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The Integration of Spiritual and STEM Education (IS-STEM) in Muhammadiyah Schools: A Systematic Review for Sustainable Learning

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ABSTRACT

Twenty-first-century education requires learners not only to achieve academic proficiency but also to be socially, morally, and environmentally responsible. STEM approaches are proven to enhance cognitive skills, yet they often neglect spiritual and value-based dimensions, limiting their contribution to sustainable learning. This study aims to analyze the concept and implementation of Spiritual-STEM (IS-STEM) for sustainable learning, focusing on teachers' understanding, classroom practices, and the dual impacts on students' cognitive and affective development. A Systematic Literature Review (SLR) was conducted using the PRISMA model. Articles were retrieved from Scopus, Web of Science, ERIC, SpringerLink, MDPI, Taylor & Francis, Wiley Online Library, covering the period 2019-2025. A total of 412 articles were identified, of which 21 met the inclusion criteria and were analyzed using data extraction and thematic synthesis. The review found that IS-STEM served as a bridge between technical competencies and the internalization of spiritual values. Common pedagogical approaches include Project-Based Learning (PjBL), Engineering Design Process (EDP), and Socio-Scientific Issues (SSI). Findings indicate dual benefits: cognitive improvement (conceptual understanding, systems thinking, and problem-solving) and affective development (environmental awareness, social empathy, and moral orientation). Integrating spirituality into STEM strengthens a holistic and sustainable education paradigm. IS-STEM is highly relevant for Muhammadiyah schools and adaptable to global contexts, balancing modern scientific literacy with spiritual development. Further research is recommended to test IS-STEM's effectiveness empirically and to develop valid instruments for evaluating the spiritual dimensions of learning.

Keywords: IS-STEM; sustainable learning; spirituality, technical competence, and values.

INTRODUCTION

Contemporary educational paradigms are shifting beyond a sole focus on academic achievement to encompass the development of skills, attitudes, and values that facilitate lifelong learning. Sustainable learning is a component of the Education for Sustainable Development (ESD) framework initiated by UNESCO, designed to cultivate students who can positively impact society and the environment (UNESCO, 2017, 2020). This comprehensive approach, which incorporates spiritual dimensions, intellect, social awareness, a vision for peace, and global consciousness, is essential for equipping a generation to confront and resolve global concerns (Bai et al., 2018; Cohen & Falkenberg, 2023; Filho et al., n.d.; Mahmoudi et al., 2012).

Nevertheless, modern education continues to prioritize cognitive aspects and practical skills exclusively, as exemplified by the implementation of the Science, Technology, Engineering, and Mathematics (STEM) framework (Vilmala et al., 2022).

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Therefore, graduates often display a notable degree of intellectual proficiency; however, they frequently struggle to adapt to professional settings and engage in social interactions effectively (Shabnam and Tung, 2013). This approach does not adequately address individuals' fundamental needs for existential meaning, spiritual connection, and emotional stability (Goleman, 2020; Nelson, 2010; Zohar & Marshall, 2000).

Numerous studies validate that the STEM method effectively cultivates critical thinking, problem-solving, and innovative skills (Debora & Pramono, 2021; English, 2023; Hebebci & Usta, 2022; Kaya-Capocci et al., 2024; Wegerif et al., 2015). STEM also contributes to connecting learning with the real world through the use of digital devices (Chu et al., 2024; Ritz & Fan, 2015), as well as encouraging cross-disciplinary collaboration that supports the mastery of 21st-century skills (Funa et al., 2024; Hebebci & Usta, 2022; Williams, n.d.). However, other findings criticize this approach for placing too much emphasis on technical, scientific, and technological aspects, thereby neglecting non-cognitive elements such as social, emotional, and spiritual skills (McComas & Burgin, 2020; Qureshi & Qureshi, 2021; Wegerif et al., 2015).

This criticism highlights a research weakness. Most studies continue to focus on the technical application of STEM, while incorporating spiritual qualities into holistic education remains minimal (Sriyanto et al., 2019). Similarly, research on the link between STEM, spiritual values, and sustainable learning is still scarce. In fact, this integration is critical for achieving a more inclusive, balanced learning method that meets the needs of a diverse society.

This study is significant because incorporating spirituality into STEM (IS-STEM) can balance information acquisition, character development, environmental awareness, and social sensitivity. IS-STEM has the potential to provide an innovative solution to the shortcomings of traditional STEM while also increasing education's contribution to long-term development. Furthermore, this integration aligns with the educational philosophy of religious-based schools, which emphasizes spirituality as the cornerstone of overall human development (Zheng, 2022).

Therefore, the objectives of this study are: (1) to analyze the concept and implementation of Spiritual-STEM Integration (IS-STEM) in sustainable learning; (2) to explore teachers' understanding of the IS-STEM approach; and (3) to identify forms of IS-STEM implementation that have an impact on sustainable learning in schools. Thus, this study is expected to contribute, both theoretically and practically, to the development of a more holistic, transformative, and sustainable education.

Research Methodology

Research Design

This study conducted a Systematic Literature Review (SLR) using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) format. This strategy was chosen to provide a thorough overview of S-STEM-based learning integration that contributes to long-term learning, particularly in Muhammadiyah schools.

Data Sources and Search Strategies

The literature search was conducted using reputable international journal databases (Scopus, Web of Science, ERIC, SpringerLink, and MDPI). The search was carried out

between March 2020 and June 2025. The keywords utilized were ("STEM education" OR "integrated STEM" OR "STEAM"); ("sustainability" OR "sustainable learning" OR "ESD" OR "SDGs"); and ("Islamic values" OR "spiritual" OR "religious values") AND ("STEM" OR "education"). This keyword combination was used to identify literature on STEM-related sustainable learning, as well as research that combines spiritual or Islamic principles into education.

Eligibility Criteria

Articles are selected based on the following criteria:

Inclusion Criteria:

a. Articles published from 2019 to 2025.
b. Reputable, peer-reviewed journals in English or Indonesian.
c. STEM/STEAM topics relating to sustainability (ESD/SDGs, climate, citizenship, and values).
d. Integrates values, spirituality, ethics, and character into education.
e. Research subject: Primary-secondary education (K-12), higher education, or teacher education.

Exclusion Criteria:

a. Conference abstracts, dissertations, and grey literature.
b. Articles that do not discuss STEM or sustainable education.
c. Purely technical studies (engineering and technology) with no educational framework

Study Selection Stages

The article selection method adhered to the four steps of PRISMA:

a. Identification: A total of 412 articles were located in the database.
b. Screening: 87 duplicates and 165 non-educational articles were deleted.
c. Eligibility: 160 papers were studied in full to determine their relevance to the IS-STEM subject and sustainable learning.
d. Inclusion: 21 articles that fit the criteria were selected and used as the primary sample.

The diagram is adapted from the PRISMA 2020 guidelines.

Data Extraction and Synthesis

Data was extracted using a systematic literature review (SLR) matrix that encompassed:

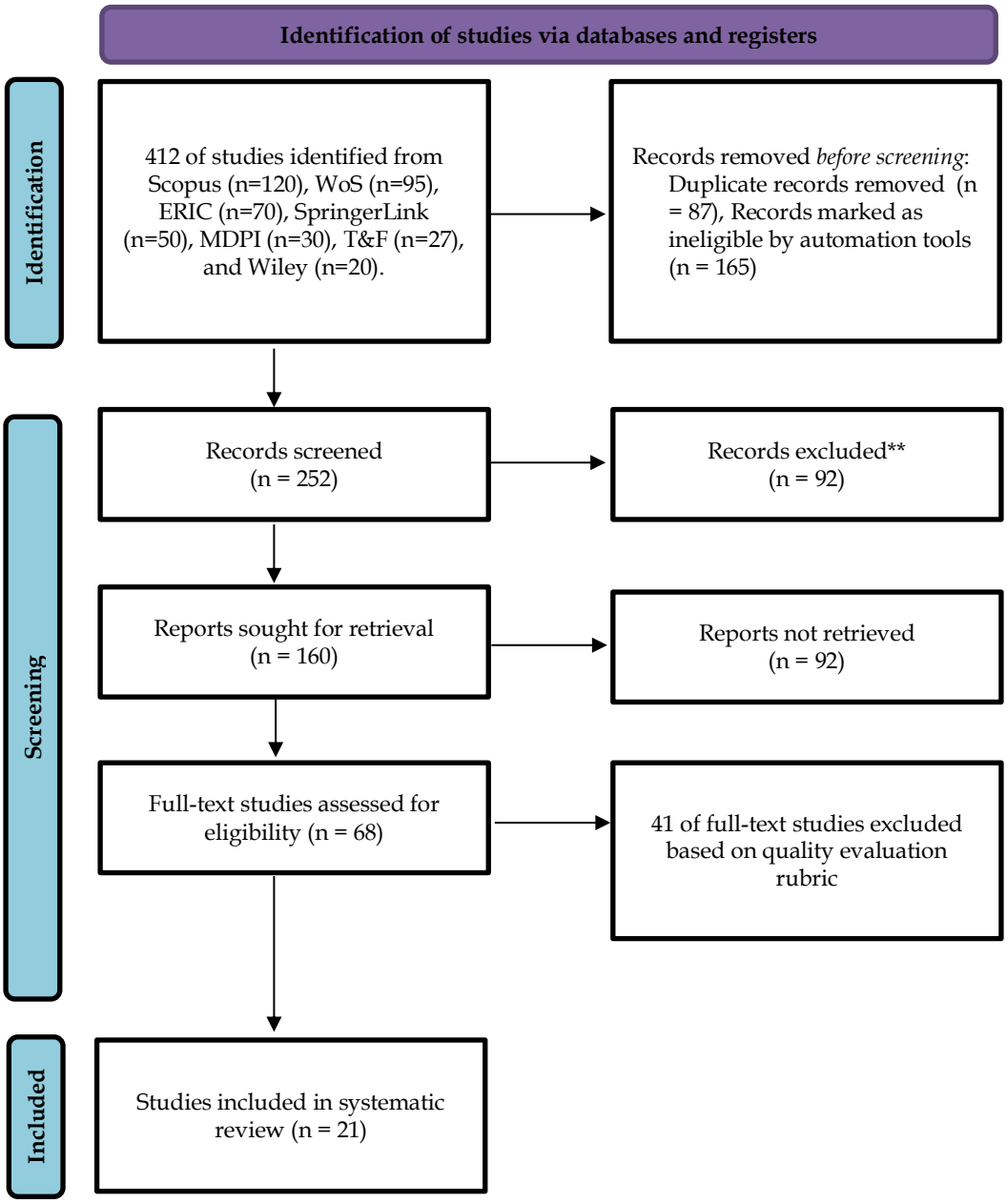
a. Article identification (author, year, country, journal).
b. Educational context (K-12, higher education, teacher education)
c. Integration of STEM (science, technology, engineering, mathematics) and STEAM.
d. Topics related to sustainability and Education for Sustainable Development (ESD), focusing on aspects such as climate change, citizenship, environmental issues, and community engagement.
e. The incorporation of values and spirituality, particularly Islamic values, ethics, character development, and social responsibility.
f. Research design and main findings.

The synthesis utilized narrative analysis and thematic coding, whereby the articles were categorized into three major clusters:

a. Integration of STEM and sustainability
b. Development of effective pedagogical approaches and outcomes
c. Incorporation of spiritual and Islamic values in STEM education

The synthesis highlighted common themes, identified research gaps, and provided directions for enhancing the implementation of Integrated STEM (IS-STEM) in Muhammadiyah schools.

Diagram 1 Study Selection Stages



The PRISMA flow diagram (Diagram 1) visualizes the selection process.

RESULTS AND DISCUSSION
Results

This systematic review analyzed 21 international articles published between 2019 and 2025 that explored the integration of STEM with dimensions of sustainability and spiritual values in education. The findings indicate that the majority of the research focused on primary and secondary education (K-12), with the remainder addressing higher education, teacher professional development, and the conceptual design of learning models. The research methodologies varied, encompassing systematic literature reviews, experimental studies, qualitative research, and the development of learning models. Notably, 24 articles explicitly discussed the connection to spirituality or value integration, although the depth of this discussion varied significantly.

Several prominent themes emerged from the analysis: First, the integration of STEM with sustainability issues was frequently highlighted, with many studies utilizing real-world contexts for learning, such as renewable energy projects, citizen science initiatives, and the examination of socioscientific issues. Second, various pedagogical approaches were employed, including Project-Based Learning (PjBL), the Engineering Design Process (EDP), the Socioscientific Issues (SSI) approach, service learning, and place-based education. Third, spiritual and value components were incorporated, emphasizing ethics, religious reflection, and character development, including the integration of Islamic values like Al-Ma'un in Muhammadiyah schools. Fourth, the reported learning outcomes revealed enhancements in STEM knowledge, systems thinking, critical thinking skills, pro-environmental attitudes, and the cultivation of meaning and social engagement among students. Lastly, the challenges of implementation included limited resources, teacher preparedness, and the lack of standardized evaluation tools to assess the spiritual and sustainability dimensions.

Table 1. STEM Extraction Data Matrix, Continuous Learning, and Spiritual Integration

No	Authors	Title	Country/ Setting	Level (K-12/Higher)	STEM Focus	Sustainability /ESD Focus	Spiritual /Values Component	Key Outcomes / Findings
1	Cordaro, J. A.; Nachimuthu, P.; et al. (2025)	Bridging STEM Education and Sustainability: Insights from K–12 Educators	USA	K-12	Integrated STEM contexts	Sustainability contexts in practice	Values implicit	K-12 teachers use sustainability to contextualize STEM but need clearer curricular guidance and resources.
2	Le, H. C.; Chai, C. S.; et al. (2023)	Integrated STEM Approaches and Associated Outcomes of K-12 Student Learning: A Systematic Review	Global	K-12	Integrated STEM	Real-world problem solving	Not explicit	Identifies which approaches align with particular outcomes; emphasizes engineering design for conceptual learning.

No	Authors	Title	Country/ Setting	Level (K-12/Higher)	STEM Focus	Sustainability /ESD Focus	Spiritual /Values Component	Key Outcomes / Findings
3	Halawa, S.; Lin, T.-C.; Hsu, Y.-S. (2024)	Exploring instructional design in K-12 STEM education: a review	Global	K-12	Instructional design	Societal relevance as theme	Not explicit	Clarifies integrated STEM design principles and typical components (engineering design, real-world problems).
4	Nalipay, M. J. N.; Huang, B.; Jong, M. S. Y. (2024)	Promoting STEM learning perseverance through recognizing communal goals	Asia	Secondary	Integrated STEM	Community needs framing	Civic/communal values	Empathy and citizenship predict perseverance in STEM when communal goals are emphasized.
5	Han, J.; Kelley, T. R.; et al. (2023)	Building a sustainable model of integrated STEM education	USA	K-12	Integrated STEM curriculum	Program sustainability	Community partnerships	Shows how schools sustained integrated STEM after funding by leveraging teacher collaboration and local partners.
6	Timko, G.; et al. (2023)	Sustainable development of community-supported STEM learning ecosystems in rural regions	Rural (USA/Canada)	K-12 ecosystem	STEM ecosystems	Community sustainability	Civic mission	Identifies strategies (partnerships, place-based projects) for durable STEM ecosystems serving sustainability goals.
7	Li, H.-C. (2025)	STEM education and sustainability: what role can mathematics play?	Global	K-12	Mathematics in STEM	Sustainability modelling	Ethical decision-making	Argues math modelling supports ESD competencies; offers classroom exemplars.
8	Madden, L.; et al. (2025)	Instructional Practices in K-12 Climate Change Education	USA (NJ)	K-12	Science (climate)	ESD/Climate literacy	Societal values implicit	Catalogues common strategies and gaps; calls for local action projects linking science and community.
9	Lee, M. Y.; et al. (2025)	Project-Based Learning as a Catalyst for Integrated STEM	Global	K-12	PBL + STEM	Real-world sustainability contexts	Collaboration/values	Synthesizes how PBL supports creativity and problem solving in authentic contexts, incl. sustainability.
10	Yang, L.; et al. (2025)	Cultivating Sustainable STEM Education: The Role of Teacher Identity	China	K-12 teachers	Teacher identity in STEM	Program sustainability	Professional values	Proposes a six-dimension STEM teacher identity model to sustain STEM teaching.
11	Efe, H. (2025)	Let's Take the Pulse of the Classroom on Sustainability!	Turkey	K-12	Science education	SDGs awareness	Civic/ethical views	Finds students' and teachers' limited views on SDGs; recommends curriculum integration across subjects.

No	Authors	Title	Country/ Setting	Level (K-12/Higher)	STEM Focus	Sustainability /ESD Focus	Spiritual /Values Component	Key Outcomes / Findings
12	Chiu, T. K. F.; Li, Y.; et al. (2025)	A decade of research contributions and emerging trends in the International Journal of STEM Education	Global	K-16	Integrated STEM	Trends incl. societal relevance	—	Summarizes 400 IJ-STEME papers; notes growth in social relevance and real-world problem framing.
13	Nurhadi, R.; Fatmaryanti, S. D.; et al. (2025)	Integration of the Values of Surah Al-Ma'un with the STEM Approach as a Learning Model for Muhammadiyah Schools	Indonesia (Muhammadiyah)	Junior Secondary	STEM	Social welfare/charity (Al-Ma'un) as context	Explicit Islamic values (Al-Ma'un)	Model valid & effective to improve scientific attitudes and social awareness.
14	Ahsani, N.; et al. (2025)	Integration of Islamic Values in STEAM Learning	Indonesia	K-12	STEAM	Holistic Islamic education	Explicit Islamic values	Identifies six needs for Islamic STEAM (flexible curriculum, teacher collaboration, resources, value-based pedagogy).
15	Khoiriyah, H. A.; et al. (2024)	Revolutionizing Islamic Curriculum in Enabling Sustainable Development Goals	Multi-country (OIC)	K-12 & Higher	Curriculum + STEM link	SDGs integration	Islamic ethics (khalifah, justice)	Proposes pathways linking SDGs with Islamic education practices; calls for interdisciplinary projects.
16	Megasari, S.; et al. (2025)	Integration of Islamic Education in the Sustainable Development Goals	Indonesia	K-12 & Pesantren	Science/Env. themes	SDGs alignment	Explicit Islamic values	Describes how Islamic schools embed sustainability in curricula and school culture.
17	Lubis, M. (2024)	Muhammadiyah journey through theology of al-'Ashr and al-Ma'un	Indonesia	—	Science–society ethos	Social praxis/al-Ma'un	Islamic ethos	Explains Muhammadiyah's integration of Qur'anic ethos with science and social action—useful for IS-STEM framing.
18	Rahardjanto, A.; et al. (2025)	Islam and sustainability issues: research trends (Scopus)	Global (Islamic world)	—	Interdisciplinary incl. STEM ed.	Sustainability	Islamic perspectives	Shows rapid growth of Islam–sustainability research; education is an emerging cluster.
19	Ibrahim, I. (2024)	Environmental Conservation in Islamic Perspective	Global	—	—	Stewardship (amanah)	Explicit Islamic values	Frames environmental stewardship from Islamic teachings; supports value integration in lessons.

No	Authors	Title	Country/ Setting	Level (K-12/Higher)	STEM Focus	Sustainability /ESD Focus	Spiritual /Values Component	Key Outcomes / Findings
20	Kozan, K.; et al. (2023)	Factors Influencing Student Outcomes in K-12 Integrated STEM Education: A Systematic Review	Global	K-12	Integrated STEM	Community & real-world issues	–	Finds student outcomes shaped by design elements (engineering design, collaboration) and context; equity considerations noted.
21	Hsu, Y.-S.; Lin, T.-C.; et al. (2024)	Instructional designs for nurturing 21st-century competencies in K-12 STEM education	Global	K-12	Instructional design	Real-world problem contexts	–	Synthesizes design features aligned to competencies such as collaboration, critical thinking, and problem solving.

Discussions

Integration of IS-STEM as a bridge between technical competence and values

The results of the study show that IS-STEM acts as a "bridge" between mastery of technical competence and internalization of moral and spiritual values. This integration is not merely an addition of religious sessions in science classes, but emphasizes learning experiences that connect science, technology, engineering, and mathematics with spiritual meaning and social responsibility. Studies by Högström and Ståhl (Hadjichambi et al., 2023) and Hadjichambi et al. (Hadjichambi et al., 2023) confirm that learning through socio-scientific issues and community projects can bring about value reflection while strengthening scientific understanding (Bajuri et al., 2021; Judijanto, 2025). This aligns with the idea that sustainable learning not only hones knowledge but also shapes students' character and agency (Le et al., 2023).

Effective Pedagogical Approaches for Integrating STEM and Sustainability

Recent studies indicate that Project-Based Learning (PjBL) and the Engineering Design Process (EDP) are among the most widely adopted methodologies for the integration of Science, Technology, Engineering, and Mathematics (STEM) with sustainability issues. These pedagogical approaches facilitate student engagement with real-world problems, thereby enhancing not only their understanding of scientific and mathematical concepts but also their design competencies and their capacity for critical reflection on value. Research conducted by Chairunnisya et al. (2023) demonstrates that PjBL and EDP significantly enhance systems thinking and complex problem-solving skills. Conversely, the Socio-Scientific Issues (SSI) approach explicitly fosters the exploration of values and ethics by encouraging students to consider the social, environmental, and moral ramifications of their decisions (Chairunnisya et al., 2023; Daulay & Asrizal, 2024; Högström et al., 2024).

Additional methodologies, such as place-based learning and service-learning, effectively link STEM knowledge to local contexts. For instance, a study by Bajuri et al. (2021) that focused on a community-based renewable energy project illustrates how integrating values, technological understanding, and social responsibility can be realized in a substantive manner.

Learning Impact: Cognitive, Affective, and Conative Domains

The majority of existing literature highlights favorable outcomes across both cognitive and affective domains. (Orgill et al., 2019) demonstrated that the incorporation of systems thinking in sustainable chemistry education enhances both conceptual understanding and environmental consciousness. Further, Nalipay et al. (2024) reported that acknowledging communal objectives in STEM education fosters greater perseverance among students. In the Indonesian context, integrating the values derived from Surah Al-Ma'un into STEM curricula in Muhammadiyah schools has been shown to foster heightened social empathy among students. However, this research remains limited in scope (Nurhadi et al., 2023).

These findings suggest that integrating Islamic values into STEM (IS-STEM) not only enables students to acquire academic knowledge but also encourages them to develop moral awareness and engage in socially and environmentally responsible actions. This alignment is particularly pertinent to the mission of Muhammadiyah Education, which emphasizes the synergy between knowledge and faith.

The Role of Teachers and Systemic Support

Existing research underscores the pivotal role of teachers in implementing IS-STEM. Educators must not only possess a robust knowledge base in STEM subjects but also be adept at facilitating discussions on ethical considerations and designing assessments that effectively measure sustainability competencies. Studies by Cordaro et al. (2025) and Yang et al. (2025) emphasize the importance of professional development programs that equip teachers with the skills to integrate Education for Sustainable Development (ESD) into the STEM curriculum. Without systemic support, including well-defined curricular frameworks, assessment methodologies, and resource allocations, the successful application of IS-STEM is largely reliant on individual initiatives, which poses a risk to its long-term sustainability (Stevenson et al., 2025).

Limitations and Research Gaps

Despite its demonstrated potential, this body of research acknowledges several limitations. Firstly, there is a dearth of quantitative longitudinal studies that can ascertain the enduring impact of IS-STEM on students' sustainable behaviors. Secondly, the dominance of qualitative or self-report instruments for assessing spiritual dimensions necessitates the development of more valid and reliable measurement tools. Lastly, the generalizability of the findings remains limited, particularly for contextual models predicated on Islamic values, which require further validation within specific schools and cultural settings.

Implications for Muhammadiyah Schools

The synthesis of the findings presented herein provides strategic directions for implementing IS-STEM within Muhammadiyah schools. Firstly, educational units could be conceptualized around community-based projects that blend straightforward technological applications with religious values, such as the development of clean energy initiatives for mosques. Secondly, local SSI issues—such as water management, waste reduction, and urban environmental challenges—can be utilized as platforms for ethical and religious discourse. Thirdly, prioritizing teacher capacity-building is essential, particularly by focusing on interdisciplinary pedagogical design that encompasses science, religion, and social studies, coupled with holistic assessment strategies. In this manner, IS-STEM can fortify the position of Muhammadiyah schools as leaders in holistic education that harmonizes knowledge with faith.

CONCLUSION

The review of 21 studies found that integrating spirituality into STEM (IS-STEM) was essential for achieving sustainable learning, particularly in Muhammadiyah schools. Although STEM had been widely applied to develop 21st-century skills, spiritual and Islamic values remained rarely embedded in learning practices. IS-STEM strengthens students' moral, social, and environmental responsibility, increases the relevance of learning in religious-based communities, and enhances sustainability awareness through the integration of science, technology, engineering, mathematics, spirituality, and local knowledge.

IS-STEM, therefore, represented a holistic, sustainability-oriented paradigm that aligned modern scientific literacy with Islamic spirituality, consistent with the mission of Muhammadiyah education. The findings understood the need for further research to develop classroom-based IS-STEM models, evaluate their impact on cognitive competence and student well-being, and design valid assessment tools to measure spiritual integration. Overall, IS-STEM could be within the Muhammadiyah context and globally.

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