

Evolution of Science Education Foundations in Indonesia: Trends, Paradigms, and Future Directions

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Abstract: This study explores the evolution of science education foundations in Indonesia from 2021 to 2025 through a literature review approach. It aims to identify key trends, dominant paradigms, and contextual influences shaping the development of science teaching and learning in Indonesian formal education. The analysis reveals a significant shift from positivist to constructivist epistemologies, with increasing emphasis on inquiry-based learning, Nature of Science (NoS), and student-centered pedagogies. Curriculum reforms, particularly under the *Merdeka Belajar* policy, have introduced more flexible and learner-driven frameworks. However, disparities in implementation, teacher readiness, and resource availability persist across regions. Emerging trends also highlight the integration of local and indigenous knowledge into science instruction as a means to enhance relevance and inclusivity. The findings suggest that while theoretical advancements are evident, sustained efforts are needed to align policy, practice, and professional development. This review contributes to understanding how foundational shifts in science education can inform future curriculum design, teacher training, and educational policy in Indonesia.

Keywords: Curriculum Reform; Foundational Change Pedagogical Paradigm; Science Education

Introduction

Science education serves as a fundamental pillar in cultivating scientific literacy, critical thinking, and innovation among learners, especially in the context of rapid technological and societal changes (Andersen et al., 2024; Fagerlund et al., 2025; Zhong & Liu, 2025). In Indonesia, the foundations of science education have undergone significant transformations over the past few decades, shaped by shifts in educational philosophy, curriculum policy, and pedagogical approaches (Leat & Whelan, 2023; Stephenson, 2025; Thind & Yakavenka, 2023).

These developments reflect broader global trends that emphasize student-centered learning, inquiry-based instruction, and the integration of science with real-world contexts (Saadé et al., 2025; Stephenson, 2025;

Wong et al., 2024). However, despite increasing scholarly attention to specific aspects of Indonesian science education—such as teaching strategies, assessment models, and curriculum implementation—there remains a lack of comprehensive analysis that synthesizes how the theoretical and practical foundations of science education have evolved over time (Handoyo, 2024; Leibovitch et al., 2025; Zheng et al., 2025).

The evolution of science education in Indonesia has been closely tied to national curriculum reforms, which have sought to align teaching and learning practices with both international standards and local cultural values. From the Competency-Based Curriculum (KBK) to the School-Based Curriculum (KTSP), and more recently, the *Merdeka Belajar* policy, each reform has introduced new epistemological and pedagogical

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paradigms aimed at improving the quality of science teaching and learning (Astari et al., 2025; Purwanto et al., 2025; Suherman et al., 2025).

These shifts have influenced not only what is taught in schools but also how science is understood, practiced, and assessed across different educational levels. Understanding this historical trajectory is essential for identifying patterns, persistent challenges, and emerging opportunities that can inform future directions in science education research and practice (Darda et al., 2024; Dunbar & Yadav, 2022; Sianturi et al., 2023).

This literature review aims to fill the existing gap by examining the evolution of science education foundations in Indonesia from 2021 to 2025. It focuses on key trends, dominant paradigms, and contextual factors that have shaped the field, offering insights into how these elements continue to influence contemporary practices and policies. By analyzing peer-reviewed publications from both international and national journals indexed in Scopus and Sinta, this study contributes to a deeper understanding of the theoretical underpinnings and practical implications of science education development in Indonesia.

Method

This study was conducted using a library research (literature review) approach to examine the evolution of science education foundations in Indonesia from 2021 to 2025. This method was chosen to explore key concepts, theoretical frameworks, and historical developments through a critical analysis of existing scholarly works and policy documents related to science education in the Indonesian context (Kataeva et al., 2024; Liu et al., 2024; Maulidiya et al., 2024). Unlike systematic literature reviews, this study focused on synthesizing conceptual and contextual insights rather than applying strict quantitative or thematic coding procedures.

The data collection process involved searching for relevant academic sources using electronic databases such as Scopus, ScienceDirect, ERIC, and Sinta (Science and Technology Index) – a national indexing system for Indonesian journals. Keywords used in the search included combinations such as "science education in Indonesia", "foundations of science teaching", "curriculum reform in Indonesian science education", and "epistemology of science learning".

To ensure relevance and academic credibility, the selection of literature was based on the following criteria: publication date between 2021 and 2025; focus on science education within Indonesian settings (primary, secondary, or tertiary level); availability of full-text access; and publication in journals indexed by

Scopus or Sinta. Non-peer-reviewed materials, conference abstracts without full papers, and studies focusing exclusively on international contexts were excluded from the analysis.

Following the selection process, the selected literature was analyzed qualitatively to identify major trends, dominant paradigms, and contextual influences shaping the development of science education in Indonesia. The analysis emphasized theoretical perspectives, pedagogical shifts, curriculum policies, and socio-cultural factors that have contributed to the evolving landscape of science education over the past five years.

By employing this approach, the study provides a comprehensive synthesis of recent scholarly discourse on science education in Indonesia. It serves as a foundational reference for understanding how educational reforms, epistemological changes, and policy directions have shaped the field, while also offering insights into potential future trajectories for research and practice.

Result and Discussion

The analysis of literature published between 2021 and 2025 reveals significant developments in the foundations of science education in Indonesia. These changes reflect both global educational trends and local contextual adaptations, particularly in epistemological perspectives, pedagogical strategies, curriculum reforms, and cultural integration.

Epistemological Shifts in Science Education

One of the most prominent changes observed is the shift from a positivist to a constructivist epistemology in science teaching. Traditional views of science as an objective, value-free, and cumulative body of knowledge have gradually been replaced by perspectives that emphasize the tentative, empirical, and inferential nature of scientific knowledge (Frejd & Pramling, 2023; Gröschner, 2023; Norton et al., 2025). This shift aligns with international movements toward teaching the Nature of Science (NoS), which encourages students to understand not only what scientists know but also how they come to know it. In Indonesia, this has influenced curriculum design and teacher education programs, promoting inquiry-based learning as a core instructional approach (Mufanti et al., 2024; Setiawan et al., 2025; Tatik et al., 2025).

Pedagogical Innovations and Instructional Approaches

There has been a growing emphasis on student-centered instructional methods such as problem-based learning (PBL), project-based learning (PrBL), and STEM

integration in Indonesian science classrooms (Ammar et al., 2024; Anderson, 2025; Asal et al., 2025). These approaches aim to enhance critical thinking, creativity, and scientific literacy by engaging students in real-world, context-rich problems. Studies indicate that when properly implemented, these strategies improve student motivation and conceptual understanding. However, challenges remain regarding teacher readiness, access to digital tools, and institutional support, especially in rural areas (Leat & Whelan, 2023).

Curriculum Reforms and Policy Influences

The implementation of the *Merdeka Belajar* policy has marked a paradigm shift in curriculum development, moving away from rigid, content-heavy syllabi toward more flexible, learner-driven frameworks (Ho et al., 2025; Kataeva et al., 2024; So et al., 2024). This reform emphasizes autonomy in learning, interdisciplinary connections, and the application of knowledge to real-life situations. While early reports suggest positive responses from educators and students, there are concerns about inconsistent implementation due to limited teacher training and assessment alignment. Therefore, continuous monitoring and professional development for teachers remain crucial to ensure effective adoption.

Cultural and Contextual Integration in Science Teaching

An emerging trend in recent literature is the integration of local wisdom and indigenous knowledge into formal science education (Liu & Wu, 2025; So, 2025; Tsang & Colpan, 2025). Researchers argue that contextualizing science instruction using familiar environmental and cultural references enhances relevance and engagement, particularly among students in rural and marginalized communities. This approach supports inclusive education by validating diverse ways of knowing while reinforcing scientific concepts through culturally meaningful examples.

Implications and Future Directions

These findings highlight the importance of re-evaluating the theoretical and practical foundations of science education in response to evolving societal and technological demands. The integration of epistemological clarity, innovative pedagogy, and culturally responsive practices can significantly enhance the quality of science education in Indonesia. However, sustained investment in teacher education, curriculum development, and policy evaluation is necessary to ensure long-term success. Future research should focus on longitudinal studies of curriculum impact, comparative analyses across regions, and the role of technology in bridging educational disparities.

Conclusion

The evolution of science education foundations in Indonesia from 2021 to 2025 reflects a shift toward constructivist epistemologies, student-centered pedagogies, and culturally responsive practices. Curriculum reforms, particularly under the *Merdeka Belajar* policy, have introduced more flexible and inquiry-based learning frameworks, though challenges remain in implementation consistency, teacher readiness, and resource distribution. While innovative teaching strategies such as STEM integration and contextual learning are increasingly adopted, their effectiveness depends on sustained professional development and policy support. The incorporation of local and indigenous knowledge further highlights the importance of contextualizing science education to enhance relevance and inclusivity. Moving forward, continued research and evaluation are essential to bridge gaps between theory, policy, and practice, ensuring equitable and high-quality science education across Indonesia.

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