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Global Trends and Research Directions in Technology Integration in Physics Education for SDG 4: A Bibliometric Analysis (2016–2025)

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ABSTRACT

Objective: This study examines the development and research potential of technology integration in physics education related to Sustainable Development Goal 4 (SDG 4) from 2016 to 2025. By mapping global scientific publications, this study identifies research trends, collaboration patterns, and emerging technological innovations that support inclusive and high-quality physics education. **Method:** A bibliometric analysis, combined with a systematic literature review following the PRISMA protocol, was employed. Data were retrieved from the Scopus database, resulting in 27,322 documents published between 2016 and 2025. After applying PRISMA screening stages – identification, screening, eligibility, and inclusion – 5 articles were selected for detailed analysis. Bibliometric mapping was conducted using VOSviewer and Bibliometrix (R-package) to visualize publication growth, author productivity, collaboration networks, and keyword co-occurrence. **Results:** The results indicate a significant increase in publications on technology-based physics learning, particularly after 2021, reflecting accelerated digital transformation in science education. The United States, India, China, and Indonesia are the most productive countries, demonstrating global participation in this research area. Keyword analysis highlights “education,” “sustainable development,” “engineering education,” and “technology” as dominant themes. At the same time, emerging topics such as “machine learning” and “augmented reality” indicate growing interest in advanced digital tools for physics learning. **Novelty:** This study provides a comprehensive bibliometric mapping of technology integration in physics education within the SDG 4 framework. It identifies future research directions involving artificial intelligence, immersive learning technologies, and innovative digital pedagogies.

INTRODUCTION

Education is a fundamental pillar of sustainable development because it directly improves human quality of life and strengthens national competitiveness. Within the global development agenda, the Sustainable Development Goals (SDGs) highlight SDG 4 as a critical objective to ensure inclusive, equitable, and high-quality education for all (Ferrer-Estévez & Chalmeta, 2021; Masuda et al., 2022; Saini et al., 2023). Achieving this goal requires continuous innovation in teaching and learning processes so that education systems can respond effectively to the demands of the 21st century, including the development of critical thinking, creativity, and problem-solving skills.

Physics education plays a particularly important role in this context because it fosters analytical reasoning and scientific literacy, which are essential for addressing global challenges in science, technology, and sustainability (Awwalina et al., 2025; Wahab et al., 2025). Unlike many other disciplines, physics often involves abstract concepts that require visualization, experimentation, and conceptual modeling. As a result, the integration of digital technologies such as simulations, virtual laboratories, artificial