTRACT

Objective: *The study aims to map the global research landscape of Problem-Based Learning (PBL) in Digital Learning Environments (DLE) using a bibliometric approach. The objective is to identify publication trends, major contributors, collaboration patterns, and emerging research themes supporting the development of sustainable digital education aligned with Sustainable Development Goal 4 (SDG 4).* ***Method:*** *The analysis was conducted on 2,134 documents retrieved from the Scopus database covering publications up to 2025. Data preprocessing involved duplicate removal, document filtering, and keyword harmonization. Bibliometric analysis employed performance indicators (annual publications, productive authors, sources, affiliations, and countries) and science mapping techniques (co-authorship, keyword co-occurrence, and citation analysis) using Bibliometrix and VOSviewer to visualize the intellectual structure of the field.* ***Results:*** *The findings reveal a substantial growth of research in this field, particularly following the global acceleration of digital education. China and the United States dominate research productivity, followed by emerging contributions from countries such as Indonesia. Publication sources are largely dominated by conference proceedings and journals in educational technology and computer science, highlighting the field's interdisciplinary nature.* ***Novelty:*** *This study provides a comprehensive mapping of the intellectual structure and thematic evolution of PBL research in Digital Learning Environments. It identifies research gaps, including limited international collaboration and the need for greater integration of emerging technologies such as artificial intelligence. The findings offer directions for future research to strengthen sustainable digital learning innovation and support the achievement of SDG 4.*

INTRODUCTION

Digital transformation in education is no longer merely an additional innovation but has become a fundamental necessity for ensuring the sustainability of the global education system. This transformation reflects the growing demand for educational systems to adapt dynamically to technological advancements to remain relevant to the needs of a knowledge-based society and the future workforce's competencies. In the context of Society 5.0, where digital technologies such as artificial intelligence, big data, and the Internet of Things are integrated to create human-centered solutions, education plays a crucial role in preparing learners with the digital literacy, critical thinking, creativity, and problem-solving skills required to thrive in an increasingly technology-driven world.

Various studies show that the integration of digital technology in education can increase learning flexibility, expand access to education across regions, and support the

development of 21st-century skills such as critical thinking, collaboration, communication, and digital literacy, which are key competencies in the era of digital transformation (Gao et al., 2024; Poonsawad et al., 2022; Nnamdi et al., 2025; Ríos-Muñoz et al., 2025). Advances in educational technology have led to the emergence of Digital Learning Environments (DLE) that integrate technology, pedagogy, and digital interaction into structured learning systems. Studies indicate that DLEs can enhance student engagement, interaction, and learning effectiveness (Oliver et al., 2024; Gao et al., 2024; Astuti, 2026; Handikaningtyas, 2024). Despite their widespread adoption, evidence of their effectiveness in fostering meaningful learning outcomes and higher-order thinking skills remains inconsistent across educational contexts. This issue highlights the need for further investigation to understand better the role of DLEs in improving educational quality.

In addition, the transformation of digital learning requires a shift in pedagogical approach from teacher-centered to student-centered learning. This shift is important because future learning will be oriented not only towards content mastery but also towards students' complex thinking and adaptive abilities. Various studies show that the student-centered learning approach improves deep learning, conceptual understanding, and higher-order thinking skills compared to traditional learning approaches oriented toward knowledge transfer (Gao et al., 2024; Nnamdi et al., 2025; Poonsawad et al., 2022). In this context, Problem-Based Learning (PBL) has become one of the most relevant pedagogical approaches for supporting the transformation of modern learning, as it focuses on real-world problems and encourages students' analytical and reflective abilities. PBL provides space for students to develop knowledge through investigation, discussion, and reflection on authentic problems. Empirical research shows that Problem-Based Learning can improve critical thinking, problem-solving, and analytical reasoning through contextualized problem-based learning that requires learners' active involvement in the learning process (Firmansyah, 2025; Rachman, 2025; Haikal, 2025; Nnamdi et al., 2025).

In addition to improving cognitive abilities, Problem-Based Learning also plays a role in developing independent learning skills, which are important competencies in modern education. This approach encourages students to develop self-directed learning through a structured inquiry process based on knowledge exploration. Recent research shows that implementing PBL can improve self-regulated learning, collaborative problem-solving skills, and students' ability to adapt to the complexity of real-world problems (Eminita, 2026; Haikal, 2025; Poonsawad et al., 2022; Ríos-Muñoz et al., 2025). The integration of Problem-Based Learning in Digital Learning Environments is a strategic approach to creating innovative learning relevant to the educational needs of the future. This combination enables the creation of technology-based learning that is not only interactive but also contextual and based on real experiences. Recent research shows that the integration of PBL with digital technologies such as simulation tools, collaborative digital platforms, and interactive multimedia can significantly improve learning motivation,