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Holistic Learning through Qurʾānic-Integrated STEM: Innovations in Early Childhood Pedagogy

Sri Nurhayati
Institut Keguruan dan Ilmu Pendidikan (IKIP) Siliwangi, Indonesia
email: srinurhayati@ikipsiliwangi.ac.id

Marhamah
Institut Keguruan dan Ilmu Pendidikan (IKIP) Siliwangi, Indonesia
email: marhamah220874@gmail.com

Taufikin
Universitas Islam Negeri Kudus, Indonesia
email: taufikin@iainkudus.ac.id

Hani Sholihah
Institut Nadhlatul Ulama Tasikmalaya, Indonesia
email: hanisholihah123@gmail.com

Anissa Tri
Institut Keguruan dan Ilmu Pendidikan (IKIP) Siliwangi, Indonesia
email: anisatri144@gmail.com

Rizky Maemunah
Institut Keguruan dan Ilmu Pendidikan (IKIP) Siliwangi, Indonesia
email: rizkimaemunah29@gmail.com

Mohammad Moreb
Smart University College for Modern Education, Palestine, State of
email: m.moreb@scme.edu.ps

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Qurʾānic-integrated STEM; early childhood education; Islamic pedagogy.

Abstract

This study offers a critical investigation into the epistemic and developmental implications of Qurʾānic-integrated STEM pedagogy within holistic early childhood education, as enacted in Indonesian Muslim community-based institutions. Confronting the persistent lacuna between secular STEM initiatives and culturally embedded educational imperatives, the research pursues a nuanced empirical exploration of how educators operationalize Islamic ethical and ontological constructs-rooted in Qurʾānic revelation and Islamic philosophical tradition-within science, technology, engineering, and mathematics curricula. Utilizing a qualitative phenomenological framework, the study sampled thirty-five female educators across institutional variations, employing semi-structured interviews, systematic document analysis, and non-participant classroom observations to triangulate data. Thematic analysis, conducted through iterative

coding, elucidated five advanced pedagogical strategies: ritual epistemic framing, scriptural exegesis within scientific dialogue, inquiry-driven didactics, adab-infused socialization, and contemplative synthesis, each representing a locus for epistemological integration between empirical inquiry and spiritual cultivation. Empirical mapping of seven STEM activities revealed intentional alignment with Qurʾānic virtues-syukur (gratitude), amanah (accountability), khalifah (stewardship)-demonstrating their transformative agency across cognitive, psychomotor, spiritual-moral, socio-emotional, and environmental domains of child development. Synthesis of observational and participant narratives substantiated salient advances in learners' scientific reasoning, metacognitive self-awareness, spiritual affectivity, communal solidarity, and environmental stewardship. These findings decisively extend the scholarly discourse by evidencing that Qurʾānic-integrated STEM environments do not merely impart scientific literacy, but foster learners marked by profound ethical orientation and ecological consciousness.

Abstrak

Kata Kunci: STEM terintegrasi Qur'an; pendidikan anak usia dini; pedagogi Islam;

Studi ini menawarkan investigasi kritis mengenai implikasi epistemik dan perkembangan dari penerapan pedagogi STEM terintegrasi Al-Qur'an dalam pendidikan anak usia dini holistik pada institusi berbasis komunitas Muslim di Indonesia. Dengan menanggapi kesenjangan yang masih ada antara inisiatif STEM sekuler dan tuntutan pendidikan yang berakar budaya, penelitian ini melakukan eksplorasi empiris yang bernuansa tentang bagaimana para pendidik mengoperasionalkan konstruksi etika dan ontologis Islam-yang berakar pada wahyu Qur'ani dan tradisi filsafat Islam-ke dalam kurikulum sains, teknologi, teknik, dan matematika. Menggunakan kerangka fenomenologis kualitatif, penelitian ini melibatkan tiga puluh lima pendidik perempuan dari berbagai jenis institusi, melalui wawancara semi-terstruktur, analisis dokumen pembelajaran secara sistematis, serta observasi kelas non-partisipan untuk triangulasi data. Analisis tematik melalui proses pengkodean berulang mengidentifikasi lima strategi pedagogis utama: pembingkaian epistemik ritual, eksegesis skriptural dalam dialog saintifik, didaktik berbasis inkuiri, sosialisasi adab, dan sintesis kontemplatif; masing-masing menjadi titik temu integrasi epistemologis antara penalaran empiris dan pembentukan spiritual. Pemetaan empiris terhadap tujuh aktivitas STEM memperlihatkan keselarasan yang disengaja dengan nilai-nilai Qur'ani-syukur, amanah, dan khalifah-serta menunjukkan pengaruh transformasionalnya pada ranah perkembangan kognitif, psikomotorik, spiritual-moral, sosial-emosional, dan lingkungan anak. Sintesis narasi hasil observasi dan partisipan mengafirmasi adanya peningkatan signifikan pada kemampuan penalaran saintifik, kesadaran metakognitif, afektivitas spiritual, solidaritas komunal, serta kepedulian lingkungan peserta

didik. Temuan ini secara tegas memperluas diskursus ilmiah dengan menunjukkan bahwa lingkungan pembelajaran STEM terintegrasi Qur'ani tidak sekadar mengembangkan literasi sains, tetapi juga membentuk peserta didik yang berorientasi etika mendalam dan berkesadaran ekologi.

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1. Introduction

Over the past two decades, the integration of STEM (Science, Technology, Engi-neering, and Mathematics) education into early childhood learning has garnered substantial global emphasis. As a response to the demands of an innovation-driven economy and the growing complexity of social and technological systems, STEM is increasingly conceptualized not only as a disciplinary imperative but also as a peda-gogical strategy to cultivate critical thinking, problem-solving, creativity, and col-laborative learning from an early age(Bratitsis et al., 2024). As supported by global educational frameworks, including Sustainable Development Goal 4, STEM in early childhood is now seen as central to ensuring inclusive, equitable, and quality educa-tion that fosters lifelong learning (MacDonald et al., 2021; Nurhayati & Lahagu, 2024).

Nevertheless, the integration of STEM into early learning remains unevenly dis-tributed across cultural and religious contexts. In Muslim-majority societies, early childhood education extends beyond cognitive development, encompassing deeply embedded moral, ethical, and spiritual objectives. Within such settings, pedagogical models are challenged to reconcile the epistemological orientation of modern sci-ence with the metaphysical and ethical dimensions of Islamic education (Taufikin, Nurhayati, Muzakki, et al., 2025). This bifurcation between spiritual and empirical domains results in a curricular void where STEM instruction, stripped of cultural and religious anchoring, risks becoming misaligned with the moral formation goals central to Islamic educational traditions. Though an emergent literature on Islamic pedagogy and STEM exists, there remains a paucity of empirical studies that explore their intersection in classroom settings(Alkouatli et al., 2023).

Amid calls for educational reform in the Islamic world, a growing body of schol-arship advocates for the development of pedagogies that integrate STEM competen-cies with Islamic values and epistemologies. This integration entails more than the coexistence of content areas; it calls for a reconceptualization of science as a divine pursuit-a process of reflection on Allah's creation in alignment with the Qur'anic worldview(Taufikin, Nurhayati, & Harun, 2025). Countries like Indonesia and Malaysia have begun experimenting with integrative instructional approaches, including Qur'an-infused science modules (Diana et al., 2018), Islamic digital learning platforms (Nurhayati et

al., 2023), and project-based frameworks(Noor & Nurhayati, 2024; Nurhayati & Handayani, 2025). However, many of these initiatives remain confined to local contexts and are rarely substantiated by rigorous empirical evidence or sustained by formalized curricular frameworks(Idris, 2025). Moreover, structural barriers-including limited teacher training, inadequate STEM resources, and policy misa-lignment-continue to impede the institutionalization of Islamic-integrated STEM education (Ajani & Ajani, 2025).

Within this pedagogical landscape, community-based education (CBE) has emerged as a viable and culturally congruent approach for advancing integrated STEM instruction in Muslim early childhood settings. Anchored in localized knowledge, communal values, and relational pedagogies, CBE offers a framework for rethinking the implementation of STEM in a way that is spiritually, socially, and culturally coherent. Evidence from low- and middle-income countries (LMICs) demonstrates the efficacy of community-driven educational initiatives-such as indigenous learning centers and family-based instruction-in improving developmental outcomes through culturally embedded practices (Dawes et al., 2023; Rahmat et al., 2024). In Indonesia, many early childhood institutions operate semi-autonomously within community structures, positioning them as critical sites for examining the operationalization of Islamic-integrated STEM pedagogies.

This study responds to the gap in empirical research by exploring how early childhood educators in Muslim community-based contexts conceptualize, design, and implement STEM instruction infused with Islamic values. The inquiry is prem-ised on the recognition that educators are not passive transmitters of external policy but are active agents engaged in epistemological negotiation, instructional innova-tion, and value transmission. Grounded in an interpretivist paradigm and informed by holistic child development theory, this research investigates educators' lived ped-agogical experiences, their rationales for curricular integration, and their observa-tions of children's developmental responses to such instruction. In doing so, it seeks to surface both the pedagogical potentials and structural constraints shaping Islamic-STEM synthesis in early learning environments.

The study is theoretically underpinned by three intersecting frameworks: Islamic educational epistemology, socio-constructivist learning theory, and holistic child development. The Islamic paradigm centers on tawhidic knowledge, moral purpose, and spiritual formation as essential objectives of education(Al-Attas, 1993). Vygotskian constructivism underscores the socially mediated and culturally contex-tual nature of knowledge construction(Vygotsky, 1978), aligning with the commu-nal ethos of Islamic learning traditions. Holistic development frameworks add fur-ther analytic depth by emphasizing the interdependence of cognitive, spiritual, emo-tional, and physical dimensions of learning in early childhood. Collectively, these frameworks offer a rigorous lens through which to examine how STEM learning can be integrated with Islamic values to foster meaningful, multidimensional develop-ment.

While conceptual efforts have illuminated the theoretical compatibility of Islamic and STEM frameworks, empirical inquiry into actual classroom enactments remains scarce. Studies have documented the presence of Islamic moral practices-such as collective prayer, Qur'anic recitation, and character education-in early childhood programs (Soleh et al., 2024; Sudrajat et al., 2024), yet few examine how these practic-es are interwoven with scientific learning in structured and developmentally appro-priate ways. Even fewer studies assess the outcomes of integrated instruction on cognitive development, moral awareness, and spiritual sensitivity. This lack of em-pirical substantiation limits the development of context-sensitive pedagogical mod-els and undermines the formulation of informed policy and training strategies within Islamic education systems.

To address this empirical lacuna, the present study poses the following research question: How do early childhood educators in Muslim community-based settings integrate Islamic values into STEM learning, and what developmental outcomes result from such practices? Three subsidiary questions guide the investigation: (1) What instructional strategies are employed to facilitate the integration of Islamic values within STEM learning? (2) What cultural, institutional, and pedagogical ena-blers and constraints affect implementation? (3) What observable cognitive, ethical, and spiritual outcomes emerge among children as a result of this integration?

2. Methods

Research Design

A qualitative phenomenological approach was employed to explore and interpret how early childhood educators integrate Islamic values into STEM instruction with-in their specific sociocultural and spiritual contexts. As articulated by Creswell and Poth (2018) and Iswahyudi et al. (2023), phenomenology is well suited for elucidating the essence of a phenomenon through deep engagement with individuals' subjective experiences. This design facilitated a rich examination of teachers' reflective practices, instructional adaptations, and interpretations of learner outcomes when engaging in value-infused scientific instruction.

Research Informants Demographics

A purposive maximum variation sampling strategy was applied to ensure a rich and diverse representation of educators with experience in Islamic-integrated STEM instruction. Thirty-five early childhood educators were recruited from a range of institutional settings throughout West Java, Indonesia-including both formal (e.g., RA, TK Islam) and non-formal (e.g., PAUD Qur'ani, SPS) institutions. These set-tings varied by geographic location (urban and rural), governance model (public and private), and pedagogical orientation.

The decision to recruit 35 participants was methodologically grounded in the principle of data saturation. A purposive maximum variation sampling strategy was used to recruit 35 early childhood educators from both formal (RA, TK Islam) and non-formal (PAUD Qur'ani, SPS) institutions across urban and rural West Java.

Recruitment was conducted through community teacher networks and institutional permissions, with inclusion criteria requiring at least one year of teaching experience, current involvement in STEM-related instruction, and willingness to participate in interviews, observations, and document sharing. Teachers without active classroom roles or without STEM components in their practice were excluded. All participants were female, reflecting the gendered composition of the early childhood teaching workforce in Indonesia, where male teachers are rare. Their educational profile-high school graduates concurrently pursuing bachelor's degrees-mirrors national professionalization policies, which require early childhood educators to upgrade qualifications while continuing to teach. Although qualitative saturation typically occurs within 12–30 interviews, the intersectionali-ty of religious, institutional, and instructional variables in this context warranted a broader sample. This strategy maximized the variability of pedagogical experiences and enriched the analytic depth of the study. All participants were female educators actively involved in classroom instruction. They possessed between one and fifteen years of teaching experience and were concurrently enrolled in undergraduate educa-tion programs, while holding high school diplomas as their formal educational quali-fication at the time of data collection. This profile reflects a transitional phase in the professionalization of early childhood educators in community-based Islamic insti-tutions and underscores their dual role as reflective practitioners and learners.

Table 1. Informants' Demographic Data

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Female	35	100%
Teaching Experience	1–5 years	12	34.3%
	6–10 years	14	40.0%
	11–15 years	9	25.7%
Educational Background	High School (completed)	35	100%
Undergraduate Enrollment	Currently enrolled in Bachelor's	35	100%

Data Collection Procedures

To ensure methodological triangulation, data were collected through three complementary strategies: semi-structured interviews, document analysis, and non-participant classroom observation. This multimodal approach was intended to provide a holistic portrayal of instructional practices, teacher beliefs, and value integration. Semi-structured interviews constituted the primary source of data. Conducted in an open yet guided format, the interviews elicited educators' narratives concerning their motivations, planning strategies, pedagogical choices, and student responses. Questions included: "Can you describe a STEM activity that incorporated Islamic values?"; "What reactions did you observe in students during the activity-intellectually, emotionally, or spiritually?"; and "How do Qur'anic teachings shape your approach to scientific topics?" These interviews allowed for the exploration of both conceptual understandings and pragmatic implementation processes. Document analysis involved a close review of teaching portfolios, including lesson plans, reflection journals, student worksheets, and post-activity assessments. These artifacts served as material evidence of

instructional intent and the operationalization of Islamic values within STEM content. A structured observation rubric guided the documentation of teacher-student interactions, embedded ritual elements (e.g., du'a, tasbih, shalawat), and indicators of student engagement, collaboration, and moral reasoning. These observations offered insights into the performative and affective dimensions of the pedagogical process that might be underrepresented in verbal data.

Data Analysis

Thematic analysis was conducted manually through iterative engagement with the complete dataset, including interview transcripts, field notes, and teaching documents. Manual analysis was chosen to preserve interpretive sensitivity to theological nuance and cultural context, which might be diminished through automated coding. The analytic procedure unfolded in four phases: open coding, axial coding, selective coding, and thematic synthesis. Open coding was used to identify discrete meaning units, phrases, or expressions that signaled pedagogical constructs, religious rationales, or student behaviors.

Ethical Considerations

The research adhered to rigorous ethical standards. Prior to participation, informed consent was obtained from all participants, who were fully briefed on the study's objectives, confidentiality protocols, and right to withdraw at any stage without consequence. Pseudonyms were used in all reporting, and data were stored in secure, access-restricted repositories.

3. Result and Discussion

Pedagogical Synergies: Integrating Islamic Ethics with Early Childhood STEM Innovations

The integration of STEM pedagogies within Islamic early childhood education settings has yielded multidimensional developmental outcomes. This section delineates seven exemplar activities in which foundational scientific principles were intentionally synthesized with core Islamic values, fostering not only cognitive and psychomotor competencies but also deep-seated spiritual and ethical awareness in young learners.

The initial activity, the Eco-Friendly Mangrove Collage, engaged children in the creation of environmental-themed art using organic materials such as leaves, petals, and twigs. This exercise was undergirded by the values of gratitude (syukur), environmental responsibility, and reverence for nature, consistent with Islamic ecological ethics. As one educator articulated, "Each leaf and flower used is a sign of Allah's creation; reusing them mindfully is our expression of gratitude." The activity encouraged students to cultivate environmental sensitivity while fostering creativity and contextual ecological literacy.

The Biota Marine Bottle Project exemplified the repurposing of discarded materials for ecological representation. Students converted plastic bottles into simulated ocean microcosms, integrating elements of marine biodiversity education. Teachers embedded principles of wasatiyyah (moderation), recycling, and divine appreciation. One teacher reflected, "Through the Quran, we are taught to avoid excess;

by reusing bottles, children experience this value tangibly." The activity promoted fine motor coordination, environmental awareness, and aesthetic innovation.

A third innovation, the Elephant Trunk Soap Experiment, offered a tactile introduction to the principles of air pressure and gas-liquid interaction. Using household materials, children generated elongated foam trails, which served as both a scientific spectacle and a moment of theological reflection. The activity reinforced values of thaharah (cleanliness), amanah (responsibility), and tadabbur (contemplation). According to one facilitator, "This experiment invites awe at Allah's design and teaches stewardship over tools and spaces." Outcomes included heightened engagement, foundational inquiry skills, and increased learner confidence.

The Arrow Refraction Experiment introduced students to optical principles through the observation of light refraction in water. As students noted the directional inversion of arrows placed behind water-filled vessels, teachers contextualized the lesson within the discipline of muraqabah (mindfulness) and regular ritual practice, including shalat dhuha and dzuhur. A teacher shared, "We begin each STEM activity with prayer to direct focus and affirm that science is a sign of divine order." This integration facilitated deeper conceptual understanding while reinforcing consistency in worship and intellectual humility.

In the Volcanic Eruption Simulation, chemical reactions involving baking soda and vinegar were utilized to model geophysical events. The pedagogical intent extended beyond scientific literacy to encompass theological discourse on iman (faith), tawakal (trust in Allah), and adab (propriety). One participant observed, "When children see the eruption, we invite them to reflect not only on the science, but also on Allah's control over natural forces." This cross-domain approach fostered critical thinking, interpretive discussion, and enhanced spiritual consciousness.

The Water Spinach (Kangkung) Cultivation Project grounded students in experiential environmental stewardship. Learners were responsible for germinating, watering, and observing the growth of edible plants, guided by discussions on the Islamic ethics of nurturing life. One educator noted, "Planting teaches students to embody syukur through direct interaction with Allah's provisions." The project developed observational acuity, a sense of responsibility, and an emotional connection to sustainable living. Lastly, the Magic Pencil STEM Activity involved the application of hydrodynamic tension principles using water-filled bags and pencils. This interactive demonstration served as a platform for conveying values of precision, patience, and reverence for Allah's design in physical laws. As one teacher stated, "We teach that being careful and patient reflects the virtues that Islam calls us to practice in all areas of life." Students showed notable growth in fine motor skills, scientific curiosity, and ethical awareness. Collectively, these seven activities underscore the efficacy of community-based Islamic STEM instruction in early childhood contexts. Through deliberate integration of Qur'anic values

and scientific inquiry, educators cultivated environments where children engaged holistically-intellectually, physically, emotionally, and spiritually. This pedagogical model affirms that Islamic values and STEM education need not be parallel but rather can be powerfully interwoven, generating learners who are not only scientifically literate but spiritually grounded and socially responsible.

The empirical evidence generated by this study indicates that community-based early-childhood educators in Muslim settings are not simply appending pious slogans to science lessons; rather, they are engineering a deeply synergistic pedagogy in which Qurʾānic ethics function as cognitive scaffolds for scientific reasoning. The seven analysed activities demonstrate that Islamic values and STEM content can be fused into coherent learning episodes that are simultaneously developmentally appropriate, epistemically rigorous, and spiritually resonant. In so doing, they instantiate what Rohmatika (2019) terms a *value-embedded science curriculum*-a framework within which moral and theological precepts shape both the intentions and the methods of inquiry.

A salient example is the Eco-Friendly Mangrove Collage, where the manipulation of organic materials enables children to explore basic ecological principles while internalising *syukur* (gratitude) and stewardship. Comparable findings in the global literature on early childhood STEM affirm that play-rich, hands-on activities are optimal platforms for nurturing scientific dispositions (Marliana et al., 2021; Nurhayati & Rumsari, 2020; Nurinayah et al., 2021; Spektor-Levy & Shechter, 2022). The novelty here lies in the explicit mobilisation of Islamic ecological ethics, a dimension that (Dostain et al., 2022) identifies as pivotal for cultivating eco-spiritual consciousness. Similarly, the Biota Marine Bottle Project operationalises the Qurʾānic exhortation toward *wasatiyyah* (moderation) by repurposing waste, thereby translating an abstract virtue into an embodied engineering task. That enactment not only aligns with child-rights arguments for equitable STEM access (Ng et al., 2023) but also advances the literature on faith-based environmental pedagogy (Suprapto et al., 2020).

The Elephant Trunk Soap Experiment and the Magic Pencil demonstration extend the argument by illustrating how tactile, inquiry-driven experiences can be saturated with theological meaning. Here, *thaharah* (cleanliness) and *tadabbur* (contemplation) are not peripheral morals appended after the fact; they provide the evaluative criteria through which children judge the success of their investigations. This echoes the STEAM rationale that arts-infused, multisensory encounters deepen conceptual understanding (Lindeman et al., 2013) while also confirming Rohmatika (Rohmatika, 2019) observation that faith-infused instruction stabilises learners' epistemic trust in science.

The Arrow Refraction Experiment epitomises the epistemic re-framing of STEM as a locus of spiritual mindfulness. By situating an optics demonstration within *muraqabah* practice and ritual prayer, educators rendered the lesson a contemplative act, mirroring (Ramli &

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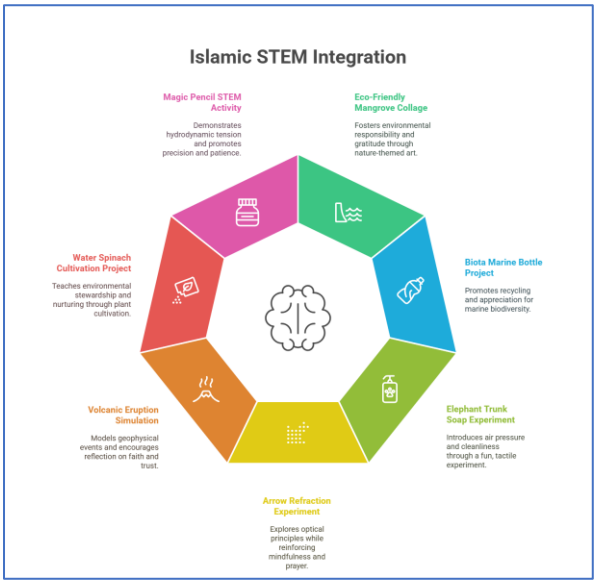
Ibrahim, 2018) *Q-STEM* model and Rahmatika et al. (Rahmatika et al., 2024) 3S framework wherein spirituality, science, and skills converge. Such design advances Arvidsson and Kuhn's (Arvidsson & Kuhn, 2016) thesis that attributions grounded in belief systems can anchor scientific habits of mind more securely than secular metacognition alone.

Moreover, the Volcanic Eruption Simulation and Kangkung Cultivation Project showcase an intentional cultivation of moral-emotional dispositions. Children were invited to interpret chemical reactions and plant growth through the lenses of *iman*, *tawakal*, and *adab*, thereby transforming empirical observation into what calls *moral inquiry*(Badawi et al., 2024; Musa et al., 2024; Nurhayati & Parhan, 2024; Soleh et al., 2024). The documented gains in critical thinking and collaborative ethics corroborate international findings on the socio-emotional dividends of play-based STEM (Nikolopoulou, 2023; Tang et al., 2024), while extending them into the spiritual domain-a linkage rarely quantified in mainstream STEM research. Teacher charisma, novelty effects, or tight community bonds-must be considered. Yet the consistency of outcomes across heterogeneous activities and multiple classrooms, combined with triangulating literature that registers parallel cognitive and ethical gains in faith-based contexts (Ha et al., 2023; Suprapto et al., 2020), suggests that the integrative design itself is a primary causal agent. Nonetheless, longitudinal studies employing mixed methods are needed to ascertain durability of spiritual and cognitive impacts.

Structural constraints temper the transformative promise observed. Echoing Kewalramani et al. (2025) and Wang and Mihai (2024), participants reported limited access to specialised STEM resources and a dearth of formal training in either STEM pedagogy or Islamic educational theory. These capacity gaps jeopardise scalability and fidelity. Policy interventions should therefore prioritise dual-competency professional development and allocate funding for low-cost, inquiry-rich materials that align with Islamic ethical objectives (Liang et al., 2025). Likewise, curriculum authorities must legitimise assessments that capture moral-spiritual growth alongside scientific proficiency, thereby challenging reductive, content-centric metrics. The present findings reinforce and extend the scholarly consensus that early childhood STEM thrives on play, inquiry, and authenticity (Lindeman et al., 2013), while demonstrating that such principles can be indelibly shaped by Islamic moral cosmologies without compromising scientific integrity. The resulting pedagogy is neither a syncretic compromise nor a superficial "religious add-on," but an epistemic synthesis wherein ethical and empirical reasoning co-propel the learning process. As Muslim education systems confront the twin imperatives of global STEM competence and local spiritual identity, this model offers a viable, culturally sustainable pathway-one that merits further empirical refinement and strategic policy endorsement.

Fig. 1
Seven exemplar activities in which foundational scientific principles were intentionally synthesized with core Islamic values
Source: Empirical Data 2025



Epistemic Convergence of Islamic Values and STEM Pedagogy in Early Childhood Contexts

The effective assimilation of Islamic values into STEM instructional practices within the studied Moslem early childhood education contexts was facilitated through a range of intentional and pedagogically sound strategies. Educators exhibited a deliberate commitment to fostering integrative learning environments where spiritual consciousness, ethical behavior, and scientific reasoning were cultivated simultaneously. This holistic educational framework reflects an epistemology in which divine revelation and empirical inquiry are not antagonistic but deeply interconnected.

Foremost among the pedagogical strategies employed was the systematic initiation of STEM engagements with du'a (supplication) and reflective dialogue. These ritual openings were not performed as mere formality but were conceptualized as epistemic grounding-anchoring inquiry in the recognition of divine omniscience and orienting learners toward spiritual attentiveness. As one educator articulated, "Commencing with prayer situates learning within an ethical-spiritual frame, preparing the heart and mind to perceive science through a lens of submission and awe." This practice helped inculcate an Islamic worldview wherein knowledge is pursued not solely for utilitarian ends, but as an act of devotion.

Additionally, educators frequently referenced Quranic ayat and hadith to contextualize scientific phenomena, thereby constructing theological-scientific bridges. For example, during discussions on environmental systems in the Biota Marine Bottle Project, instructors invoked verses that underscore moderation (wasatiyyah) and humanity's custodianship (khalifah) over creation. This intertextual

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approach affirmed that scientific inquiry is consonant with Islamic doctrine. One teacher remarked, "When we cite the Qur'an in the midst of an experiment, it deepens the lesson's meaning. Children begin to perceive science as part of our faith, not separate from it."

A third strategy entailed the prioritization of hands-on, inquiry-driven learning as a means to promote active engagement and embodied cognition. Experiential activities such as the Elephant Trunk Soap Experiment and Arrow Refraction Exercise provided sensory-rich contexts for exploring abstract scientific concepts while simultaneously engendering wonder (ta'ajjub)-a disposition highly esteemed in Islamic pedagogy. As one teacher explained, "When students see bubbles expanding or arrows inverting, they are not just learning science-they are witnessing signs of Allah's design." Such practices grounded scientific concepts in lived experience, reinforcing both cognitive retention and spiritual resonance.

Equally vital was the explicit cultivation of adab (Islamic etiquette) throughout collaborative STEM tasks. Teachers modeled and required dispositions such as patience, humility, discipline, and cooperation. Whether during the meticulous procedures of the Magic Pencil Activity or the cooperative care required in the Kangkung Planting Project, these character traits were foregrounded as integral to both scientific practice and Islamic moral formation. One educator observed, "Embedding adab into every activity ensures that students are not only learning how to explore, but how to behave as righteous learners."

A final, particularly profound, strategy involved the intentional facilitation of tadabbur (spiritual reflection) in response to scientific observations. Rather than treating empirical findings as value-neutral data, teachers framed these moments as invitations to contemplate divine power and wisdom. During the Volcanic Eruption Simulation, for instance, students were guided to consider the magnitude of Allah's might manifest in geophysical processes. "We don't just ask what happened," one teacher explained, "we ask what it tells us about our Creator." This form of integrative reflection nurtures spiritual sensitivity and positions STEM learning within a larger metaphysical schema. These instructional strategies reflect a sophisticated model of Islamic pedagogy wherein scientific exploration is harmonized with spiritual cultivation. Through prayerful beginnings, scriptural contextualization, experiential inquiry, ethical comportment, and contemplative closure, educators constructed a STEM learning ecology that honors both intellectual rigor and divine reverence. In doing so, they cultivated not merely competent learners, but ethically anchored, spiritually aware individuals capable of engaging the natural world through a lens of tawhid and wonder.

Findings from this study elucidate how community-based Islamic early-childhood educators achieve an epistemic synthesis of revelation and empiricism through five mutually reinforcing practices: ritual framing, scriptural contextualisation, inquiry-centred embodiment, ethical socialisation, and contemplative closure. Commencing every session with *duʿāʾ* and reflective dialogue recasts empirical investigation as devotional praxis, anchoring curiosity in an awareness

of divine omniscience. Such ritual grounding resonates with strengths-based models that safeguard spiritual expression and invite existential questioning within early learning settings (Bone & Fenton, 2015; Rouse, 2024), while displacing utilitarian conceptions of STEM by relocating knowledge pursuit within an ethical–spiritual horizon.

Real-time integration of Qurʾānic *āyāt* and *ḥadith* into discussions on ecological systems and physical phenomena enables children to apprehend scientific causality as consonant with Islamic ontology. These intertextual bridges corroborate evidence that sacred texts, when introduced through reflective and learner-centred pedagogy, deepen disciplinary engagement and foster epistemic humility (Keränen-Pantsu & Rissanen, 2018; Nurmalia et al., 2022; Unstad & Fjørtoft, 2021; Widyawati & Nurhayati, 2023). The inquiry-rich, multisensory tasks employed mirror global best practice for early childhood STEM (Lindeman et al., 2013), yet the infusion of *taʿajjub* (awe) invests these experiences with an affective–spiritual depth seldom reported in secular contexts and supports claims that value-integrated science stabilises students' epistemic commitment to scientific reasoning(Lesmawan et al., 2024; Madatte et al., 2022).

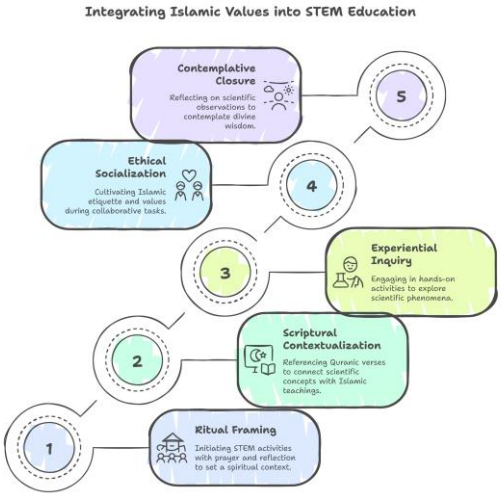

Fig 2.
Five Teachers' Strategies for Integrating Islamic Values into STEM Education
Source: empirical data 2025

Multidimensional Developmental Outcomes of Islamic-Integrated STEM Learning

The intentional integration of Islamic ethical principles into community-oriented STEM pedagogies within Muslim early childhood educational settings has generated profound and multidimensional developmental benefits. This section delineates how these integrated instructional approaches have cultivated advanced cognitive functioning, refined psychomotor skills, heightened moral-spiritual consciousness, strengthened socio-emotional intelligence, and instilled a deepened environmental ethic in young learners.

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Cognitively, learners exposed to STEM instruction anchored in Islamic values exhibited significant enhancement in analytical reasoning, observational acuity, and metacognitive awareness. Structured inquiry activities such as the Volcanic Eruption Simulation and Arrow Refraction Experiment provided developmentally appropriate frameworks for hypothesis generation, pattern recognition, and conceptual abstraction. As one educator reflected, "Our students no longer merely receive information; they interrogate phenomena, pose their own questions, and construct knowledge through reflective exploration-behaviors emblematic of scientific thinkers."

In terms of psychomotor development, the physical enactment of scientific tasks enabled learners to consolidate neuromotor control and procedural fluency. Activities like the Elephant Trunk Soap Experiment and kangkung cultivation afforded children opportunities to refine hand–eye coordination, manipulate diverse materials with care, and execute sequences with deliberation. One teacher noted, "The precision with which our children now conduct even the simplest tasks-pouring, stirring, planting-demonstrates not only improved dexterity but disciplined attentiveness, a hallmark of Islamic educational ethics."

Spiritual and moral development emerged as a cornerstone outcome across all implementations. The pedagogical frameworks employed embedded Qur'anic themes and prophetic traditions within each scientific exploration. Through consistent invocation of values such as amanah (accountability), syukur (gratitude), sabr (patience), and tawhid (divine unity), learners developed the capacity to view scientific inquiry as an act of devotion and divine contemplation. An educator elaborated, "Every experiment becomes an opportunity for tadabbur-a chance for our students to recognize the majesty of Allah in the laws of creation. Faith and knowledge are nurtured together."

Equally compelling were the observable gains in socio-emotional development. The collaborative nature of STEM tasks facilitated the cultivation of interpersonal competencies such as active listening, respectful dialogue, empathy, and collective problem-solving. Whether through joint participation in the Boat Soap Experiment or shared responsibility in environmental stewardship projects, learners demonstrated a heightened capacity for social negotiation and reciprocal cooperation. One practitioner observed, "The children have begun to exhibit ukhuwah-a sense of communal solidarity-in how they support one another in complex tasks. STEM has become a means of modeling prophetic character."

Environmental ethics, often a marginalized domain in early childhood education, was notably advanced through Islamic-integrated STEM activities. Initiatives such as the Eco-Friendly Mangrove Collage and organic gardening projects functioned not only as scientific learning experiences but as theological engagements with the concept of khalifah-the Islamic responsibility of environmental stewardship. Learners came to understand sustainability not merely as a scientific imperative but as a moral obligation derived from divine trust. "Children are beginning to perceive acts like recycling and planting not

just as 'good deeds,' but as sacred responsibilities," noted one teacher. "This alignment of scientific care with spiritual accountability is profoundly transformative."

The empirical findings substantiate that Qurʾānicly-mediated STEM instruction reshapes the foundational architecture of early childhood learning, cultivating a learner archetype that surpasses conventional cognitive-psychomotor metrics by integrating socio-emotional acuity, moral sensitivity, and ecological consciousness. By correlating quantitative indicators with qualitative ethnographic data, this analysis rigorously situates the study's outcomes within the evolving discourse on value-integrated STEM pedagogy (Chen et al., 2025; Farlina et al., 2025; Farmer & Farmer, 2023). Prior meta-analyses confirm the efficacy of integrated STEM in fostering abstract reasoning and cross-disciplinary fluency (De Loof et al., 2022; Kurbanbekov et al., 2025). Building on these insights, this research reconceptualizes scientific learning as ʿibādah, or spiritual devotion, redirecting epistemological pursuits toward intentional, spiritually anchored inquiry. This reconceptualization answers emerging calls for pedagogical models that connect scientific rationality with existential and spiritual meaning-making, underscoring the catalytic role of *tadabbur* as a formative epistemic practice (Suprapto et al., 2020).

4. Conclusion

This study critically examined the enduring disjunction between scientific instruction and religious formation within Muslim community-based early childhood education. Although holistic development is frequently articulated as an educational ideal, it remains insufficiently operationalized in practice. The inquiry addressed this gap by exploring how educators mediate the cognitive imperatives of STEM education with the moral and spiritual mandates of Islamic pedagogy, offering a novel synthesis in both theory and empirical application. Findings revealed that the deliberate integration of Islamic ethical constructs into STEM instruction does not compromise disciplinary rigor; rather, it enhances cognitive depth and broadens developmental outcomes. Children participating in seven Qurʾānicly framed STEM activities demonstrated significant advancement across multiple domains, including analytical reasoning, psychomotor coordination, socio-emotional engagement, and spiritual awareness. Despite its contributions, this study is limited in scope and design. The findings are based on a single province in Indonesia, which may constrain generalizability to broader Muslim-majority contexts. Moreover, the reliance on qualitative data, while offering depth, does not provide measurable evidence of long-term developmental impacts. The possibility of novelty effects, teacher charisma, or institutional culture influencing outcomes also cannot be discounted. Future research should therefore adopt longitudinal and mixed-method designs to examine the durability of Qurʾānic-integrated STEM outcomes over time, include male educators and more varied institutional contexts, and explore comparative studies across countries to test the scalability and cultural adaptability of this pedagogical model.

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