



Blockchain and IoT Integration in Digitalpreneurship Curricula: A Framework for Enhancing Halal Traceability

*Alif Ringga Persada

Universitas Islam Negeri Syekh
Nurjati Cirebon

Rijal Assidiq Mulyana

Universitas Islam Negeri Syekh
Nurjati Cirebon

Abdul Muizz Abdul Wadud
Kasyful Anwar

Universitas Islam Negeri Syekh Nurjati
Cirebon

Refaldo Fanther

Universitas Islam Negeri
Syekh Nurjati Cirebon

***Corresponding author:**

Alif Ringga Persada, Universitas Islam Negeri
Syekh Nurjati Cirebon, Indonesia.

✉ alifringgapersada@uinssc.ac.id

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Abstract

Background: The global halal market is expanding rapidly, yet formal halal certification among Indonesian MSMEs stagnates at approximately 0.08%, reflecting systemic barriers in digital literacy and inefficiencies in manual self-declare compliance systems.

Objective: This study aims to reconstruct a digitalpreneurship incubator curriculum through the "Halal Metric" framework, integrating Blockchain and IoT technologies to automate Shariah compliance and enhance end-to-end halal traceability.

Methods: Utilizing a mixed-methods R&D design with the ADDIE instructional model, the study developed a pedagogical approach centered on three competency pillars: Halal Digital Presence, Blockchain Integrity, and Smart Contract Verification. The curriculum was pilot-tested with 50 purposively selected MSME tenants from UIN Siber Syekh Nurjati Cirebon's business incubator. Performance was measured through blockchain transaction logs, verification time benchmarks, and validated Likert-scale surveys assessing administrative burden and consumer trust.

Results: The intervention enabled real-time digital traceability, reducing verification time from seven days to under 30 minutes, with 99.8% accuracy in deviation detection. Administrative burdens decreased by 85%, and consumer trust increased by 89% compared to manual baselines.

Conclusion: The synergy between digital entrepreneurship education and Halal Metric technology serves as essential trust infrastructure for MSME participation in both national and global halal ecosystems.

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INTRODUCTION

The global halal industry has undergone a radical transformation, evolving from a niche religious requirement into a sophisticated global quality benchmark that dictates international trade patterns and consumer behavior (Qadri, 2024). This sector represents a multi-trillion-dollar market that appeals to both Muslim and non-Muslim consumers seeking ethical and *thayyib* (pure and wholesome) products. However, a profound "halal paradox" remains evident within the Indonesian economic landscape. Despite possessing the world's largest Muslim population and a clear strategic vision to become a global halal hub, the formal participation of micro, small, and medium enterprises (MSMEs) in this ecosystem is critically low. Current empirical data reveals a stagnation in certification realization, with only approximately 0.08% of Indonesian MSMEs successfully obtaining formal halal certificates (Badan Penyelenggara Jaminan Produk Halal [BPJPH], 2023; based on cumulative certification data through December 2022 relative to the total

registered MSME population of approximately 64.2 million enterprises).

This phenomenon signifies a systemic crisis in digital literacy and reflects the inherent vulnerabilities of conventional, manual compliance systems that provide no baseline reduction in administrative complexity for small-scale producers. As noted in recent studies, the impact of government policy on the entrepreneurship ecosystem often fails to reach its full potential due to a lack of robust technological integration in business incubators (Guerrero et al., 2021; Kaggwa et al., 2024; Sattiraju et al., 2026).

The root of this inefficiency lies in the traditional "self-declaration" and manual auditing processes, which are often perceived by MSME owners as an insurmountable bureaucratic and administrative burden. Empirically, the manual *penelusuran* (tracing) of raw materials and production flows often requires a minimum of seven days to complete, a timeframe that is increasingly incompatible with the rapid pace of digital commerce and global supply chain requirements. These manual systems are not only time-consuming but also prone to human error and data manipulation, failing to provide the end-to-end transparency that modern, tech-savvy consumers demand. In an era where digital integrity is a non-negotiable market requirement, reliance on subjective verification methods has created a persistent "trust gap." Previous research highlights that the implementation of IoT and blockchain for halal product traceability in global supply chains is essential to ensure data immutability and real-time compliance (Khan et al., 2025).

Without such technology, MSMEs struggle to provide verifiable proof of Sharia compliance to international partners who prioritize data-backed quality assurance. Empirical studies confirm that manual halal certification processes exhibit error rates exceeding 15% due to subjective interpretation of compliance criteria, and that MSMEs relying on paper-based documentation experience certification abandonment rates three to four times higher than those with digital traceability systems (Ab Talib et al., 2017; Tieman & Darun, 2022).

The transition toward a digital-based halal ecosystem is no longer optional but an academic and social necessity (Dupi & Inayat, 2025; Nurhamidah, 2025; Thani, 2026). However, this transition is hindered by a significant digital literacy gap among MSME actors, who often lack the technical competence to navigate complex digital platforms (Coco et al., 2024; Hermansyah et al., 2025; Mohammed Shebeen et al., 2024). Previous scholarly work has established that digital entrepreneurship incubator curriculum development is essential to improve entrepreneurship skills, particularly in helping MSMEs adapt to the demands of the digital economy (Persada, 2024; Safitri et al., 2026). While there is an increasing volume of technical research on Halal 4.0, these discussions often remain fragmented and detached from the pedagogical frameworks of business incubators.

A conspicuous research gap exists at the intersection of instructional design and high-integrity technology. Existing business incubator models in Indonesia predominantly focus on general market access and branding, yet fail to incorporate technical competency modules relating to automated Sharia compliance as a core operational requirement. Unlike existing digitalpreneurship training models, which primarily address general e-commerce skills and market access strategies Nambisan (2017), the proposed framework uniquely positions automated Sharia compliance verification as the central pedagogical objective, integrating technological proficiency with religious governance requirements, a combination absent from current incubator curricula.

To address this critical gap, the present study proposes a systematic reconstruction of the digital entrepreneurship incubator curriculum through the *Halal Metric* framework. This research moves beyond normative training by integrating three specialized digital-halal integrity pillars: Halal Digital Presence, Blockchain-Integrity, and Smart Contracts Verification. By employing the systematic ADDIE model (comprising Analysis, Design, Development, Implementation, and Evaluation) the research develops an instructional intervention that transforms technology from a peripheral tool into a mandatory business competency (Persada & Agung, 2024). The novelty of this approach lies in its ability to bridge the digital literacy gap by embedding "Digital Presence" modules directly into the curriculum, ensuring that even entrepreneurs with limited technical backgrounds can master automated traceability systems. Unlike previous models, this framework positions technology as the primary driver for achieving 99.8% accuracy in deviation detection

and reducing tracing times from days to mere minutes.

Each pillar is theoretically grounded and functionally interconnected: Halal Digital Presence draws upon digital literacy theory Eshet (2012) and addresses the foundational competency of navigating digital platforms for halal documentation and marketplace visibility; Blockchain-Integrity operationalizes distributed ledger theory to ensure data immutability and tamper-proof recording of supply chain transactions from raw materials to finished products; and Smart Contracts Verification applies computational contract theory to automate compliance verification through self-executing protocols that trigger alerts upon any detected deviation from predetermined Sharia parameters. The three pillars function sequentially: digital presence enables data entry, blockchain ensures data integrity, and smart contracts automate compliance validation, collectively producing an integrated competency framework for end-to-end halal traceability (Parakkasi & Akib, 2025; Sunmola et al., 2025).

The primary objective of this research is to evaluate the efficacy of this reconstructed curriculum in accelerating the national halal ecosystem and restoring consumer confidence through verifiable digital traceability. By pilot-testing this reconstruction with 50 MSME tenants, the research seeks to provide empirical evidence on how automated traceability can optimize operational efficiency and substantively reduce administrative burdens, potentially achieving an 85% reduction in manual paperwork.

This study argues that the business incubator must function as an infrastructure of trust, providing the necessary pedagogical and technical support to enable MSMEs to thrive in the global halal market. Ultimately, this research positions the *Halal Metric* framework as a vital paradigm shift in entrepreneurship education, offering a scalable model for emerging economies to protect religious and ethical standards while enhancing international competitiveness. By synthesizing instructional design with 4.0 technologies, this study contributes to a more resilient, transparent, and globally integrated halal ecosystem. Beyond its immediate pedagogical objectives, this research carries broader implications for national halal ecosystem policy development, MSME digital empowerment strategies, and Indonesia's competitive positioning in the US\$7 trillion global halal market.

METHOD

This study employed a mixed-methods Research and Development (R&D) design, specifically adopting the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) instructional model to reconstruct the digitalpreneurship incubator curriculum. This approach was selected for its systematic ability to align pedagogical objectives with the technical requirements of high-integrity digital systems, providing a robust framework to address the complexities of the halal ecosystem.

The R&D component provided the systematic instructional design structure through the ADDIE model, while the mixed-methods component enabled triangulation of quantitative performance data (blockchain logs and survey metrics) with qualitative participant feedback (semi-structured interviews), thereby enhancing both the validity and practical relevance of the findings. The research was conducted within the business incubator environment at Universitas Islam Negeri (UIN) Siber Syekh Nurjati Cirebon, focusing on a purposive sample of 50 MSME tenants from the consumer goods sector. This context was justified by the urgent need to address the critical certification gap in Indonesia, where halal realization for MSMEs had stagnated at approximately 0.08% due to low digital literacy and the inefficiencies of manual self-declare systems.

The implementation procedures followed the five sequential stages of the ADDIE model, beginning with an Analysis phase that identified the limitations of manual tracing processes, which historically required seven days for verification. During the Design and Development phases, the curriculum was reconstructed to integrate three specialized competency pillars: Halal Digital Presence, Blockchain-Integrity, and Smart Contracts Verification. The technical instruments employed included blockchain and Internet of Things (IoT) sensors designed to facilitate automated Sharia compliance and upstream-to-downstream (*hulu-hilir*) transparency. In the Implementation phase, the 50 MSME tenants participated in a structured pilot program, utilizing these digital prototypes to manage production traceability in real time.

Data collection relied on technical performance logs from the blockchain network to measure accuracy and verification speed, alongside structured surveys using validated Likert-scale instruments (Cronbach's $\alpha = 0.87$ for administrative burden scale; $\alpha = 0.91$ for consumer trust scale) administered to both MSME operators and a convenience sample of 200 consumers who interacted with the traceability system.

The administrative burden reduction was calculated as the percentage decrease in mean processing hours per certification cycle relative to documented manual baselines. Consumer trust was measured using a 12-item adapted scale based on the Technology Acceptance Model (TAM) and Perceived Trust Framework Pavlou (2003), administered before and after exposure to blockchain-verified product traceability information. Specifically, the Analysis phase produced a needs assessment report documenting seven critical competency gaps among MSME tenants.

The Design phase generated a curriculum blueprint mapping each competency gap to specific learning outcomes, instructional strategies, and assessment rubrics aligned with the three competency pillars. The Development phase produced digital learning modules, blockchain prototype configurations, and IoT sensor calibration protocols. The Implementation phase consisted of a 12-week structured pilot program with weekly facilitated sessions. The Evaluation phase employed both formative assessments (weekly quizzes and practical demonstrations) and summative evaluation (final performance metrics and post-intervention surveys).

The data analysis process was conducted step-by-step, beginning with the extraction of quantitative metrics from the blockchain logs to evaluate deviation detection accuracy and tracing time reductions. These technical findings were analyzed using descriptive statistics to determine the percentage of efficiency gain relative to manual baselines. Subsequently, the process incorporated qualitative feedback, analyzed through thematic analysis following Braun (2006) six-phase framework, to evaluate the effectiveness of the pedagogical intervention with reference to Digitalpreneurship Incubator Curriculum theory.

This study did not involve human or animal participants requiring clinical ethical approval; however, all procedures were conducted in accordance with institutional ethical standards. All 50 MSME participants provided written informed consent prior to data collection, and their business identities were protected under strict confidentiality principles to ensure academic integrity and objectivity. Ethical clearance was obtained from the Research Ethics Committee of UIN Siber Syekh Nurjati Cirebon (Reference No. EC/UIN-SNC/2025/034).

RESULTS AND DISCUSSION

Results

Participant Profile and Baseline Assessment

The 50 MSME tenants who participated in the 12-week pilot program comprised 32 food and beverage producers (64%), 12 cosmetics and skincare enterprises (24%), and 6 household product manufacturers (12%). Baseline assessment during the ADDIE Analysis phase revealed that 78% of participants had no prior experience with digital traceability systems, and 92% relied exclusively on manual paper-based documentation for halal compliance. The mean digital literacy score at baseline was 2.1 out of 5.0 on the adapted Digital Competence Framework scale, confirming the critical competency gap identified in the needs assessment.

Technical Performance Outcomes

Following the 12-week curriculum intervention, technical performance was evaluated through blockchain transaction logs and IoT sensor output data. The automated traceability system achieved a deviation detection accuracy of 99.8% across 12,450 recorded supply chain transactions, compared to the estimated 85% accuracy of manual inspection methods documented at baseline. Verification processing time was reduced from an average of 7.2 working days under the manual system to 27.4 minutes under the blockchain-integrated system, representing a 99.7% reduction in processing time. Table 1 summarizes the comparative performance metrics.

Table 1. Comparative Performance Metrics: Manual vs. *Halal* Metric System

Performance Indicator	Manual System	Halal Metric System	Improvement
Deviation detection accuracy (%)	85.0%	99.8%	+14.8% increase
Average verification time	7.2 days	27.4 minutes	Significantly reduced
Administrative processing time per certification cycle	48.5 hours	7.3 hours	85% reduction
Data entry errors per 100 transactions	12.3	0.2	98.4% reduction

The impact of the Halal Metric curriculum on administrative burden and consumer trust was assessed through validated survey instruments. MSME operators reported a mean administrative burden reduction of 85% (SD = 4.2%), measured as the decrease in mean processing hours per halal certification cycle from 48.5 hours to 7.3 hours. Among the 200 consumers surveyed, the mean trust score increased by 89% from pre-exposure ($M = 2.14$, $SD = 0.68$) to post-exposure ($M = 4.05$, $SD = 0.52$) on the adapted 5-point Perceived Trust scale after interacting with blockchain-verified product information. Qualitative feedback from MSME participants further corroborated these findings. Thematic analysis of semi-structured interviews identified three dominant themes: (1) increased confidence in meeting compliance standards, (2) perceived reduction in bureaucratic complexity, and (3) enhanced market credibility through digital verification badges displayed on product packaging.

Discussion

The empirical findings of this study confirm that the integration of Blockchain and IoT technologies within a structured digitalpreneurship curriculum produces substantial improvements in halal traceability performance. The 99.8% deviation detection accuracy achieved by the Halal Metric system represents a significant advancement over manual inspection methods, which are inherently limited by subjective interpretation and human error. This finding validates the theoretical proposition that distributed ledger technology can serve as an infrastructure of trust by ensuring data immutability across the halal supply chain. The near-elimination of processing delays—from 7.2 days to under 30 minutes—demonstrates that smart contract automation fundamentally transforms the verification paradigm from a bureaucratic bottleneck into a seamless digital process.

The 85% reduction in administrative burden directly addresses the primary barrier to MSME halal certification identified in the literature, namely the perception of certification as an insurmountable bureaucratic process (Fathoni et al., 2025). This finding extends the digitalpreneurship incubator curriculum theory proposed by Persada (2024) demonstrating that pedagogical interventions embedding technology as a core competency, rather than a supplementary tool, can produce measurable operational efficiencies. The curriculum's three-pillar architecture proved functionally effective: Halal Digital Presence modules increased baseline digital literacy scores from 2.1 to 4.3 (out of 5.0), Blockchain-Integrity modules enabled participants to independently operate distributed ledger systems, and Smart Contracts Verification modules equipped participants to configure automated compliance protocols.

The 89% increase in consumer trust is particularly noteworthy, as it suggests that blockchain-verified traceability information generates significantly higher consumer confidence than conventional certification labels. This finding aligns with the Technology Acceptance Model's proposition that perceived reliability and transparency are primary determinants of trust in digital systems (Pavlou, 2003). The novelty of this finding lies in its demonstration that trust can be technologically constructed and pedagogically disseminated, a contribution that extends existing halal governance literature, which has predominantly focused on regulatory and theological dimensions of trust.

From an international perspective, the Halal Metric framework addresses a universal

challenge in global halal supply chains: the absence of standardized, technology-driven verification mechanisms that transcend national regulatory boundaries. The framework's architecture is inherently scalable because blockchain operates on decentralized protocols that are not jurisdiction-dependent. This positions the model as potentially applicable to emerging halal markets in Central Asia, sub-Saharan Africa, and European Union member states that are developing *halal* certification infrastructure (Tiemann & Darun, 2022).

Despite these promising results, several limitations must be acknowledged. First, the study was conducted within a single institutional incubator context with 50 MSME tenants from the consumer goods sector, which limits generalizability to other sectors such as pharmaceuticals, halal tourism, or financial services. Second, the 12-week intervention period, while sufficient for pilot evaluation, does not capture long-term adoption sustainability or behavioral persistence. Third, the consumer trust assessment relied on a convenience sample of 200 consumers, which may not represent broader market perceptions. Fourth, the blockchain prototype operated on a permissioned network within a controlled environment, and performance metrics may differ under full-scale commercial deployment with higher transaction volumes and network complexity. Future research should employ longitudinal and multi-site experimental designs to address these constraints.

CONCLUSION

This research demonstrates that the reconstruction of the digitalpreneurship incubator curriculum through the 'Halal Metric' framework serves as a transformative solution to the persistent stagnation of halal certification among MSMEs. By synthesizing systematic instructional design with high-integrity technologies, the study concludes that the integration of Blockchain and Internet of Things (IoT) into entrepreneurial pedagogy moves beyond mere technical adoption; it establishes a fundamental infrastructure of trust within the digital economy. The transition from manual, subjective verification to an automated, data-driven system effectively bridges the critical gap between religious compliance and digital traceability, positioning the business incubator as a vital laboratory for transparency. This research asserts that when traceability is embedded as a core competency rather than an auxiliary tool, MSMEs can overcome the literacy and administrative barriers that have historically hindered their participation in the formal halal ecosystem.

The main scholarly contribution of this study lies in the proposal of the 'Digital-Halal Integrity' paradigm, which provides a novel theoretical reinforcement to the field of digitalpreneurship education. By demonstrating that automated Sharia compliance can be democratized for small-scale producers, this research offers a scalable framework for trust infrastructure that is applicable to emerging economies worldwide. This study challenges the traditional view of business incubation by emphasizing that *hulu-hilir* transparency is an essential asset for global competitiveness, rather than a bureaucratic burden.

Practically, the findings provide a clear roadmap for higher education institutions to modernize their incubator programs by adopting standardized digital traceability SOPs, thereby bolstering the national halal ecosystem's resilience. The framework's scalability is supported by its modular curriculum architecture, which allows adaptation to sector-specific requirements, and by the jurisdiction-independent nature of blockchain protocols. Cross-country applicability has been preliminarily assessed through alignment with international halal standards (OIC/SMIIC and UAE ESMA frameworks), suggesting potential transferability to halal markets in Malaysia, Turkey, and the United Arab Emirates.

Despite the significant efficiency gains observed, this study acknowledges limitations regarding its specific focus on the consumer goods and skincare sectors within a single regional incubator context. Consequently, future research should explore the contextual expansion of the 'Halal Metric' framework into diverse industries such as pharmaceuticals or halal tourism to evaluate its cross-sectoral adaptability. Furthermore, there is a need for longitudinal studies to examine the long-term impact of this integrated curriculum on MSME export performance and cross-border halal trade.

Exploration into the application of different decentralized autonomous organization

(DAO) models within the incubator structure could also provide alternative understandings of community-based digital-halal governance. Ultimately, this study serves as a foundational take-home message for policymakers and academics: the future of the halal industry depends on the convergence of digital integrity and pedagogical innovation to create a transparent, inclusive, and globally integrated market. Additionally, multi-sector comparative studies employing randomized controlled trial designs across different MSME categories and geographical regions would strengthen the evidence base for policy adoption. Testing the framework's efficacy in pharmaceutical, halal tourism, and halal logistics sectors using longitudinal pre-post designs with control groups is particularly recommended.

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