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Teachers' Understanding of STEM Education in Secondary Schools: A Systematic Literature Review and Bibliometric Mapping Towards SDG 4

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ABSTRACT

Objective: The study aims to map research on teachers' STEM understanding in secondary education, identify major themes and emerging trends, and examine research gaps related to teacher competence and STEM implementation across junior and senior secondary education. **Method:** A systematic literature review and bibliometric analysis were conducted on studies published between 2010 and 2025. Following the PRISMA framework, 884 records were initially identified, of which 144 studies met the inclusion criteria. The analysis covered keyword co-occurrence, thematic evolution, research density, geographical distribution, and qualitative synthesis of the selected studies. **Results:** The findings show that research has shifted from early attention to teachers' perceptions, attitudes, knowledge, and preparedness toward STEM pedagogical content knowledge, interdisciplinary competence, professional development, inquiry, engineering design, creativity, sustainability, and classroom implementation. STEM education, teacher training, professional development, and pedagogical content knowledge emerged as central themes. However, substantial gaps remain between teachers' STEM awareness, conceptual understanding, pedagogical readiness, and actual classroom implementation. Comparative studies between junior and senior secondary teachers also remain limited. **Novelty:** The study provides an integrated systematic and bibliometric mapping of teachers' STEM understanding across secondary education levels and highlights teacher competence as a potential bridge between quality education and sustainable development, particularly in relation to SDG 4, SDG 9, and SDG 13.

INTRODUCTION

STEM education has emerged as an important approach for developing interdisciplinary knowledge, problem-solving skills, creativity, and the capacity to address complex real-world challenges (English, 2023; Pinar et al., 2025; Sokolova et al., 2025). The increasing prominence of STEM education, teaching, teacher professional development, pedagogical content knowledge, and STEM identity in the research landscape indicates that teachers play a central role in determining the quality of STEM implementation (Hamad et al., 2022; Khuyen et al., 2020; Lin et al., 2025; Wu et al., 2022). Existing research demonstrates that teachers' understanding of STEM extends beyond conceptual awareness to include pedagogical competence, interdisciplinary integration, curriculum understanding, self-efficacy, and readiness to translate STEM principles into classroom practices.

Research trends further indicate a shift from examining teachers' perceptions, attitudes, knowledge, and preparedness toward investigating their capacity to implement integrated STEM through inquiry, engineering design, creativity, problem-based learning, and authentic learning experiences. The temporal visualization shows that recent studies increasingly emphasize integrated STEM education, engineering design, sustainability, motivation, and curriculum integration, particularly within middle and high school contexts (Kegels et al., 2026; Kopbossyn et al., 2025; Liu & Liu, 2025; Saseendran & Thomas, 2025; Zhan et al., 2022; Zhan & Niu, 2023). This development