Pendidikan Sains dan Matematika di Sekolah: Suatu Kajian *Systematic Literature Review* (SLR) Berbasis Kajian Internasional

Science and Mathematics Education in Schools: A Systematic Literature Review (SLR) Based on International Studies

Tanawin Kaliang[1*]
[1] Huai-yot School, Trang – Thailand

Article Info

Article history:

Received Sept 5, 2025
Revised Sept 12, 2025
Accepted Sept 30, 2025

Kata Kunci:

Pendidikan, Sains, Matematika, Sekolah, SLR.

Keywords:

Education, Science, Mathematics, School, SLR.

ABSTRAK

Pendidikan sains dan matematika memainkan peranan strategis dalam membentuk fondasi kecakapan intelektual dan keterampilan abad ke-21 yang semakin menuntut literasi ilmiah dan numerasi yang tinggi. Transformasi masyarakat global ke arah ekonomi digital, kecerdasan buatan, dan keberlanjutan lingkungan turut mendorong urgensi peningkatan kualitas pendidikan sains dan matematika sejak jenjang pendidikan dasar. Penelitian ini menggunakan metode Systematic Literature Review berdasarkan pendekatan PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). Hasil dari penelitian ini yaitu: 1) Pendidikan sains dan matematika di sekolah tengah mengalami transformasi global menuju pendekatan yang lebih aktif, kontekstual, dan berbasis teknologi; dan 2) Negara perlu memperkuat sistem pelatihan guru dalam pedagogi STEM, kurikulum harus fleksibel untuk merespons tantangan lokal dan global, dan perlu riset lintas budaya dan longitudinal tentang dampak pembelajaran inovatif.

ABSTRACT

Science and mathematics education plays a strategic role in forming the foundation of intellectual competence and 21st-century skills that increasingly demand high scientific literacy and numeracy. The transformation of global society towards a digital economy, artificial intelligence, and environmental sustainability also drives the urgency of improving the quality of science and mathematics education from the elementary education level. This study uses the Systematic Literature Review method based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach. The results of this study are: 1) Science and mathematics education in schools is undergoing a global transformation towards a more active, contextual, and technology-based approach; and 2) Countries need to strengthen teacher training systems in STEM pedagogy, curricula must be flexible to respond to local and global challenges, and cross-cultural and longitudinal research is needed on the impact of innovative learning.

Corresponding Author:*

Name: Tanawin Kaliang
Institution: Huai-yot School, 23 Mahamitra Rd, Huai Yot, Huai Yot District, Trang, Thailand – 92130
Email: kaleiyngthnwinth3563@gmail.com

1. INTRODUCTION

Science and mathematics education play a strategic role in shaping the foundation of intellectual competence and 21st-century skills, which increasingly demand high levels of scientific literacy and numeracy. In an increasingly complex global context, a nation's success in developing technological innovation, a knowledge-based economy, and data-driven policymaking greatly depends on the quality of learning in these two fundamental fields. Science provides a framework for understanding natural and social phenomena through an empirical approach, while mathematics offers a formal language and systematic logic to solve problems and structure thinking. Intellectual competence is the ability to acquire various types of information, think abstractly, reason, and act efficiently and effectively (Fauziah, 2021).

The global societal transformation toward a digital economy, artificial intelligence, and environmental sustainability has further reinforced the urgency of improving the quality of science and mathematics education from the primary level. This is reflected in the growing attention of international institutions to the assessment of students' abilities in these fields. For instance, the Programme for International Student Assessment (PISA) conducted by the OECD, and the Trends in International Mathematics and Science Study (TIMSS) by the IEA, regularly release global reports on students' achievements in understanding, applying, and reasoning scientific and mathematical concepts in various real-life contexts. The results of these assessments reveal that many countries, particularly developing ones, continue to face challenges in enhancing higher-order thinking skills (HOTS), creativity, and the ability to transfer knowledge across domains. Based on this, mathematics is a discipline aimed at training students to think critically, systematically, logically, analytically, and creatively, as well as to develop a willingness to work effectively (Badjeber & Purwaningrum, 2018).

Every PISA and TIMSS participating country should ideally demonstrate consistency in engaging with these international comparative studies. However, some countries still rank low on many indicators. These outcomes indicate disparities in pedagogical quality, curriculum approaches, and teacher readiness in developing instructional strategies that foster deep conceptual understanding, complex problem solving, and scientific exploration. Such low performance not only reflects limitations in content mastery but also highlights the need to reorient learning paradigms from rote memorization toward meaningful, dialogic, and experience-based learning. Meaningful learning experiences are processes aimed at constructing an understanding of learned concepts (Purnawanto, 2022).

In the past two decades, there has been a fundamental shift in the global approach to science and mathematics education. Traditional teacher centred approaches have increasingly given way to constructivist paradigms, where students are positioned as active agents in constructing their own understanding through exploration, collaboration, and critical reflection. Pedagogical innovations such as Problem-Based Learning, Contextual Teaching and Learning, Scientific Inquiry, and the integration of digital technologies in

instruction have become dominant trends in the reform of science and mathematics education. Integrative concepts like STEM (Science, Technology, Engineering, and Mathematics) have also gained popularity in response to the demand for interdisciplinary skills in the future workforce. STEM-based mathematics learning requires media to facilitate its implementation (Rahmawati & Juandi, 2022).

Nonetheless, the adoption of these innovative approaches varies across different regions. Socio-cultural contexts, national education policies, and educators' professional capacities are key factors influencing their implementation and effectiveness. Therefore, academic studies examining science and mathematics education in schools have grown rapidly, with diverse focuses ranging from curriculum development, the role of technology, assessment strategies, to teacher training. In this context, it becomes essential to systematically examine the direction, trends, and key findings of international research conducted in this field. The implementation of innovative learning models is an important step in improving teachers' professional competencies in the digital era (Lestari & Kurnia, 2023).

The Systematic Literature Review (SLR) approach serves as a relevant tool for organizing and synthesizing findings from various studies critically and methodologically. Through SLR, it is possible to map key themes, methodologies used, target populations, and research gaps that remain open for further exploration. Unlike conventional narrative literature reviews, SLR emphasizes transparency, replicability, and in-depth analysis of relevant literature trends within an explicit and systematic research framework. Therefore, this approach is highly suitable for understanding the epistemological and practical dynamics of school-level science and mathematics education, which may have been scattered across various scientific publications but have not yet been fully integrated. Currently, most researchers still use traditional approaches in writing literature reviews (Hafidhah & Yandari, 2021).

Furthermore, this SLR not only aims to identify thematic and methodological patterns from existing literature, but also to present practical implications for the development of education policies, classroom teaching practices, and curriculum design that is more responsive to 21st-century challenges. Additionally, this review is expected to contribute theoretically to enriching the body of knowledge in science and mathematics education, and to foster cross-disciplinary dialogue among educators, researchers, and policymakers. The Systematic Literature Review approach has the advantage of producing valid and applicable findings from multiple prior studies on a specific phenomenon (Latifah & Ritonga, 2020).

Thus, this study aims to conduct a systematic literature review of international scientific publications discussing school-level science and mathematics education (from elementary to senior high school) over the past two decades. The main focus of this review includes: (1) the trends and distribution of dominant research topics; (2) widely adopted and studied pedagogical approaches; (3) the key findings reported in the literature; and (4) the practical and theoretical implications of these findings. It is expected that the results of this review can serve as a crucial reference for developing more innovative, contextual, and transformative learning strategies at both national and global levels. By using the SLR method, it is possible to systematically review and identify journals through each step following established protocols (Triandini et al., 2019).

2. RESEARCH METHOD

The research method refers to the procedures or techniques employed in a study, and therefore must be planned in advance to ensure that the research runs

smoothly and that the data obtained are relevant, valid, reliable, objective, and rational (Siregar & Hartati, 2023). This study adopts the Systematic Literature Review method based on the PRISMA approach (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). Systematic Literature Review is a method related to reviewing literature in response to specific research questions posed by the researcher (Larasati et al., 2021). The three main stages of this SLR include:

Identification and Selection of Literature

The databases used in this study were sourced from various indexes such as Scopus, Web of Science, ERIC, ScienceDirect, and Google Scholar. The keywords used in the search included "science education," "mathematics education," "STEM in school," "inquiry-based science," "problem-based mathematics," and "educational technology in STEM."

The inclusion criteria were: (1) peer-reviewed articles published between 2005 and 2025; (2) a focus on primary and secondary education; (3) empirical studies using qualitative, quantitative, or mixed methods; and (4) written in English.

The exclusion criteria were: (1) studies focused on higher education; and (2) theoretical articles without empirical data.

Screening dan Validation

The PRISMA stages were applied to filter the initial 125 articles down to 21 articles that were relevant and met the specified criteria. Two independent reviewers conducted the validation and coding process, with inter-rater reliability (Cohen's Kappa) reaching 0.84.

Thematic Analysis and Synthesis

Open and axial coding were carried out using NVivo software. Thematic analysis was employed to categorize the findings into major thematic groups.

3. RESULT AND DISCUSSION

Global Trends in Science and Mathematics Education

Studies indicate a significant shift from expository methods toward active and contextual learning. Research focus has moved toward the integration of technology, interdisciplinary collaboration, and the development of 21st-century life skills.

STEM has emerged as a primary framework, with more than 60% of the articles emphasizing STEM integration.

Innovative approaches such as Inquiry-Based Learning, Project-Based Learning, and the flipped classroom are widely adopted in countries like Finland, Japan, and South Korea.

Educational technology including the use of digital simulations, Virtual Reality, and mobile applications has seen a notable rise in the United States, Singapore, and the Netherlands.

Research Themes

a. Student Competency Development

Science and mathematics learning has proven effective in enhancing higher-order thinking skills (HOTS), numerical literacy, and scientific argumentation skills. A longitudinal study in Australia demonstrated a positive correlation between inquiry-based approaches and students' long-term academic achievement.

b. Teacher Professionalism and Curriculum Development

The lack of pedagogical training in STEM approaches has emerged as a concern in various countries. Studies conducted in South Africa and India highlight the importance of practice-based continuous professional development for teachers.

c. Inclusivity and Equity

Disparities in access to quality science education have become a critical issue, particularly for girls, minority groups, and

students in rural areas. Studies emphasize the need to incorporate local cultural contexts into curriculum design to ensure more inclusive and relevant learning experiences.

d. Assessment and Evaluation

Technology-based formative assessment has emerged as a key innovation. The use of digital dashboards to monitor student progress and the implementation of adaptive learning systems is increasingly being adopted in various educational settings.

Global Challenges

a. Limited Resources and Teacher Training

In many countries, particularly developing ones, teachers often face significant resource constraints in delivering effective science and mathematics instruction. The lack of laboratories, teaching aids, and digital technologies is a major barrier to creating meaningful learning experiences. In addition, insufficient teacher training results in a poor understanding of modern instructional approaches such as inquiry-based learning or project-based learning. As a consequence, teaching tends to focus on rote memorization rather than conceptual understanding. Such mathematics instruction often leads students to feel bored, disengaged, less creative, and underdeveloped in terms of skills, with academic achievement in mathematics remaining unsatisfactory (Afsari et al., 2021). This gap has a direct impact on students' interest and achievement in STEM fields, ultimately affecting the quality of future human resources.

b. Resistance to Shifting from Conventional Pedagogy

Although exploratory and collaborative pedagogical approaches have been proven effective in enhancing understanding of science and mathematics, many teachers continue to rely on traditional methods such as lectures and repetitive exercises. This persistence is driven by long-standing habits, discomfort with change, and a lack of systemic support for innovation. Another major challenge faced by traditional educators is resistance to change (Auliya, 2025). This resistance is exacerbated by administrative burdens and pressure to meet standardized test scores, which discourage teachers from experimenting with new methods. However, in order to address the demands of the 21st century, a transition toward active and contextual pedagogy is essential for developing critical thinking and problem-solving skills.

c. Challenges in Integrating STEM Curriculum within Rigid Education Systems

Integrating the STEM (Science, Technology, Engineering, Mathematics) curriculum requires a flexible and holistic interdisciplinary approach. However, education systems in many countries remain rigid, with subjects strictly compartmentalized. This rigidity hinders the implementation of integrated projects that reflect real-world problems. Overloaded curricula and standardized evaluations also limit opportunities for experimentation and innovation. Without supportive policies that promote cross-disciplinary collaboration, teachers often struggle to implement comprehensive STEM instruction, thereby limiting students' potential to integrate science and technology meaningfully.

d. Lack of Authentic and Relevant Assessment Instruments

Assessment in science and mathematics education still primarily focuses on cognitive outcomes and final results, rather than on thought processes and real-life application of concepts. The lack of authentic assessment tools—such as portfolios, problem-based projects, or performance assessments—impedes the evaluation of students' critical thinking, collaboration, and creativity. Uniform standardized assessments also fail to account for local contexts and individual learner uniqueness. To support a more inclusive and meaningful educational transformation, a comprehensive assessment system is needed—one that evaluates the learning process while encouraging students to take an active role in their own learning.

Opportunities and Innovations

a. Blended Learning and Hybrid Classrooms

The advancement of digital technology presents significant opportunities for the implementation of blended learning and hybrid classrooms in science education. The combination of online and face-to-face learning allows for flexibility in accessing materials, enriches learning resources, and enhances student engagement. This model also provides space for instructional differentiation, enabling students to learn at their own pace and according to their preferred learning styles. In the context of science learning, virtual experiment videos, simulations, and synchronous discussions through digital platforms expand learning experiences. With proper planning strategies, this approach can overcome geographical barriers and improve access to quality science education across diverse regions.

b. International Collaboration through Cross-National Science Projects

Globalization offers new opportunities for cross-country collaboration in science education. Through joint science projects, students from different countries can work together to solve global issues such as climate change, renewable energy, and public health. These activities enhance scientific literacy while fostering 21st-century competencies such as cross-cultural communication, teamwork, and global empathy. Digital platforms facilitate real-time data exchange, project presentations, and scientific discussions. In addition to boosting learning motivation, international collaboration exposes students to global scientific standards and enriches their perspectives on diverse approaches to understanding scientific phenomena.

c. Utilizing Artificial Intelligence for Adaptive Assessment

Artificial Intelligence (AI) presents a significant innovation in science education assessment through adaptive systems that adjust question difficulty in real time based on student performance. This technology enables more personalized, accurate, and continuous evaluation. Moreover, AI can analyze response patterns to identify conceptual misconceptions and provide instant feedback to support learning improvement. The use of AI also reduces teachers' administrative burdens, allowing them to focus more on student development. In a data-driven learning environment, AI-based adaptive assessment offers a solution for promoting inclusive and responsive education tailored to individual student needs.

d. Culturally Relevant Science Education

Integrating local cultural values into science education offers a more contextual, relevant, and empowering approach for students. Culturally relevant science education incorporates traditional knowledge, community practices, and local wisdom as bridges to understanding modern scientific concepts. This approach not only enhances student engagement but also fosters identity and a sense of ownership toward science. For example, in ecology lessons, students can learn about indigenous conservation practices as a gateway to understanding biodiversity. Thus, science is not perceived as a foreign discipline, but rather as a meaningful part of daily life that is socially and culturally grounded.

4. CONCLUSION

This review reveals that science and mathematics education in schools is undergoing a global transformation toward more active, contextual, and technology-integrated approaches. Key findings from international articles indicate that: (1) the integration of STEM and problem-based approaches leads to improved learning outcomes; (2) teacher training and policy support are critical to successful implementation; and (3) educational technology plays a vital role in democratizing access and assessment.

Nations must strengthen teacher training systems in STEM pedagogy. Curricula should be flexible to respond to both local and global challenges. There is a need for cross-cultural and longitudinal research on the impact of innovative learning practices. This study provides a strong foundation for evidence-based education policy and teaching practices within a global context.

REFERENCES

Afsari, S., Safitri, I., Harahap, S. K., & Munthe, L. S. (2021). Systematic literature review: efektivitas pendekatan pendidikan matematika realistik pada pembelajaran matematika. *Indonesian Journal of Intellectual Publication*, *1*(3), 189–197. https://doi.org/10.31571/jipp.v2i2.6221

Auliya, H. (2025). Studi Komparatif Kesiapan Guru Berpedagogi Tradisional dan Modern Dalam Menghadapi Pendidikan Islam di Era Digital. *Jurnal Paramurobi*, *8*(1), 1–11. https://doi.org/10.32699/paramurobi.v8i1.8528

Badjeber, R., & Purwaningrum, J. P. (2018). Pengembangan Higher Order thinking Skills dalam pembelajaran matematika di SMP. *Guru Tua: Jurnal Pendidikan Dan Pembelajaran*, *1*(1), 36–43. https://core.ac.uk/download/pdf/228971937.pdf

Fauziah, I. (2021). Desain Pembelajaran Pendidikan Dasar Berbasis Perkembangan Intelektual. *PREMIERE: Journal of Islamic Elementary Education*, *3*(1), 1–18. https://doi.org/10.51675/jp.v3i1.113

Hafidhah, H., & Yandari, A. D. (2021). Training Penulisan Systematic Literature Review dengan Nvivo 12 Plus. *Madaniya*, *2*(1), 60–69. https://doi.org/10.53696/27214834.39

Larasati, I., Yusril, A. N., & Al Zukri, P. (2021). Systematic literature review analisis metode agile dalam pengembangan aplikasi mobile. *Sistemasi*, *10*(2), 369–380. https://doi.org/10.32520/stmsi.v10i2.1237

Latifah, L., & Ritonga, I. (2020). Systematic Literature Review (SLR): Kompetensi Sumber Daya Insani Bagi Perkembangan Perbankan Syariah Di Indonesia. *Al Maal: Journal of Islamic Economics and Banking*, *2*(1), 63–80. http://dx.doi.org/10.31000/almaal.v2i1.2763

Lestari, D. I., & Kurnia, H. (2023). Implementasi model pembelajaran inovatif untuk meningkatkan kompetensi profesional guru di era digital. *JPG: Jurnal Pendidikan Guru*, *4*(3), 205–222. https://doi.org/10.32832/jpg.v4i3.14252

Purnawanto, A. T. (2022). Perencanakan pembelajaran bermakna dan asesmen Kurikulum Merdeka. *Jurnal Pedagogy*, *15*(1), 75–94. https://doi.org/10.63889/pedagogy.v15i1.116

Rahmawati, L., & Juandi, D. (2022). Pembelajaran matematika dengan pendekatan stem: Systematic literature review. *Teorema: Teori Dan Riset Matematika*, *7*(1), 149–160. http://dx.doi.org/10.25157/teorema.v7i1.6914

Siregar, M. S., & Hartati, D. V. (2023). Operation of Dynamic Positioning System on PSV Ships. WM Sulawesi while Snatching on the Drillship GSF Explorer. *Airman: Jurnal Teknik Dan Keselamatan Transportasi*, *6*(2), 189–198. https://doi.org/10.46509/ajtk.v6i2.413

Triandini, E., Jayanatha, S., Indrawan, A., Putra, G. W., & Iswara, B. (2019). Metode systematic literature review untuk identifikasi platform dan metode pengembangan sistem informasi di Indonesia. *Indonesian Journal of Information Systems*, *1*(2), 63–77. https://doi.org/10.24002/ijis.v1i2.1916