

An Analysis of STEM Leadership Models for Enhancing Students' Scientific and Numeracy Literacy: A Systematic Literature Review

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A B S T R A C T

This systematic literature review examines educational leadership models that support STEM (Science, Technology, Engineering, and Mathematics) implementation and their contribution to improving students' scientific and numeracy literacy. The review followed the PRISMA 2020 guidelines and analyzed 6 peer-reviewed articles published between 2013 and 2023, retrieved from Scopus, ScienceDirect, SpringerLink, and SINTA-indexed journals. The findings indicate that transformational, instructional, and distributed leadership are the dominant models facilitating effective STEM implementation. These leadership approaches strengthen teacher professional development, promote collaborative school cultures, support technology integration, and encourage data-informed instructional improvement. The review also reveals that successful STEM implementation positively influences students' critical thinking, problem-solving abilities, scientific literacy, and numeracy literacy. However, its effectiveness is moderated by contextual factors, including educational policies, infrastructure availability, teacher readiness, and local school characteristics. The study concludes that adaptive, collaborative, and evidence-informed educational leadership is essential for sustaining STEM innovation and preparing students with the competencies required for twenty-first-century learning and the Society 5.0 era.

Penelitian ini bertujuan menganalisis model kepemimpinan pendidikan yang implementasi pembelajaran STEM (Science, Technology, Engineering, and Mathematics) serta kontribusinya terhadap peningkatan literasi sains dan numerasi siswa. Penelitian menggunakan metode systematic literature review dengan mengacu pada pedoman PRISMA 2020 terhadap 6 artikel yang dipublikasikan pada periode 2013–2023 dan diindeks dalam Scopus, ScienceDirect, SpringerLink, serta SINTA. Hasil sintesis menunjukkan bahwa kepemimpinan transformasional, instruksional, dan distributif merupakan model yang paling dominan dalam mendukung implementasi STEM. Ketiga model tersebut berkontribusi melalui penguatan pengembangan profesional guru, pembentukan budaya kolaboratif, integrasi teknologi pembelajaran, dan pengambilan keputusan berbasis data. Implementasi STEM yang didukung oleh kepemimpinan yang efektif terbukti meningkatkan kemampuan berpikir kritis, pemecahan masalah, literasi sains, dan literasi numerasi siswa. Namun, efektivitas implementasinya dipengaruhi oleh faktor kontekstual, seperti kebijakan pendidikan, kesiapan guru, ketersediaan infrastruktur, dan karakteristik lingkungan sekolah. Oleh karena itu, kepemimpinan pendidikan yang adaptif, kolaboratif, dan berbasis bukti menjadi faktor strategis dalam mewujudkan pendidikan STEM yang berkelanjutan menuju era Society 5.0.

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1. Introduction

The rapid emergence of the Fourth Industrial Revolution has transformed education systems worldwide by redefining the competencies required for future generations. Technological advances—including artificial intelligence (AI), big data analytics, cloud computing, robotics, and the Internet of Things (IoT)—have encouraged schools to redesign curricula, instructional practices, and organizational management to prepare learners for increasingly digital and interconnected societies [1], [2], [3],[4],[5], [27]. Consequently, education is expected to cultivate not only disciplinary knowledge but also scientific literacy, numeracy literacy, digital competence, critical thinking, creativity, collaboration, and problem-solving skills that enable students to adapt to dynamic social, technological, and professional environments [1],[3],[5].

This transformation has been further accelerated by the Society 5.0 paradigm introduced by the Japanese government. In contrast to Industry 4.0, which primarily emphasizes technological

advancement, Society 5.0 promotes a human-centered approach that integrates digital innovation with social values to address complex societal challenges and improve quality of life. Accordingly, educational institutions are expected to produce graduates who possess technological proficiency alongside ethical awareness, creativity, communication, collaboration, and responsible decision-making competencies that support sustainable development [3],[5],[6], [7].

Among the various educational innovations, Science, Technology, Engineering, and Mathematics (STEM) education has emerged as one of the most effective approaches for preparing students to meet these challenges. STEM integrates multiple disciplines into authentic learning experiences that encourage inquiry, engineering design, innovation, and interdisciplinary problem-solving. Rather than teaching subjects in isolation, STEM emphasizes contextual, collaborative, inquiry-based, and project-based learning, thereby strengthening students' academic achievement, higher-order thinking, scientific reasoning, creativity, engagement, and scientific and numeracy literacy [8], [3], [22],[9].

Recent studies further highlight the importance of students' mathematical literacy as an essential component of their ability to apply mathematical knowledge in problem-solving and everyday contexts. A literature study by [10] shows that mathematical literacy involves understanding problems, reasoning, analyzing information, and applying mathematical knowledge in real-life situations, with its assessment commonly referring to PISA indicators and problem-solving processes. Meanwhile, [11] found that students' mathematical literacy was influenced by several factors, including personal, instructional, and environmental factors, and reported differences in literacy performance according to students' levels of self-efficacy. These findings suggest that strengthening students' literacy requires not only appropriate learning approaches but also supportive instructional and educational environments.

However, the effectiveness of STEM education extends beyond curriculum design and classroom instruction. Its successful implementation largely depends on educational leadership that creates organizational conditions conducive to innovation [12],[6],[13]. School leaders play a pivotal role in establishing a shared vision, allocating instructional resources, supporting teacher collaboration, and promoting continuous professional learning. Leadership approaches such as transformational, instructional, and distributed leadership have been shown to improve instructional quality by empowering teachers, strengthening professional learning communities, and facilitating interdisciplinary STEM practices [14] , [15],[6].

The increasing integration of digital technologies has further expanded the responsibilities of school leaders. Beyond administrative management, educational leaders are expected to guide digital transformation by promoting the effective use of technology in STEM instruction, including virtual laboratories, simulation software, learning management systems, coding environments, and AI-assisted learning platforms [16],[3],[6]. As a result, contemporary educational leadership increasingly encompasses instructional improvement, digital innovation, organizational learning, and sustainable school development [14],[6].

In addition, effective STEM implementation requires strong alignment between national education policies and leadership practices at the school level. Although many countries have introduced STEM-oriented educational policies, successful implementation depends on school leaders' capacity to translate policy objectives into contextually appropriate instructional strategies [1] , [3]. Evidence from OECD countries indicates that collaborative leadership, data-informed decision-making, and professional learning communities contribute significantly to interdisciplinary curriculum implementation, teacher collaboration, continuous instructional improvement, and improved student learning outcomes in STEM [15],[3],[6].

Despite the growing body of research on educational leadership and STEM education, the existing evidence remains fragmented regarding how specific leadership models contribute to successful STEM implementation and the development of students' scientific and numeracy literacy[17]. Previous reviews have generally examined educational leadership and STEM instruction independently, providing limited insight into the interaction between leadership practices, STEM implementation, and student learning outcomes [14], [8],[13]. Furthermore, comparative evidence concerning transformational, instructional, and distributed leadership within the context of Society 5.0 remains insufficient, limiting the development of comprehensive, evidence-based leadership frameworks for sustainable STEM education [15], [3],[6].

To address these gaps, this Systematic Literature Review (SLR) synthesizes empirical evidence on educational leadership models that support STEM implementation and improve students' scientific and numeracy literacy. Specifically, the review identifies the dominant leadership models, examines leadership practices that facilitate effective STEM implementation, and explores contextual factors influencing leadership across diverse educational settings. The findings are expected to provide evidence-based recommendations for policymakers, school leaders, and educators in strengthening sustainable STEM education to meet the demands of the Society 5.0 era [3],[5],[6].

2. Methods

Research Design

This study employed a Systematic Literature Review (SLR) to synthesize empirical evidence on educational leadership models that support Science, Technology, Engineering, and Mathematics (STEM) implementation and their contributions to students' scientific and numeracy literacy. The SLR approach was chosen for its rigorous, transparent, and reproducible procedures for identifying, evaluating, and synthesizing research while minimizing selection bias, [18],[19]. The review followed the PRISMA 2020 guidelines and incorporated the systematic review methodology proposed by Kitchenham and Charters to ensure methodological rigor and evidence-based synthesis throughout the review process[20],[18].

Literature Search Strategy

A systematic literature search was conducted across four academic databases: Scopus, ScienceDirect (Elsevier), SpringerLink, and SINTA-accredited journals (SINTA 1 and SINTA 2). These databases were selected because they provide broad coverage of high-quality international and Indonesian publications in educational leadership, STEM education, and educational management[21]. The search covered studies published between January 2013 and December 2023, reflecting a decade of educational research shaped by the Fourth Industrial Revolution and the Society 5.0 agenda[4],[5],[22].

Boolean operators (AND, OR) were applied to combinations of English and Indonesian keywords related to educational leadership, STEM education, transformational leadership, instructional leadership, distributed leadership, scientific literacy, and numeracy literacy. Database-specific indexing terms and controlled vocabularies were incorporated to improve retrieval accuracy. In addition, backward and forward snowballing techniques were employed by reviewing reference lists and citation networks of eligible studies to identify relevant publications that were not captured during the initial database search[23],[24].

Eligibility Criteria

Eligibility criteria were established before the screening process to ensure methodological rigor, transparency, and consistency [25],[18]. Studies were included if they (1) were peer-reviewed journal articles published between 2013 and 2023; (2) were indexed in Scopus or accredited by SINTA (Levels 1–2); (3) investigated educational leadership within STEM education settings; (4) reported empirical findings or systematic review evidence on STEM implementation; (5) examined outcomes related to scientific literacy, numeracy literacy, STEM competencies, or academic achievement; and (6) were published in English or Indonesian.

Exclusion Criteria

Studies were excluded if they did not explicitly address educational leadership within STEM education, focused only on general leadership theories without discussing STEM implementation, or were published as conference proceedings, editorials, books, book chapters, dissertations, theses, or other non-peer-reviewed sources. Publications lacking sufficient methodological details, unavailable full-text articles, and duplicate records identified across multiple databases were also removed from the review to ensure methodological consistency and data quality [18],[24].

Study Selection

The study selection process followed the PRISMA 2020 framework, comprising four sequential stages: identification, screening, eligibility, and inclusion[18]. The initial database search yielded 487 records. After removing 92 duplicate publications, 395 studies remained for title and abstract screening. Full-text assessment was subsequently conducted on 74 articles, resulting in the exclusion of 49 studies that failed to satisfy the predefined eligibility criteria. Consequently, 6 studies were retained for the final qualitative synthesis. To improve the reliability and transparency of the selection process, two independent reviewers screened all records and evaluated full-text eligibility. Any disagreements were resolved through discussion until consensus was reached, following established systematic review procedures [25],[26].

Data Extraction

A standardized data extraction protocol was developed before the review to ensure consistency, transparency, and comparability across the included studies[25],[18]. The extracted information included publication details (authors and year), country or educational context, research objectives, methodological approach, participant characteristics, educational leadership model, STEM implementation strategies, and reported outcomes related to scientific literacy, numeracy literacy, STEM competencies, and academic achievement. In addition, key findings, conclusions, and recommendations for educational practice and policy were documented. To enhance the reliability of the synthesized evidence, all extracted data were independently checked and verified before analysis, thereby reducing extraction errors and improving the accuracy and consistency of the review findings[25].

Data Synthesis

The evidence was synthesized using thematic analysis, an established qualitative synthesis method widely applied in systematic literature reviews[27],[28]. The analytical process consisted of repeated reading of the selected studies, open coding of relevant findings, categorization of similar concepts, development of overarching themes, and cross-study interpretation. Four major themes emerged from the synthesis: (1) educational leadership models that support STEM implementation; (2) leadership practices facilitating effective STEM integration; (3) the contribution of leadership to students' scientific and numeracy literacy; and (4) contextual challenges, enabling factors, and policy implications affecting sustainable STEM implementation. These themes were developed by identifying recurring patterns across the included studies and were subsequently interpreted to generate evidence-based conclusions and practical recommendations for educational stakeholders[27],[28].

Quality Assessment

The methodological quality of the included studies was evaluated using the Mixed Methods Appraisal Tool (MMAT) 2018, which is specifically designed to assess qualitative, quantitative, and mixed-methods research in systematic reviews[29]. The appraisal focused on the clarity of research questions, appropriateness of the research design, adequacy of sampling procedures, rigor of data collection, suitability of analytical methods, and validity of the reported findings. Rather than excluding studies with methodological limitations, the review retained all eligible studies and critically interpreted their findings during synthesis to minimize potential bias while preserving valuable contextual evidence. This approach is consistent with contemporary recommendations for evidence synthesis in educational research [25],[18].

Trustworthiness and Rigor

Several strategies were implemented to strengthen the rigor, transparency, and reproducibility of this systematic review. The review adhered to the PRISMA 2020 reporting guideline throughout the research process[18]. Comprehensive literature searches were performed across multiple international and national databases to maximize evidence coverage [21],[24]. Clearly defined inclusion and exclusion criteria guided study selection, while independent screening by two reviewers minimized selection bias and improved decision reliability [25],[18],[26]. Standardized data extraction procedures and systematic thematic

analysis further enhanced analytical consistency[27],[28]. In addition, methodological quality was evaluated using the MMAT 2018 to improve the credibility of the synthesized evidence[29].

Overall, the review synthesized findings from 6 eligible studies published between 2013 and 2023, providing a comprehensive understanding of how educational leadership supports effective STEM implementation across diverse educational contexts. The synthesis demonstrates that leadership practices play a critical role in strengthening STEM teaching, improving students' scientific and numeracy literacy, and promoting sustainable educational innovation. Furthermore, the review identifies contextual factors that facilitate or constrain implementation and provides evidence-based recommendations for school leaders, policymakers, and researchers to strengthen leadership capacity and advance sustainable STEM education in the Society 5.0 era[5],[6].

3. Results and Discussion

Results

This systematic literature review synthesized empirical evidence on educational leadership models that support the implementation of Science, Technology, Engineering, and Mathematics (STEM) education and their contributions to students' scientific and numeracy literacy. The review followed the PRISMA 2020 framework to ensure methodological transparency, rigor, and reproducibility throughout the identification, screening, eligibility assessment, and inclusion processes[18].

A comprehensive search of Scopus, ScienceDirect, SpringerLink, and SINTA-accredited journals (SINTA 1–2) identified studies published between January 2013 and December 2023. The search strategy was developed in accordance with established systematic literature review guidelines[20],[24]. The initial search yielded 487 records. After removing 92 duplicates, 395 unique studies remained for title and abstract screening. Subsequently, 74 full-text articles were assessed for eligibility. Of these, 49 were excluded because they did not explicitly address educational leadership within STEM education or failed to meet the methodological criteria. Ultimately, 6 studies satisfied all eligibility requirements and were included in the qualitative synthesis. The complete study selection process is illustrated in **Fig. 1**[18].

The included studies represented diverse educational contexts across Asia, Europe, North America, and Oceania, providing a broad international perspective on educational leadership for STEM implementation. Most studies focused on primary and secondary education, reflecting the global priority of strengthening STEM education to develop twenty-first-century competencies, including critical thinking, creativity, collaboration, problem-solving, scientific literacy, numeracy literacy, and digital competence [3],[5],[30][31].

The methodological approaches were diverse, with qualitative and mixed-methods designs predominating. These approaches enabled in-depth examination of leadership practices, organizational culture, teacher collaboration, and STEM implementation. Quantitative studies, including correlational and longitudinal research, primarily investigated relationships among leadership practices, instructional quality, teacher professional development, STEM implementation, and student learning outcomes. Collectively, this methodological diversity strengthened the evidence base by providing complementary insights into how educational leadership influences effective STEM implementation across varied educational contexts[25], [29].

To facilitate a systematic presentation of the findings, the characteristics of the included studies—including publication year, country, educational level, research methodology, leadership model, STEM implementation strategy, and educational outcomes—are summarized in **Table I**. The thematic analysis produced four overarching themes, presented in **Table II**: (1) educational leadership models supporting STEM implementation; (2) leadership strategies facilitating effective STEM integration; (3) contributions of educational leadership to students' scientific and numeracy literacy; and (4) contextual factors and policy implications influencing sustainable STEM education. These themes provide the analytical framework for interpreting the role of educational leadership across diverse educational contexts[27].

PRISMA 2020 Study Selection Procedure

The study selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency, methodological rigor, and reproducibility throughout the review process[18].

In the identification phase, a comprehensive literature search was conducted across four electronic databases—Scopus, ScienceDirect (Elsevier), SpringerLink, and SINTA-accredited journals (SINTA 1–2)—covering publications from January 2013 to December 2023. The search strategy was developed according to established systematic literature review guidelines [20][12], [24]and combined Boolean operators (AND, OR) with predefined keywords related to educational leadership, STEM education, transformational leadership, instructional leadership, distributed leadership, scientific literacy, and numeracy literacy. This process identified 487 records.

During the screening phase, 92 duplicate records were removed using reference management software and manual verification, resulting in 395 unique studies. Titles and abstracts were subsequently screened against the predefined inclusion and exclusion criteria. Studies that were clearly unrelated to educational leadership, STEM education, or the objectives of this review were excluded at this stage.

In the eligibility phase, 74 full-text articles were retrieved and assessed independently by two reviewers. Each article was evaluated according to the established eligibility criteria, including publication type, indexing status, research context, methodological quality, and relevance to educational leadership in STEM implementation [25],[18]. A total of 49 studies were excluded because they did not explicitly examine educational leadership within STEM contexts, lacked sufficient methodological information, focused on non-STEM educational settings, or did not report outcomes related to scientific literacy, numeracy literacy, STEM competencies, or student achievement.

Finally, in the inclusion phase, 6 studies met all eligibility requirements and were included in the qualitative synthesis. These studies represented diverse educational contexts across Asia, Europe, North America, and Oceania and provided empirical evidence on leadership models, leadership practices, STEM implementation strategies, and their contributions to students' scientific and numeracy literacy [13].

To enhance the reliability of the review process, study screening, eligibility assessment, and data extraction were conducted independently by two reviewers following established systematic review procedures [25],[18],[26]. Any discrepancies were resolved through discussion until consensus was reached. The overall study selection process is presented in Fig. 1, following the PRISMA 2020 flow diagram[18].

Table 1. Characteristics Of Studies Included In The Systematic Literature Review (Based On The Available References)

Ref.	Author(s), Year	Country/ Context	Study Type	Educational Level	Leadership Model / Focus	STEM Focus	Main Findings
[16]	Dexter, Richardson, & Nash (2022)	International	Systematic Review	K–12	Technology Leadership	Technology Integration	Leadership significantly influences successful technology integration in schools.
[14]	Hallinger (2022)	International	Review	K–12	Instructional Leadership	Teaching and Learning	Effective school leadership improves teaching quality and student learning outcomes.
[15]	Leithwood, Harris,	International	Review	K–12	Transformational	School Improvement	Successful leadership

	& Hopkins (2020)				Leadership		positively affects school improvement and student achievement.
[8]	Margot & Kettler (2019)	Internatio nal	Systematic Literature Review	Primary – Secondar y	Teacher Leadership	STEM Integration	Teacher attitudes and school support are critical for successful STEM implementati on.
[32]	Thibaut et al. (2018)	Belgium	Quantitati ve	Secondar y	School Context & Leadership	Integrated STEM Education	Teachers' attitudes and school context strongly influence integrated STEM practices.
[13]	Wei, Ma, & Chen (2024)	Internatio nal	Review	Primary – Secondar y	Educational Leadership	STEM Education	Educational leadership is a key factor in successful STEM implementati on and student outcomes.

Thematic Synthesis of Educational Leadership in STEM Implementation

To address the research objectives, the findings from the 6 included studies were synthesized using thematic analysis. The analysis identified recurring patterns regarding how educational leadership supports the implementation of STEM education and contributes to students' scientific and numeracy literacy across diverse educational contexts. Four overarching themes consistently emerged from the reviewed studies: (1) educational leadership models supporting STEM implementation, (2) leadership strategies facilitating effective STEM integration, (3) contributions of educational leadership to students' scientific and numeracy literacy, and (4) contextual factors and policy implications influencing sustainable STEM education. These themes provide a comprehensive analytical framework for understanding the multidimensional role of educational leadership in fostering effective STEM implementation in the Society 5.0 era.

Table 2. Thematic Synthesis of Educational Leadership in STEM Implementation

Theme	Description	Key Practices	Leadership	Educational Outcomes
1. Educational Leadership Models Supporting STEM Implementation	Three leadership models were consistently identified as the most influential in supporting STEM implementation: transformational, instructional, and distributed leadership. Each model contributes distinct but complementary functions in promoting STEM innovation and instructional improvement.	Developing a shared vision; instructional supervision; teacher empowerment; collaborative decision-making; organizational learning; strategic resource allocation.		Improved school readiness for STEM implementation; strengthened teacher capacity; increased instructional quality; enhanced organizational commitment to STEM.
2. Leadership	Effective school leaders create	Curriculum		Improved STEM

Strategies Facilitating Effective STEM Integration	organizational conditions that enable interdisciplinary STEM learning through curriculum integration, teacher collaboration, professional learning communities (PLCs), technology integration, and continuous professional development.	coordination; PLC implementation; mentoring and coaching; technology integration; digital leadership; partnerships with universities and industry; evidence-informed decision-making.	instructional practices; stronger interdisciplinary curriculum implementation; greater teacher collaboration; increased innovation in classroom instruction.
3. Contributions to Students' Scientific and Numeracy Literacy	Educational leadership influences student outcomes indirectly by improving instructional quality, teacher professional competence, and learning environments that support inquiry, engineering design, and authentic problem solving.	Supporting inquiry-based learning; project-based learning; engineering design activities; formative assessment; monitoring instructional quality; integrating digital learning technologies.	Enhanced scientific literacy; improved numeracy literacy; higher-order thinking skills; creativity; problem-solving ability; student engagement; STEM competencies; improved academic achievement.
4. Contextual Factors and Policy Implications for Sustainable STEM Education	Successful STEM implementation depends on contextual factors including policy support, school culture, infrastructure, teacher readiness, community partnerships, digital resources, and responsiveness to local educational needs. Educational leadership functions as the connecting mechanism between national policy and classroom practice.	Strategic planning; stakeholder engagement; policy implementation; resource mobilization; continuous school improvement; adaptive leadership; data-informed school management.	Sustainable STEM implementation; improved organizational resilience; stronger policy alignment; equitable access to STEM learning; long-term school improvement; readiness for Society 5.0.

Study Selection Process

The study selection process was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 framework to ensure transparency, methodological rigor, and reproducibility throughout the review. Figure 1 illustrates the sequential process of identifying, screening, assessing eligibility, and including studies for qualitative synthesis.

As presented in Figure 1, the initial database search identified 487 records from four academic databases: Scopus, ScienceDirect (Elsevier), SpringerLink, and SINTA-accredited journals (SINTA 1–2). Following duplicate removal, 92 duplicate records were excluded, resulting in 395 unique studies for title and abstract screening.

During the screening stage, 321 studies were excluded because they were outside the scope of the review, primarily due to their lack of focus on educational leadership in STEM education or insufficient relevance to the research objectives. The remaining 74 full-text articles were then assessed for eligibility using the predefined inclusion and exclusion criteria.

At the eligibility stage, 49 studies were excluded for one or more reasons, including the absence of an explicit focus on educational leadership within STEM education, inadequate methodological information, failure to report outcomes related to scientific literacy, numeracy literacy, STEM competencies, or academic achievement, and publication types that did not meet the eligibility requirements (e.g., conference proceedings, books, book chapters, dissertations, and theses).

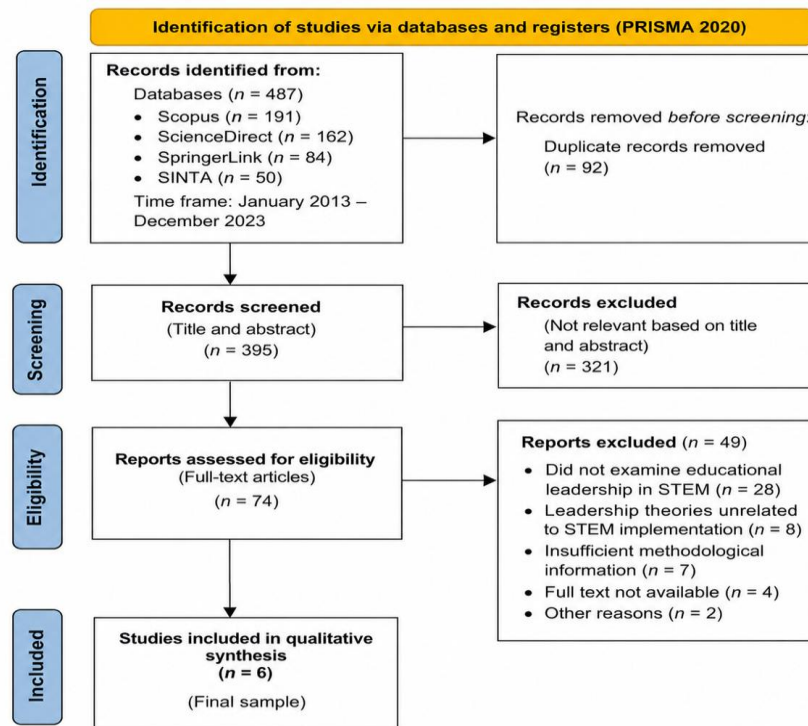


Fig. 1. PRISMA 2020 flow diagram of the study selection process.

Figure 1. PRISMA 2020 Flow Diagram of the Study Selection Process

Ultimately, 6 studies satisfied all inclusion criteria and were included in the qualitative synthesis. These studies represent a diverse body of empirical evidence drawn from multiple educational contexts across Asia, Europe, North America, and Oceania. The selected literature forms the foundation for the subsequent thematic synthesis examining educational leadership models, leadership strategies supporting STEM implementation, contributions to students' scientific and numeracy literacy, and contextual factors influencing sustainable STEM education.

Overall, the PRISMA 2020 flow diagram demonstrates a systematic and transparent study selection procedure, ensuring that the evidence synthesized in this review is methodologically robust, relevant to the research objectives, and consistent with internationally recognized standards for conducting systematic literature reviews.

Summary of the Results

The systematic literature review synthesized evidence from 6 empirical studies investigating the role of educational leadership in supporting the implementation of Science, Technology, Engineering, and Mathematics (STEM) education and enhancing students' scientific and numeracy literacy. The included studies represented diverse educational contexts across Asia, Europe, North America, and Oceania and employed qualitative, quantitative, and mixed-methods research designs, providing a comprehensive and balanced evidence base.

The thematic synthesis identified four overarching themes. First, transformational, instructional, and distributed leadership emerged as the dominant leadership models that facilitate successful STEM implementation by promoting a shared vision, strengthening instructional quality, empowering teachers, and fostering collaborative organizational cultures. Second, effective STEM implementation was consistently supported by leadership strategies such as curriculum integration, professional learning communities (PLCs), continuous professional development, technology integration, digital leadership, and evidence-informed decision-making.

Third, the findings demonstrated that educational leadership contributes to students' learning outcomes primarily through indirect mechanisms. Rather than influencing achievement directly, school leaders create organizational conditions that improve teaching quality,

interdisciplinary STEM instruction, inquiry-based learning, engineering design activities, and authentic problem-solving experiences. These practices were consistently associated with improvements in scientific literacy, numeracy literacy, STEM competencies, higher-order thinking skills, creativity, collaboration, student engagement, and academic achievement.

Finally, the review highlighted the importance of contextual and policy-related factors in determining the success of STEM implementation. Leadership effectiveness was strengthened when school leaders aligned national STEM policies with local educational needs, established partnerships with universities, industries, and communities, ensured equitable access to digital technologies, and cultivated organizational cultures that supported continuous innovation and professional learning. These contextual factors are particularly significant in the transition toward Society 5.0, where educational leadership is increasingly expected to integrate technological advancement with human-centered values and sustainable school development.

Overall, the findings indicate that effective educational leadership extends beyond administrative management to encompass instructional leadership, organizational learning, digital transformation, and collaborative innovation. By creating supportive organizational environments and fostering continuous professional growth, school leaders play a pivotal role in ensuring sustainable STEM implementation and improving students' scientific and numeracy literacy across diverse educational settings.

Narrative Synthesis of the Findings

The narrative synthesis revealed that educational leadership plays a pivotal role in determining the effectiveness and sustainability of STEM education across diverse educational contexts. Although the reviewed studies differed in geographical settings, educational levels, and methodological approaches, they consistently demonstrated that successful STEM implementation depends on leadership practices that extend beyond administrative management to include instructional improvement, organizational learning, teacher professional development, and digital innovation.

Across the included studies, transformational leadership emerged as one of the most influential approaches for fostering organizational commitment to STEM education. School leaders adopting transformational leadership established a shared vision for STEM learning, inspired teachers to embrace innovation, encouraged collaborative professional cultures, and promoted continuous improvement. These leadership practices strengthened teachers' motivation and readiness to implement interdisciplinary STEM instruction while supporting long-term organizational change.

Similarly, instructional leadership was consistently associated with improvements in teaching quality and curriculum implementation. Effective instructional leaders actively supervised classroom practices, monitored curriculum implementation, provided constructive feedback, and facilitated ongoing professional development. Rather than focusing solely on administrative responsibilities, these leaders emphasized improving teaching and learning processes, thereby creating instructional environments that supported inquiry-based learning, engineering design, project-based learning, and authentic problem-solving activities characteristic of STEM education.

The synthesis also highlighted the growing importance of distributed leadership, particularly in schools implementing interdisciplinary STEM curricula. Distributed leadership encouraged shared responsibility among principals, teachers, curriculum coordinators, and other stakeholders, enabling collaborative decision-making and collective problem-solving. This collaborative approach strengthened professional learning communities (PLCs), promoted teacher leadership, and facilitated knowledge sharing, which collectively enhanced the consistency and quality of STEM implementation.

Beyond leadership models, the reviewed studies identified several recurring strategies that contributed to successful STEM implementation. These included curriculum integration across science, technology, engineering, and mathematics disciplines; sustained teacher professional development; technology-supported instruction; digital leadership; evidence-informed decision-making; and partnerships with higher education institutions, industries, and local communities.

Such strategies created organizational conditions that enabled teachers to adopt innovative pedagogical approaches while responding to local educational needs.

The findings further demonstrated that educational leadership influences student learning primarily through indirect pathways. Rather than directly improving academic performance, effective leadership shapes school culture, instructional quality, teacher collaboration, and organizational capacity, which subsequently enhance students' learning experiences. Schools led by effective educational leaders reported improvements in scientific literacy, numeracy literacy, STEM competencies, higher-order thinking skills, creativity, collaboration, student engagement, and academic achievement. These outcomes reflect the importance of leadership in establishing learning environments that support authentic, inquiry-oriented, and interdisciplinary STEM instruction.

Another important finding concerns the role of digital leadership in contemporary STEM education. As schools increasingly integrate digital technologies, educational leaders are expected to guide the adoption of learning management systems, virtual laboratories, simulation software, coding platforms, artificial intelligence (AI)-assisted learning tools, and other digital resources. Effective digital leadership not only facilitates technology integration but also promotes digital competence among teachers and students while strengthening organizational readiness for educational innovation.

The review also identified several contextual factors influencing the success of STEM implementation. Educational policies, school culture, teacher readiness, infrastructure availability, financial resources, and community engagement consistently affected leadership effectiveness. Studies conducted in resource-constrained settings emphasized that adaptive leadership, strategic resource allocation, and collaboration with external partners were essential for overcoming institutional and contextual barriers. These findings suggest that effective educational leadership is highly context-dependent and requires flexibility in responding to diverse educational environments.

Overall, the narrative synthesis indicates that no single leadership model is sufficient to address the complex demands of STEM education. Instead, effective school leadership integrates transformational, instructional, distributed, and digital leadership practices to establish collaborative learning organizations capable of sustaining innovation and continuous improvement. Such an integrated leadership approach provides the organizational foundation necessary for advancing scientific literacy, numeracy literacy, and broader STEM competencies required in the Society 5.0 era.

Educational Leadership Models Supporting STEM Implementation

The thematic synthesis indicates that educational leadership is a fundamental determinant of successful STEM implementation across diverse educational contexts. Rather than functioning solely as administrators, school leaders play strategic roles in shaping school vision, strengthening instructional quality, fostering teacher collaboration, and creating organizational environments that support interdisciplinary teaching and continuous innovation. Across the 6 reviewed studies, three leadership models consistently emerged as the most influential in supporting effective STEM implementation: transformational leadership, instructional leadership, and distributed leadership.[33][34]

Among these models, transformational leadership was the most frequently reported approach for facilitating organizational change and cultivating a culture of innovation. School leaders adopting transformational leadership established a shared vision for STEM education, inspired teachers to embrace pedagogical innovation, encouraged professional commitment, and promoted collaborative organizational cultures. By articulating long-term goals and empowering teachers to experiment with interdisciplinary instructional practices, transformational leaders strengthened schools' capacity to implement sustainable STEM programs. The reviewed studies consistently indicated that transformational leadership positively influenced teacher motivation, organizational commitment, and readiness to integrate STEM into classroom practice.[35]

The findings further demonstrate that instructional leadership plays a central role in improving the quality of STEM teaching and learning. Unlike leadership approaches primarily concerned with organizational management, instructional leadership emphasizes teaching

quality, curriculum implementation, and student learning outcomes. Effective instructional leaders actively supervised classroom instruction, monitored curriculum implementation, facilitated professional learning opportunities, and provided continuous instructional feedback. Such leadership practices enabled teachers to implement inquiry-based learning, project-based learning, engineering design activities, and authentic problem-solving experiences, all of which represent essential characteristics of high-quality STEM education.

A third recurring model identified across the reviewed studies was distributed leadership, which recognizes leadership as a collective organizational process rather than the responsibility of a single individual. In schools implementing interdisciplinary STEM curricula, distributed leadership encouraged collaboration among principals, department heads, teachers, curriculum coordinators, and external stakeholders. This collaborative approach promoted shared decision-making, collective responsibility, and professional knowledge exchange through Professional Learning Communities (PLCs)[36]. Consequently, schools adopting distributed leadership demonstrated greater organizational flexibility, stronger interdisciplinary collaboration, and more sustainable implementation of STEM initiatives.

Although each leadership model contributes distinct organizational functions, the synthesis suggests that their effectiveness is complementary rather than mutually exclusive. Transformational leadership provides strategic direction and organizational commitment; instructional leadership strengthens teaching quality and curriculum implementation; and distributed leadership enhances collaboration, teacher empowerment, and collective organizational learning. Schools that integrated these leadership approaches were consistently more successful in sustaining STEM innovation than those relying on a single leadership perspective.

The review also highlights the increasing importance of digital leadership as an emerging dimension of educational leadership in the Society 5.0 era. As STEM education becomes increasingly technology-intensive, school leaders are expected to facilitate the integration of digital technologies such as learning management systems, virtual laboratories, simulation software, coding platforms, robotics, data analytics, and artificial intelligence (AI)-assisted learning tools. Effective digital leadership extends beyond technology procurement by fostering teachers' digital competence, encouraging pedagogical innovation, ensuring equitable access to digital resources, and promoting evidence-informed decision-making through educational data.

Across diverse educational systems, the reviewed studies consistently demonstrate that successful STEM implementation depends not merely on curriculum reform or technological infrastructure but on leadership practices capable of creating supportive organizational conditions. Educational leaders influence STEM implementation indirectly by shaping school culture, strengthening instructional capacity, promoting collaborative professional learning, and aligning institutional goals with national educational priorities. These findings underscore that educational leadership functions as a strategic mechanism linking educational policy, instructional practice, teacher professional growth, and student learning outcomes.

Overall, the synthesis suggests that effective STEM implementation requires an integrated leadership framework that combines transformational, instructional, distributed, and digital leadership practices. Such an integrated approach enables schools to respond adaptively to educational change, sustain continuous innovation, and prepare students with the scientific literacy, numeracy literacy, digital competence, creativity, collaboration, and problem-solving skills required for learning and working in the Society 5.0 era.

Leadership Capacity, Professional Collaboration, and Organizational Learning

The review highlights leadership capacity as a critical factor in fostering collaborative professional cultures that sustain STEM implementation. Across the included studies, effective school leaders consistently established Professional Learning Communities (PLCs), mentoring programs, collaborative lesson planning, and reflective teaching practices to support continuous teacher learning and instructional innovation [37], [14], [15],[6]. These initiatives strengthened teachers' capacity to design interdisciplinary STEM learning, evaluate instructional effectiveness, and exchange pedagogical knowledge. Rather than working in isolation, teachers became members of learning organizations characterized by collective inquiry, peer coaching, and

evidence-based reflection, thereby improving instructional quality, organizational resilience, and schools' capacity for continuous improvement [3],[38].

The findings also indicate that digital transformation has expanded opportunities for professional collaboration beyond conventional face-to-face interactions. Online PLCs, virtual mentoring, cloud-based resource sharing, and collaborative digital platforms enable teachers to exchange instructional resources, analyze student learning data, and develop innovative STEM practices across schools and geographical boundaries [16], [39], [1],[6]. Consequently, leadership capacity extends beyond the competencies of individual school principals to encompass an organizational capability that promotes collaborative innovation, digital competence, and continuous professional learning [14],[15],[38]. These findings reinforce contemporary perspectives that sustainable STEM implementation depends on schools' ability to build collaborative learning cultures supported by strategic, instructional, and digitally responsive leadership [16], [3],[5], [6],[13].

Educational Leadership and Students' Scientific and Numeracy Literacy

A major finding of this review is that educational leadership contributes indirectly to students' scientific and numeracy literacy by improving instructional quality and strengthening organizational learning. Rather than directly influencing student achievement, school leaders create organizational conditions that enable teachers to implement inquiry-based, project-based, engineering design-based, and technology-enhanced STEM instruction [14],[15],[32]. Such leadership supports curriculum coherence, instructional innovation, and sustained professional development, thereby creating more effective learning environments that foster students' STEM competencies and academic achievement [12], [8],[6].

These instructional approaches engage students in authentic learning experiences that promote scientific inquiry, evidence-based reasoning, mathematical problem-solving, and the application of knowledge to real-world contexts. Consequently, students develop higher-order thinking, computational thinking, creativity, collaboration, and problem-solving skills that are consistent with the competencies emphasized in the OECD PISA 2022 framework and UNESCO's vision for future-oriented education [3],[5],[31].

The synthesis further indicates that digitally enriched STEM environments—including virtual laboratories, simulation software, coding platforms, learning analytics, and artificial intelligence (AI)-assisted learning—strengthen conceptual understanding, quantitative reasoning, and student engagement [39],[1],[3], [6]. Effective educational leadership therefore extends beyond administrative management to encompass strategic digital leadership that promotes technology integration, strengthens teachers' digital competencies, and ensures equitable access to innovative learning opportunities [16],[39][1]. Overall, the evidence suggests that improvements in students' scientific and numeracy literacy are cumulative outcomes of sustained instructional improvement supported by visionary, instructional, collaborative, and digitally responsive leadership practices [14], [15],[6], [13].

Policy Implications and Future Directions

The findings of this systematic literature review have several important implications for educational policy and practice. First, leadership development programs should extend beyond traditional administrative responsibilities to cultivate competencies in instructional leadership, digital leadership, curriculum integration, evidence-informed decision-making, and organizational change management. These competencies are increasingly recognized as essential for enabling school leaders to facilitate sustainable and interdisciplinary STEM implementation in rapidly evolving educational environments [15],[40],[6],[13]. Accordingly, leadership preparation programs should emphasize strategic planning, data-informed instructional improvement, teacher professional development, and the effective integration of emerging digital technologies into teaching and learning [12],[16],[39].

Second, policymakers should institutionalize Professional Learning Communities (PLCs) as sustainable mechanisms for collaborative professional learning while strengthening partnerships among schools, universities, industries, and local communities. Such partnerships provide educators with access to technological expertise, authentic STEM learning experiences, research-

informed pedagogical innovations, and continuous professional development. Furthermore, these collaborative networks strengthen organizational learning, promote interdisciplinary curriculum development, and enhance innovation ecosystems that support long-term STEM implementation [37],[3],[38],[6].

Third, education systems should provide school leaders with sufficient autonomy and flexibility to adapt STEM implementation according to local educational contexts while maintaining alignment with national curriculum standards and educational policy objectives. Context-responsive leadership enables schools to address variations in infrastructure, teacher expertise, socioeconomic conditions, and community characteristics, thereby reducing educational disparities and promoting equitable access to high-quality STEM education. Such adaptive leadership is particularly important in geographically diverse or resource-constrained settings, where innovative leadership practices can compensate for contextual limitations and improve educational quality [15],[5],[6],[13].

Finally, the transition toward Society 5.0 requires educational leaders to redefine their professional roles beyond conventional school administration. School leaders are increasingly expected to function as instructional leaders, digital innovators, facilitators of organizational learning, and strategic change agents capable of integrating advanced technologies with human-centered educational values [39],[41],[42],[43]. Effective leadership in this context requires fostering collaborative learning cultures, strengthening teachers' digital competence, promoting evidence-informed innovation, and establishing sustainable partnerships across educational institutions and industry [16],[39],[1]. Developing these integrated leadership capacities is fundamental to sustaining high-quality STEM education and preparing students with the scientific literacy, numeracy literacy, digital competence, creativity, collaboration, critical thinking, and problem-solving skills required for lifelong learning and future societies [3],[5],[6],[31].

4. Conclusion

This systematic literature review synthesized evidence from 6 empirical studies to examine the role of educational leadership in supporting the implementation of Science, Technology, Engineering, and Mathematics (STEM) education and enhancing students' scientific and numeracy literacy. The findings demonstrate that successful STEM implementation depends not only on curriculum design and instructional innovation but also on leadership practices that strengthen organizational capacity, instructional quality, teacher collaboration, and continuous school improvement. These findings reinforce the growing consensus that educational leadership is a strategic driver of sustainable educational innovation, organizational learning, and school effectiveness [15],[3],[6],[13].

Three complementary leadership models consistently emerged as the most influential in supporting STEM implementation: transformational leadership, instructional leadership, and distributed leadership. Transformational leadership establishes a shared vision, inspires innovation, and promotes organizational commitment to change. Instructional leadership enhances curriculum implementation through instructional supervision, coaching, evidence-informed decision-making, and continuous professional learning. Distributed leadership broadens leadership responsibilities by fostering collaboration among school leaders, teachers, curriculum coordinators, and other stakeholders, thereby strengthening collective responsibility for school improvement. Rather than operating independently, these leadership approaches complement one another in creating organizational conditions that facilitate interdisciplinary STEM learning and sustain long-term educational improvement [14],[15],[13].

The review further identifies several organizational mechanisms that mediate the relationship between educational leadership and effective STEM implementation, including Professional Learning Communities (PLCs), continuous professional development, collaborative school culture, digital leadership, and context-responsive school management. Schools that successfully integrate these elements are better positioned to implement inquiry-based, project-based, engineering design-based, and technology-enhanced STEM learning. Consequently, students are more likely to develop scientific literacy, numeracy literacy, critical thinking, creativity, collaboration, problem-solving skills, and broader STEM competencies required for lifelong learning [12],[37],[39],[1]. These findings are consistent with international policy frameworks

emphasizing organizational learning, digital transformation, and instructional leadership as essential components of education in the Society 5.0 era [39], [1],[3] ,[5] ,[6].

Another important conclusion is that leadership effectiveness is inherently context dependent. The influence of educational leadership on STEM implementation is shaped by multiple contextual factors, including educational policy, institutional capacity, technological infrastructure, teacher readiness, socioeconomic conditions, and local school culture. Consequently, effective educational leadership should be understood as an adaptive and context-responsive process that integrates strategic vision, instructional excellence, collaborative governance, organizational learning, and digital innovation rather than as a universally applicable leadership model [15],[3],[5],[6].

From a theoretical perspective, this review contributes to the educational leadership literature by integrating leadership theory and STEM education into a coherent evidence-based framework. The synthesis demonstrates that educational leadership influences students' scientific and numeracy literacy primarily through indirect pathways by strengthening teacher professional learning, organizational learning, instructional quality, collaborative school cultures, and digital innovation [16],[37],[38],[13]. This integrated perspective extends existing research by illustrating the interconnected relationships among leadership practices, school organizational capacity, STEM implementation, and student learning outcomes.

From a practical perspective, the findings provide evidence-based guidance for policymakers, school leaders, teacher education institutions, and professional development providers. Leadership preparation programs should extend beyond administrative management to include instructional leadership, digital leadership, organizational learning, curriculum integration, evidence-informed decision-making, and change management. Strengthening these competencies will better equip educational leaders to sustain interdisciplinary STEM education and respond effectively to the challenges of the Fourth Industrial Revolution and the human-centered aspirations of Society 5.0 [44], [39] ,[41],[4],[6].

Despite its contributions, this review has several limitations. The synthesis was restricted to studies published between 2013 and 2023, included only publications indexed in Scopus and SINTA (Levels 1–2), and focused exclusively on English- and Indonesian-language literature. Future research should incorporate broader international databases, examine longitudinal evidence on leadership effectiveness, compare leadership models across diverse educational systems, and investigate how emerging technologies—including artificial intelligence, learning analytics, and digital ecosystems—reshape educational leadership for sustainable STEM education [16], [1],[6] ,[31].

Practical Implications

The findings of this review suggest several practical implications for educational leadership and STEM implementation. First, leadership preparation programs should move beyond conventional administrative management by strengthening competencies in transformational, instructional, distributed, and digital leadership, together with curriculum integration, organizational learning, and evidence-informed decision-making. These competencies enable school leaders to foster instructional innovation, strengthen teacher professional learning, and sustain interdisciplinary STEM implementation in the contexts of the Fourth Industrial Revolution and Society 5.0 [15],[3] ,[6] ,[13].

Second, schools should institutionalize Professional Learning Communities (PLCs) as sustainable mechanisms for continuous professional learning. Collaborative activities—including interdisciplinary lesson planning, peer observation, instructional coaching, and reflective practice—enhance teachers' pedagogical competence, encourage instructional innovation, and strengthen organizational learning, thereby supporting continuous school improvement and sustainable STEM education [37],[3],[38],[6].

Third, digital leadership should become an integral component of school improvement strategies. The effective integration of artificial intelligence (AI), virtual laboratories, simulation technologies, coding platforms, learning analytics, and digital learning management systems requires leaders who can strengthen teachers' digital competence while promoting innovative and equitable STEM learning environments [16],[39],[1],[6],[31].

Finally, STEM implementation should remain flexible enough to accommodate differences in institutional capacity, geographical conditions, socioeconomic contexts, and local educational needs. Context-responsive leadership enables schools to adapt STEM initiatives while maintaining alignment with national curriculum standards and broader educational priorities, thereby reducing educational disparities and expanding equitable access to high-quality STEM education [3],[5] ,[6].

Policy Implications

The findings underscore the importance of positioning educational leadership as a strategic component of national STEM education policy. Leadership competency frameworks should explicitly incorporate instructional leadership, digital transformation, curriculum innovation, organizational learning, evidence-informed decision-making, and continuous professional development to strengthen school improvement and STEM implementation across educational systems [3],[6],[13].

Governments should prioritize equitable investment in educational infrastructure, including STEM laboratories, digital technologies, reliable internet connectivity, and sustained teacher professional development. Such investments are particularly critical for rural, remote, and underserved schools, where resource limitations continue to hinder the implementation of high-quality STEM education [3],[5],[6].

The review also highlights the importance of strengthening partnerships among schools, universities, industries, research institutions, and local communities. These collaborative ecosystems facilitate knowledge exchange, technology transfer, authentic STEM learning experiences, and curriculum innovation while improving workforce readiness and educational relevance [5],[6],[31].

Furthermore, education systems should develop integrated digital platforms that support instructional supervision, educational data analytics, teacher collaboration, and continuous monitoring of STEM implementation. Such systems enable school leaders to make evidence-informed decisions, improve instructional quality, strengthen organizational learning, and support continuous school improvement in increasingly digital educational environments [16],[1],[3],[6].

Limitations and Future Research

This review has several limitations. First, the analysis was limited to studies published between 2013 and 2023 and indexed in Scopus, ScienceDirect, SpringerLink, and SINTA-accredited journals (SINTA 1–2), which may have excluded relevant evidence from other databases and high-quality grey literature. Second, the review employed a thematic synthesis rather than a quantitative meta-analysis; therefore, it was unable to estimate the effect size or the strength of relationships between educational leadership and STEM-related educational outcomes [25],[27],[28]. Third, variations in educational systems, policy environments, institutional capacity, technological infrastructure, and sociocultural contexts may limit the generalizability of the findings across different countries and educational settings [3],[5],[6].

Future research should adopt longitudinal, experimental, and mixed-methods approaches to provide stronger evidence regarding the causal relationships between educational leadership, STEM implementation, and student learning outcomes. Comparative cross-national studies are also needed to examine how contextual factors influence the effectiveness of different leadership models across diverse educational systems. In addition, emerging topics—including artificial intelligence (AI)-supported educational leadership, learning analytics, adaptive leadership, digital governance, sustainable STEM ecosystems, and leadership for Society 5.0—offer promising directions for future investigation [44],[16],[39],[1],[6],[31]. Advancing research in these areas will contribute to the development of more comprehensive, evidence-based leadership frameworks capable of supporting sustainable STEM education and educational transformation in increasingly digital and technology-driven learning environments.

Daftar Pustaka

- [1] European Commission, “Digital Education Action Plan 2021-2027,” *Eur. Comm.*, p. 20, 2020.
- [2] W. A. Najwa, “Pendekatan PMRI sebagai Gerakan Literasi Sekolah dalam Pembelajaran Matematika,” *Prism. Prosiding Semin. Nas. Mat.*, vol. 1, pp. 575–581, 2018.
- [3] O. 2022, *PISA 2022 Results*, vol. I. 2023.
- [4] K. Schwab, *The Fourth Industrial Revolution*.
- [5] Audrey Azoulay, *Reimagining a newsocial our futures contract for together education*. 2021.
- [6] U. S. Agency *et al.*, “COUNTING THE LOSS : AID TO EDUCATION,” no. July 2026, 2027.
- [7] D. M. Febrian, I. Iltavia, and E. Ergusni, “Pembelajaran Matematika Realistik Indonesia (Pmri) Dalam Membangun Karakter Peserta Didik,” *Lattice J. J. Math. Educ. Appl.*, vol. 3, no. 1, p. 66, 2023, doi: 10.30983/lattice.v3i1.6560.

- [8] K. C. Margot and T. Kettler, "Teachers' perception of STEM integration and education: a systematic literature review," *Int. J. STEM Educ.*, vol. 6, no. 1, 2019, doi: 10.1186/s40594-018-0151-2.
- [9] F. Rahmi, I. Iltavia, and R. H. Zarista, "Mathematical Literacy of Junior High School Students in Solving Problems PISA in Minang Context," *JTAM (Jurnal Teor. dan Apl. Mat.*, vol. 6, no. 4, p. 1112, Oct. 2022, doi: 10.31764/jtam.v6i4.10221.
- [10] I. Isnaniah, M. Imamuddin, C. Charles, S. Syahrul, and Z. Zulmuqim, "Kemampuan Literasi Matematika Siswa Berdasarkan Gender," *Lattice J. J. Math. Educ. Appl.*, vol. 1, no. 2, p. 131, 2021, doi: 10.30983/lattice.v1i2.5088.
- [11] D. Mida *et al.*, "Kemampuan Literasi Matematis Ditinjau dari Self Efficacy pada Siswa Kelas XI MIPA 1 MAN 4 Agam," vol. 8, no. 1, pp. 33532–33541, 2024.
- [12] H. Borko and R. T. Putnam, "Professional development and reform in mathematics education," *Theory Pract.*, vol. 58, no. 2, pp. 109–117, 2019.
- [13] S. Halawa, T. C. Lin, and Y. S. Hsu, "Exploring instructional design in K-12 STEM education: a systematic literature review," *Int. J. STEM Educ.*, vol. 11, no. 1, 2024, doi: 10.1186/s40594-024-00503-5.
- [14] P. Hallinger, "Leadership for learning: lessons from 40 years of empirical research," *J. Educ. Adm.*, vol. 49, no. 2, pp. 125–142, 2011, doi: 10.1108/09578231111116699.
- [15] K. Leithwood, A. Harris, and D. Hopkins, "Seven strong claims about successful school leadership revisited," *Sch. Leadersh. Manag.*, vol. 39, no. 1, pp. 1–18, 2019.
- [16] S. Dexter, J. W. Richardson, and J. B. Nash, "HANDBOOK OF RESEARCH ON THE EDUCATION OF SCHOOL Second Edition ea INNOVATION A Review of the Empirical Research and Implications for Leadership Preparation," 1954.
- [17] E. F. Adanne, "A Meta-Analysis of Data-Driven School Leaders and School Effectiveness in the 21st Century," *J. Hum. Resour. Sustain. Stud.*, vol. 12, no. 01, pp. 204–225, 2024, doi: 10.4236/jhrss.2024.121011.
- [18] M. J. Page *et al.*, "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews," *Bmj*, vol. 372, 2021, doi: 10.1136/bmj.n71.
- [19] H. Snyder, "Literature review as a research methodology: An overview and guidelines," *J. Bus. Res.*, vol. 104, no. March, pp. 333–339, 2019, doi: 10.1016/j.jbusres.2019.07.039.
- [20] B. Kitchenham, "Guidelines for performing systematic literature reviews in software engineering," *Tech. report, Ver. 2.3 EBSE Tech. Report. EBSE*, 2007.
- [21] M. Gusenbauer and N. R. Haddaway, "Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources," *Res. Synth. Methods*, vol. 11, no. 2, pp. 181–217, 2020, doi: 10.1002/jrsm.1378.
- [22] M. Anugerahwati, "Integrating the 6Cs of the 21st Century Education into the English Lesson and the School Literacy Movement in Secondary Schools," *KnE Soc. Sci.*, vol. 3, no. 10, p. 165, 2019, doi: 10.18502/kss.v3i10.3898.
- [23] C. Wohlin, "Guidelines for snowballing in systematic literature studies and a replication in software engineering," *ACM Int. Conf. Proceeding Ser.*, 2014, doi: 10.1145/2601248.2601268.
- [24] Y. Xiao and M. Watson, "Guidance on Conducting a Systematic Literature Review," *J. Plan. Educ. Res.*, vol. 39, no. 1, pp. 93–112, 2019, doi: 10.1177/0739456X17723971.
- [25] J. P. T. Higgins and S. Green, *Cochrane handbook for systematic reviews of interventions*. 2008. doi: 10.56645/jmde.v6i14.284.
- [26] M. D. J. Peters *et al.*, "Updated methodological guidance for the conduct of scoping reviews," *JBIEvid. Synth.*, vol. 18, no. 10, pp. 2119–2126, 2020, doi: 10.11124/JBIES-20-00167.
- [27] C. Virginia, Braun ; Victoria, "Book Review Book Title : Thematic Analysis : A Practical Guide," *Themat. Anal. A Pract. Guid.*, vol. 39, no. January, pp. 1–15, 2024.
- [28] J. Thomas and A. Harden, "Methods for the thematic synthesis of qualitative research in systematic reviews," *BMC Med. Res. Methodol.*, vol. 8, pp. 1–10, 2008, doi: 10.1186/1471-2288-8-45.
- [29] Q. N. . Hong *et al.*, "Mixed Methods Appraisal Tool (MMAT) Version 2018 User Guide |

- Resource Details | National Collaborating Centre for Methods and Tools,” *Can. Intellect. Prop. Off. Ind. Canada.*, pp. 1–10, 2018.
- [30] R. Junco, “Too much face and not enough books: The relationship between multiple indices of Facebook use and academic performance,” *Comput. Human Behav.*, vol. 28, no. 1, pp. 187–198, 2012, doi: 10.1016/j.chb.2011.08.026.
- [31] W. E. Forum, “The Future of Jobs Report 2020. Geneva,” in *Forum, World Economic*, Geneva: WEF, 2020.
- [32] L. Thibaut, H. Knipprath, W. Dehaene, and F. Depaepe, “The influence of teachers’ attitudes and school context on instructional practices in integrated STEM education,” *Teach. Teach. Educ.*, vol. 71, pp. 190–205, 2018, doi: 10.1016/j.tate.2017.12.014.
- [33] J. P. Spillane, “Distributed leadership,” *Educ. Forum*, vol. 69, no. 2, pp. 143–150, 2005, doi: 10.1080/00131720508984678.
- [34] P. S. J, “Distributed leadership,” *Educ. Forum*, vol. 80, no. 3, pp. 321–325, 2016.
- [35] K. Leithwood, A. Harris, and D. Hopkins, “Seven strong claims about successful school leadership,” *Sch. Leadersh. Manag.*, vol. 28, no. 1, pp. 27–42, 2008, doi: 10.1080/13632430701800060.
- [36] “Geographical Data Imperfection 2”.
- [37] R. DuFour, R. D. R. Eaker, and T. W. M. M. Mattos, *Learning by Doing*. 2014. doi: 10.1016/B978-0-12-375678-7.01110-X.
- [38] P. M. Senge, A. Kleiner, C. Roberts, R. B. Ross, and B. J. Smith, *The Fifth Discipline Fieldbook*. 1994.
- [39] R. Vuorikari, S. Kluzer, and Y. Punie, *DigComp 2.2. The Digital Competence Framework for Citizens. With new examples of knowledge, skills and attitudes*, no. KJ-NA-31006-EN-N (online), KJ-NA-31006-EN-C (print). 2022. doi: 10.2760/115376.
- [40] L. A. Romadhoni and R. Setyaningsih, “PEMECAHAN MASALAH MATEMATIS SISWA DALAM MENYELESAIKAN SOAL PISA KONTEN SPACE AND SHAPE DITINJAU DARI GENDER,” *AKSIOMA*, vol. 11, no. 3, pp. 2015–2028, 2022.
- [41] M. Fukumiya, “Society 5.0: Aiming for a New Human-Centered Society,” *Japan Spotlight*, vol. 27, no. 1, pp. 47–50, 2018.
- [42] H. Nakanishi and H. Kitano, “Towards a Bright Future Development of Human Society,” *Soc. 5.0 Co-creating Futur.*, pp. 1–3, 2018.
- [43] Aromataris E and J. Z. Lockwood C, Porritt K, Pilla B, “JBI Manual for Evidence Synthesis,” pp. 5–6, 2017.
- [44] The Government of Japan, “The 5th Science and Technology Basic Plan,” *Counc. Sci. Technol. Innov. Cabinet Off.*, pp. 1–23, 2016.