

COMMUNITY-BASED STEM ECOSYSTEM IN INDONESIAN MUSLIM COMMUNITIES

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Keyword

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Abstract

This study aims to formulate a model of a community-based STEM innovation ecosystem within the context of non-formal education in Indonesian Muslim communities. The background of this review is rooted in the limited access to relevant STEM education for Muslim communities, particularly in rural and peri-urban areas, alongside the substantial potential of Islamic non-formal educational institutions—such as Islamic boarding schools (pesantren), Qur'anic learning centers (TPA), and Islamic study groups (majelis taklim)—to serve as venues for contextual learning. The research employed a literature review of over 50 sources—including peer-reviewed journals, academic books, policy documents, and research reports—analyzed thematically and critically. The analysis process involved thematic coding, conceptual synthesis, critical evaluation, and the construction of a conceptual model. Findings indicate that an effective STEM innovation ecosystem requires six key components: (1) community-based learning environments, (2) local actors serving as facilitators, (3) contextual curricula integrated with Islamic values, (4) project-based learning methods, (5) accessible low-tech support, and (6) strategic partnerships with external stakeholders. This model is holistic and participatory, aligning with the social, cultural, and spiritual characteristics of Muslim communities. The findings provide a conceptual contribution to value-driven, locally grounded non-formal education innovations and offer insights for more responsive policy and practical frameworks. The study recommends capacity-building for facilitators, adaptive curriculum development, and strengthened multi-sectoral collaboration as strategic measures for the sustainable implementation of the model.

INTRODUCTION

Addressing the global challenges of the 21st century, education in science, technology, engineering, and mathematics (STEM) has become increasingly vital as a foundation for developing individual and collective capacities in innovation and technology. STEM literacy is not only essential for students in formal education pathways but also constitutes a critical need within broader community contexts, including non-formal education settings (Kuswanto et al., 2024). Amidst the accelerating pace of industrial revolutions and digital transformation, critical thinking, problem-solving, and the comprehension of scientific and technological concepts have emerged as indispensable competencies for cultivating productive, adaptive, and competitive citizens (AlAli et al., 2023; Anwar et al., 2023; Widyawati et al., 2024).

However, STEM education in Indonesia remains predominantly concentrated in formal, urban educational institutions (Farwati et al., 2021). Muslim communities dispersed across

various regions, particularly in areas with limited access to formal education, continue to face challenges in obtaining STEM education that is both contextualized and relevant to their daily lives. Community-based non-formal education institutions—such as Qur’anic Learning Centers (TPQ), Islamic study groups (majelis taklim), Islamic boarding schools (pesantren), and Community Learning Centers (PKBM)—hold significant potential to serve as platforms for advancing STEM literacy through approaches aligned with Islamic values and local socio-cultural contexts (Nugroho et al., 2021; Sujarwanto et al., 2021).

A growing body of research has highlighted the benefits of community-based approaches in education, particularly in enhancing participation, contextual relevance, and the sustainability of learning processes (Artunduaga Garzón & Palomino Herrera, 2023; Chowdhury & Alzarrad, 2025). Within Indonesian Muslim communities, education is perceived not merely as cognitive development, but also as an act of worship, a means of moral development, and a catalyst for social transformation. Hence, non-formal education is one of the effective media to deliver STEM content, combined with Islamic value teaching, to empower communities in a meaningful and collective approach (Desfitri et al., 2024).

Regrettably, there remain limited comprehensive studies and conceptual models that integrate a STEM innovation ecosystem approach with the framework of community-based non-formal education tailored to Muslim contexts. This gap has resulted in limited practical guidance for non-formal education practitioners in designing STEM curricula and learning strategies that are responsive to the unique conditions of their communities.

In response to this limitation, the present article aims to conduct an extensive review of the literature on STEM education, non-formal education, community-based pedagogical approaches, and Islamic educational values. The primary aim is to construct a conceptual model of a community-based STEM innovation ecosystem that can serve as an alternative means to enhance the capacities of Muslim communities through non-formal educational pathways in Indonesia. By synthesizing prior research findings and exemplary practices across diverse contexts, this study aspires to contribute both theoretically and practically to the development of educational innovations that are relevant, inclusive, and contextually grounded. The proposed model is expected not only to enhance STEM literacy among Muslim communities but also to foster greater community participation in collaborative and transformative learning processes.

METHOD

This study employs a qualitative approach, utilizing a narrative literature review method. This approach was selected due to its suitability for collecting, examining, and synthesizing a broad range of academic and policy-related literature in order to construct a conceptual model that is both innovative and contextually grounded. A narrative literature review enables researchers to identify relationships among concepts and develop a comprehensive theoretical understanding of the topic under investigation.

This literature review is conceptual in nature rather than systematic or meta-analytic, as its primary focus is the development of a theoretical model and conceptual framework tailored to the context of non-formal education in Muslim communities. The model is intended to serve as a conceptual novelty, providing a basis for further development and empirical testing in subsequent research.

The literature collection process was carried out systematically through several stages designed to ensure that the selected sources were relevant, credible, and capable of supporting the development of a comprehensive conceptual model. The initial stage involved identifying data sources, from which literature was gathered from a wide array of academic and policy references closely aligned with the research topic. These sources included national and international peer-reviewed journals indexed in databases such as Scopus, DOAJ, Google Scholar, and SINTA; scholarly books on education, STEM, Islamic education, and community development; national and international policy documents such as the Indonesian Ministry of Education and Culture regulations, UNESCO reports, and the National Education System Law (UU Sisdiknas); and institutional research reports from agencies such as Balitbang Kemendikbud and Bappenas. The

diversity of these sources aimed to enrich perspectives and support an interdisciplinary approach in model formulation.

Subsequently, literature searches were conducted using specific keywords in both Indonesian and English that represent the core dimensions of the study. These keywords included “STEM education,” “community-based education,” “non-formal education,” “Islamic education values,” “Muslim community learning,” and “innovation ecosystem in education,” along with their Indonesian equivalents such as “pendidikan nonformal”, “komunitas Muslim”, “nilai Islam dalam pendidikan”, and “ekosistem inovasi pembelajaran”. The selection of these keywords was intended to capture diverse theoretical and practical approaches relevant to the research theme and to map the discourse as it appears in both global and local literature.

A set of rigorous inclusion and exclusion criteria was applied to ensure the quality and focus of the reviewed literature. The inclusion criteria encompassed publications from the past 5 to 10 years (2015–2025), thematic relevance to the study focus, availability in either Indonesian or English, and full-text accessibility (open access). Conversely, opinion pieces lacking empirical or theoretical grounding, duplicate articles, or those unrelated to the context of Muslim community education were excluded from the analysis.

In total, more than 50 primary sources were selected for in-depth review. These included research journal articles, academic books, policy reports, and dissertations directly associated with five major theoretical domains: STEM education, non-formal education, Islamic education, community-based development, and educational innovation ecosystems. The selected literature was analysed thematically to generate a conceptual synthesis that forms the foundation for developing a community-based STEM innovation ecosystem model in the context of non-formal education within Indonesian Muslim communities.

The analytical process was carried out both thematically and critically to obtain a comprehensive understanding of STEM education, non-formal education, Islamic education, and community development. The process began with thematic coding to identify key themes, including STEM learning approaches, the characteristics of non-formal education, the role of community actors, Islamic values, and the structural components of educational innovation ecosystems. These findings were then synthesized into five core theoretical pillars to uncover interrelated concepts and identify overarching narratives that support the formulation of the conceptual model. A critical appraisal of each source was conducted to assess its relevance, strengths, limitations, and the potential integration of Islamic values into STEM education, particularly within Muslim communities located in rural and peri-urban areas. The final stage involved constructing a conceptual model of a community-based STEM innovation ecosystem, mapping the interrelationships among actors, processes, values, learning environments, and collaborative networks. This model aims to provide a robust and contextually relevant conceptual contribution to policy development and innovative practices in non-formal education.

RESULTS AND DISCUSSION

1. Main Findings from Literature

The findings of this literature review reveal several gaps and strategic opportunities in the development of STEM education within Indonesian Muslim communities, particularly through non-formal education pathways. One of the primary gaps lies in the limited access to and relevance of STEM programs for Muslim populations residing in rural and peri-urban areas. Existing STEM education initiatives in Indonesia are predominantly formal and academically oriented, often overlooking the cultural, spiritual, and practical dimensions that are vital to local communities (Arlinwibowo et al., 2021). This disconnect between STEM learning content and the lived realities of the community results in low participation levels and limited educational impact (Wekke, 2024).

Conversely, there is significant potential within Islamic non-formal education institutions, which are widely distributed and possess strong social foundations. Institutions such as Qur’anic Learning Centers (TPQ), Islamic study groups (majelis taklim), Islamic boarding schools (pesantren), and Community Learning Centers (PKBM), rooted in Islamic values, serve not only

as venues for religious instruction but also as social spaces that can be mobilized to deliver contextualized, community-based, and accessible STEM education (Balyk et al., 2022; Masykur et al., 2024). A key advantage of these institutions lies in their integration of Islamic values as a form of social capital that could be organically embedded into STEM learning. Values such as accountability (*amanah*), cooperation (*ta'awun*), and environmental stewardship (*rahmatan lil'alamin*) can serve as ethical and motivational foundations for fostering sustainable social innovation within the community (Abas et al., 2024).

Furthermore, the role of the community and local actors emerges as a critical element in supporting the success of a community-based STEM education model (Fahmi et al., 2024). Religious leaders, mosque youth groups, women in *majelis taklim*, and volunteer educators in PKBM possess high levels of social proximity and trust within their communities. Their function extends beyond content delivery; they act as agents of change and facilitators of innovation, capable of bridging modern scientific knowledge with the cultural and religious values embedded in the community (Hua & Zarazaga, 2024). Therefore, constructing a participatory and contextualized STEM education ecosystem rooted in Muslim communities is not only feasible but holds great promise for driving a more inclusive, relevant, and equitable educational transformation (Vasinayanuwatana et al., 2021).

2. Conceptual Synthesis of Model Components

Based on the literature findings analysed, six core components have been identified to construct a conceptual framework for a community-based STEM innovation ecosystem model within the context of non-formal education in Indonesian Muslim communities. These six components are interconnected and form a dynamic system that enables STEM learning to occur in a contextualized, inclusive, and sustainable manner.

The first component is the learning environment, which refers to community spaces such as mosques, Islamic boarding schools (*pesantren*), learning houses, religious study circles (*majelis taklim*), and community learning centres. These settings have long served as both social and spiritual centres of informal education within Muslim communities (Alkouatli, 2018; Baldridge et al., 2017). They function as open and inclusive learning spaces grounded in the real needs of the community (Barizi et al., 2025; Machali et al., 2023).

The second component concerns the key actors involved in the learning process, which include religious scholars (*ulama*), Islamic teachers (*ustadz/ustadzah*), non-formal tutors, mosque youth groups, university students, STEM volunteers, and community facilitators. These actors serve not only as knowledge transmitters but also as agents of innovation and as bridges connecting modern scientific knowledge with Islamic values (Huda et al., 2016; Nabil et al., 2024).

The third component is a contextual curriculum that integrates STEM content with locally relevant issues such as clean water management, sanitation, renewable energy, sustainable agriculture, and waste management (Elbashir et al., 2024; Moslimany et al., 2024). This curriculum is developed with consideration for Islamic teachings, enabling learners to perceive STEM education not as contradictory to their beliefs but rather as part of religious duty (*ibadah*) and social responsibility (Baehaqi et al., 2024; Masykur et al., 2024; Siron, 2024).

The fourth component involves participatory and project-based learning methods, which enable learners to engage with their immediate environment through hands-on practice, group discussions, and collaborative problem-solving (Alkouatli, 2023; Nasih et al., 2020). These methods resonate with dialogical approaches in Islamic pedagogy, which emphasize *musyawarah* (public consultation) and critical reflection (Inayati et al., 2025).

The fifth component is supporting technology, referring to the use of simple digital media such as instructional videos, Android-based educational applications, and low-cost experimental tools made from recycled or locally available materials. In this context, technology is not intended to replace face-to-face learning, but rather to enhance accessibility and learning effectiveness (Major et al., 2021).

The sixth and final component is collaboration and networking, which involves strategic partnerships between communities and external institutions, such as universities, civil society organizations (NGOs), government agencies, and private sector entities. These collaborations are

essential for facilitating training, providing teaching resources, and ensuring the ongoing validation and quality assurance of educational programs (Azorín, 2020; Johnsen, 2022).

Together, these six components form the foundation of a community-based STEM innovation ecosystem model designed not only to enhance STEM literacy within Muslim communities but also to strengthen community capacity in generating locally driven, participatory, and values-aligned solutions to pressing societal challenges.

The six key components of the community-based STEM innovation ecosystem model are summarized as follows:

<i>Component</i>	<i>Description</i>
<i>Learning Environment</i>	Community spaces such as mosques, <i>pesantren</i> , learning houses, and community centres serve as open and contextual learning environments.
<i>Key Actors</i>	Religious scholars, Islamic teachers, non-formal tutors, youth leaders, STEM volunteers, university students, and community facilitators.
<i>Contextual Curriculum</i>	STEM materials linked to local issues (e.g., clean water, sanitation, energy, agriculture) and harmonized with Islamic values.
<i>Learning Methods</i>	Project-based learning, environmental exploration, and hands-on activities employing dialogical and participatory pedagogical approaches.
<i>Supporting Technology</i>	Simple digital media, mobile educational apps, and experimental tools are designed using recycled or locally sourced materials.
<i>Collaboration & Network</i>	Partnerships between communities and universities, NGOs, government institutions, and the private sector to support training, resources, and validation.

3. Articulation of the Community-Based STEM Ecosystem Model

Drawing upon the synthesized literature and the mapped key components, the proposed community-based STEM innovation ecosystem model within the context of non-formal education in Indonesian Muslim communities is conceptualized as a dynamic, collaborative system rooted in contextual relevance and spiritual values. The model is designed not only to enhance STEM literacy but also to strengthen community capacity in addressing local challenges (such as environmental problems, educational gaps, health disparities, economic hurdles, or social inequities) through value-driven, culturally grounded, and participatory approaches. Structurally, the model consists of three interrelated and mutually reinforcing layers: the core layer, the supporting layer, and the networking layer.

The core layer represents the central domain of activity in the model, encompassing both contextual and applied STEM learning. This layer emphasizes not merely the acquisition of theoretical knowledge but the practical application of STEM concepts to daily life. Learning activities are framed as simple, community-based projects that integrate science and technology with local practices (Hua & Zarazaga, 2024; Starr et al., 2022; Tomkin et al., 2019). Examples include transforming household waste into compost, designing sensor-based irrigation systems, or developing energy-saving tools using recycled materials. Learners are encouraged to explore their environment, reflect on social realities, and engage in collaborative problem-solving, thereby internalizing scientific knowledge while cultivating scientific attitudes and civic awareness (Nation & Hansen, 2021; Solanki et al., 2019).

The second layer, the supporting layer, encompasses the social, cultural, and infrastructural elements that sustain the learning process. Within this layer, Islamic values serve as the ethical foundation that reinforces learning motivation (Judijanto, 2025). For example, learning is viewed as an act of worship, communal work (*gotong royong*) is understood as a form of charity, and environmental responsibility is perceived as part of the human mandate of stewardship (*khalifah*). The learning process is facilitated by local actors, such as *ustadz*, non-formal education tutors, and mosque youth, who are familiar with both the technical aspects of STEM and the religious and cultural values embedded in the community (Elbashir et al., 2024). Learning spaces are flexible and inclusive, utilizing mosques, *pesantren*, community centres, and informal learning houses as alternative educational environments.

The third layer, the networking layer, refers to cross-sectoral collaborations that provide communities with access to resources, expertise, and institutional support. External stakeholders—such as universities, non-governmental organizations (NGOs), local governments, and small industries—play a critical role in this layer. Their involvement may include facilitator training, the provision of educational tools and materials, contextual curriculum development, as well as the documentation and dissemination of best practices (Hackmann et al., 2019; Huijser et al., 2024; Nilsson Brodén, 2022). This collaborative network acts as an innovation catalyst, enhancing the reach and sustainability of the program while advancing the transformation of non-formal education toward a more strategic and collaborative direction (Kolleck et al., 2020; Soliz et al., 2023).

Through these three interwoven layers, the proposed model not only addresses the urgent need for STEM literacy among Muslim communities but also harmoniously integrates religious, social, and technological dimensions. It demonstrates that STEM education can be presented in a simple, grounded, and highly practical format, capable of nurturing grassroots innovation and fostering sustainable, community-driven development.

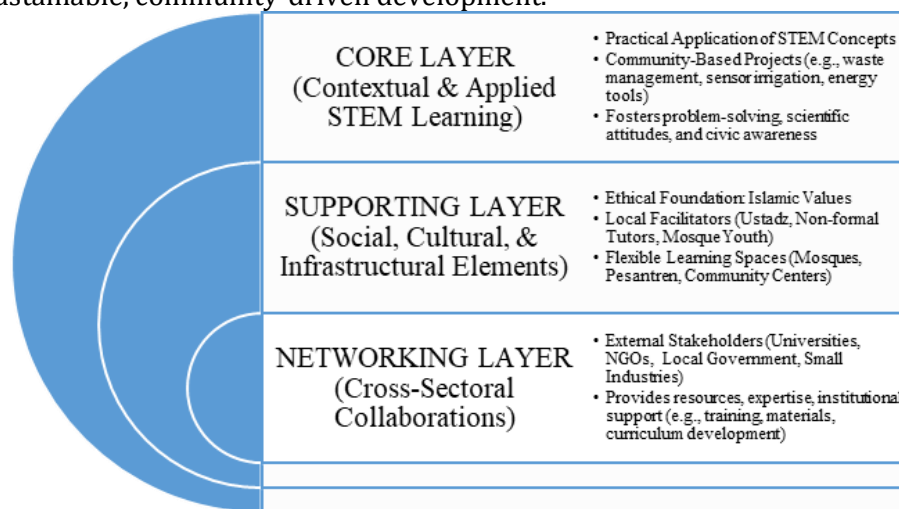


Figure 1. Community-Based STEM Innovation Ecosystem Model Framework

4. Critical Analysis of the Model

The community-based STEM innovation ecosystem model developed in this study demonstrates several strengths that are relevant, adaptive, and potentially applicable within the context of non-formal education for Muslim communities in Indonesia (Indah & Jannah, 2024). The first notable strength is in its contextual and religious nature, wherein Islamic values are not perceived as barriers to STEM learning but rather as motivational drivers that enrich the meaning and purpose of education. Core values such as amanah (trustworthiness), ta'awun (mutual assistance), and social responsibility are organically integrated into learning activities, allowing learners to perceive STEM education as an act of worship and community service (Šimunović & Babarović, 2020).

The second strength of the model is its needs-based approach that learning activities are not guided by rigid, standardized curricula but are instead designed to address real-world challenges faced by the community (AlAli, 2024). Issues such as access to clean water, waste management, alternative energy, and local agriculture form the basis of learning projects, making education more meaningful and action-oriented.

Furthermore, the model promotes inclusivity and participation by encouraging the involvement of all community members without discrimination (York et al., 2021). Women, youth, and marginalized groups are provided with space to engage as both learners and drivers of the learning process, fostering an equitable and collaborative educational dynamic (Kricorian et al., 2020; Saw, 2020). The role of community facilitators—including religious teachers (ustadz),

PKBM tutors, and youth volunteers—further strengthens the spirit of collective action (gotong royong) and local empowerment in STEM education delivery.

Nevertheless, the model also encounters several challenges that must be strategically anticipated and addressed. One major challenge pertains to human resource capacity, particularly among facilitators who may lack adequate competence in delivering STEM content in an integrative manner that incorporates Islamic values. Therefore, continuous professional development is urgently needed to ensure that the model's implementation does not overly depend on a few individuals (Anning, 2025; Martin et al., 2022; Sabirova et al., 2020).

Another challenge lies in the limited access to technology and learning resources, especially in geographically and economically marginalized communities. Barriers to accessing digital tools, experimental media, and affordable STEM literature continue to impede effective learning processes (Eugenijus, 2023; Todorov et al., 2024). Additionally, program sustainability emerges as a crucial concern. While the model is socially and normatively strong, its long-term viability relies heavily on supportive policies, enduring partnerships, and sufficient incentives for community-level implementers. Without strong commitment from key stakeholders—including government agencies, higher education institutions, and civil society organizations—there is a risk that the model may remain a temporary initiative lacking deep institutional roots. Hence, the success of this model is not solely determined by the strength of its design, but also by the degree to which the broader system is committed to supporting community-based, contextualized, and empowerment-oriented education.

CONCLUSION

This literature review suggests that integrating STEM education within the context of Indonesian Muslim communities through non-formal education pathways holds significant potential for enhancing science and technology literacy in a contextually grounded manner, rooted in Islamic values. Various findings from the literature reinforce the argument that STEM education does not necessarily need to be confined to formal settings or advanced laboratory environments. The community-based STEM innovation ecosystem model developed in this study presents a holistic, participatory, and problem-solving-oriented approach that addresses real-life issues encountered in daily community life. The model is structured into three core layers: (1) the core layer, which involves contextual STEM learning processes; (2) the supporting layer, which encompasses values, learning environments, and local actors; and (3) the networking layer, which includes external partnerships and supporting technologies. This model is flexible, replicable, and highly relevant for implementation in Muslim community contexts across various regions in Indonesia.

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