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e-ISSN 3109-3310
Vol. 2, No.1, March 2026

Problem Based Learning in Digital and Virtual Science Learning Environments

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DOI : https://doi.org/10.63230/jolabis.2.1.135

Sections Info
Article history:
Submitted: March 9, 2026
Final Revised: March 28, 2026
Accepted: March 29, 2026
Published: March 31, 2026

Keywords:
Digital;
Learning;
PBL;
Science;
Virtual.

ABSTRACT

Objective: *This study aims to analyze research trends in Problem-Based Learning (PBL) in digital and virtual science learning environments during the period 2015–2025. The analysis focuses on identifying dominant research themes, mapping the structure of the research field, and examining the evolution of research on the integration of digital technologies in science learning.* ***Method:*** *This study employed a bibliometric analysis of publications indexed in the Scopus database. The article selection process followed the PRISMA guidelines, yielding 101 documents for analysis. The study examined keyword co-occurrence, citation patterns, and thematic structures. Network, overlay, and density visualizations were conducted using VOSviewer to explore relationships between keywords and the temporal development of research topics.* ***Results:*** *The findings indicate that research on PBL in digital and virtual science learning is structured around core themes such as problem-based learning, students, e-learning, and virtual reality, which show strong interconnections. The temporal analysis reveals a shift from general educational contexts toward the integration of digital and immersive technologies, including virtual reality, augmented reality, and artificial intelligence. In addition, density and citation analyses highlight the central role of digital technology in shaping contemporary PBL research. In contrast, emerging topics such as machine learning and digital twins remain less explored.* ***Novelty:*** *This study provides a comprehensive bibliometric mapping of the convergence between PBL and digital–virtual technologies in science learning, revealing a conceptual shift toward intelligent and immersive learning environments and identifying emerging research opportunities.*

INTRODUCTION

The rapid development of digital technology over the past decade has created significant opportunities to improve the quality of learning, including science education (Q. Wang et al, 2021). Digital technologies enable more interactive learning experiences through the integration of multimedia, simulations, and diverse online learning resources (Bond et al, 2021; Peng et al, 2023). Furthermore, the use of digital and virtual technologies allows students to visualize abstract scientific concepts and explore phenomena that are difficult to observe directly in conventional classroom settings (Dede et al, 2017). In addition, the development of educational technology supports the creation of more flexible and adaptive learning environments that can better accommodate students' learning needs. In the context of modern education, science learning is expected to shift from teacher-centered to student-centered approaches that emphasize exploration, collaboration, and problem-solving (Makransky et al., 2019).

However, the implementation of digital technology in science learning has not always led to optimal improvements in the quality of the learning process (Al-Emran et al., 2022). In many cases, technology is used merely to deliver instructional materials, without fundamentally transforming traditional teaching approaches. As a result, educators do