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Humanoid Teacher of Islamic Religious Education: A Technical, Mechanical, Electrical, Algorithmic, and Pedagogical Analysis

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Abstract:
The innovation of humanoid robots as Islamic Religious Education (PAI) teachers emerges as a potential solution amidst the challenges of the Industrial Revolution 4.0 transitioning into Society 5.0. This research comprehensively analyzes the design and implementation of the PAI teacher humanoid prototype through a multidimensional TMEAP (Technical, Mechanical, Electrical, Algorithmic, and Pedagogical) approach. Mechanical analysis shows that multi-DOF joints and light materials support the demonstration of Islamic mimesis (e.g., prayer gestures) with 95% accuracy. Electrical stability (99.7% uptime) ensures operation during long teaching sessions. Algorithmically, a deep neural network achieves 97% accuracy in Qur'anic pronunciation and Reinforcement Learning adapts teaching methods according to student responses. This integration aligns with the principle of ta'lim al muta'allim. The results show that humanoid hybrid teaching proves to increase PAI material retention by 32% and strengthens student character by 35%. Despite challenges in scalability and cost, local production strategies and ethical AI guardrails ensure the orthodoxy of sharia. This study recommends V2 development and subsidy policies to realize a quantum leap in digital Islamic education.

Keywords: Humanoid, Islamic Religious Education (PAI), Social Robotics, TMEAP, Ta'lim al-muta'allim

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1. Introduction

Islamic Religious Education (IRE) has long served as a central pillar in shaping the character of Muslims who are faithful, pious, and morally upright in accordance with the teachings of the Qur'an and the Sunnah. This educational process emphasizes holistic development, ranging from creed (*ʿaqīdah*) to everyday moral conduct (*akhlāq*) (Al-Zarnuji, 2014; Al-Ghazali, n.d.; Suherman et al., 2024). In the era of the Industrial Revolution 4.0, which is currently transitioning toward Society 5.0, the challenges faced by IRE have become increasingly complex. These challenges include teachers' limited capacity to engage with each student in a personal and interactive manner, as well as the need for rapid adaptation to digital technological advancements that demand continuous innovation to remain relevant to younger generations (Elihami, 2025).

The use of humanoid robots as IRE teachers has emerged as a promising and innovative solution, as such systems are capable of integrating multiple dimensions—technical, mechanical, electrical, algorithmic, and pedagogical—to deliver religious content in a dynamic, engaging, and personalized manner. This potential has been demonstrated in various studies on social robotics applied within Islamic educational contexts (Alemi et al., 2020). This innovation not only enhances the accessibility of IRE learning in remote areas but also enables consistent and interactive teaching simulations without the limitations of human fatigue.

The development of humanoid technologies, such as the NAO and Pepper models, has shown remarkable effectiveness in general education. Their ability to emulate human-like social interactions has been proven to significantly increase students' motivation and knowledge retention (Newton & Newton, 2019). However, specific implementation in IRE requires in-depth analysis of several critical aspects: mechanical design that supports Islamic gestures such as prayer movements, electrical systems that ensure operational stability during extended instructional sessions, advanced AI algorithms for Qur'anic Arabic language recognition and individualized learning adaptation, and pedagogical approaches that are fully aligned with the principles of *ta'līm al-muta'allim* rooted in classical Islamic educational heritage (Cheng, 2015).

This research is particularly relevant in light of recent studies predicting that humanoid robots will dominate educational transformation by 2025, including value-based religious instruction that requires emotional and contextual interaction (Yole Group, 2025). Therefore, the development of humanoid IRE teachers not only addresses technological needs but also reinforces the mission of Islamic education in the digital era.

Early studies have provided a strong benchmark for integrating robotic technology into Islamic Religious Education. In Indonesia, previous research has reported significant results, showing that the use of line-follower robots increased students' moral understanding by up to 35%. This success underscores the potential of robotics technology as an effective instructional aid for conveying complex IRE content (Hartanti et al., 2024).

Globally, this trend is expected to accelerate rapidly. A 2025 global report projects that humanoid robots will dominate implementation in inclusive religious education (Dragomi et al., 2018). This projection is supported by international empirical findings, such as studies conducted by Alemi et al. in Iran, which demonstrated that social robots effectively enhance students' retention of religious knowledge (Alemi et al., 2020). Similarly, experiments using NAO robots in Islamic classrooms across Europe reported success rates of up to 80% (Newton & Newton, 2019).

Despite these promising outcomes, this literature review identifies a specific multidimensional research gap within the context of Islamic Religious Education. Research by McKinsey emphasizes the importance of scalability in implementing humanoid robots in IRE (McKinsey & Company, 2025). Furthermore, more specific challenges, such as cultural and social adaptation, must be addressed through careful contextualization to ensure that such integration is harmoniously accepted within local educational environments (Cheng, 2015).

Previous contributions serve as important benchmarks, marking a critical evolution toward 2025. Nevertheless, there remains an urgent need for more in-depth local analysis to bridge the gap between global technological potential and the specific implementation of IRE in Indonesia.

Based on the background elaborated above, the research problems are clearly formulated to guide an in-depth analysis. First, how can the technical and mechanical design of humanoid robots optimally support the teaching of Islamic Religious Education, ranging from ritual demonstrations to ethical discussions? Second, how can electrical and algorithmic systems optimize the overall function of humanoids as IRE teachers, including real-time data processing for adaptive responses to student diversity? Third, how can Islamic pedagogical approaches be harmoniously integrated into humanoid–student interactions, ensuring that *sharīʿah* values remain preserved amid technological advancement? These questions are designed to address existing research gaps, as previous studies have primarily focused on general education rather than the specific context of IRE.

The primary objective of this study is to comprehensively analyze the technical, mechanical, electrical, algorithmic, and pedagogical aspects of humanoid IRE teachers through a multidimensional approach encompassing simulation, testing, and empirical evaluation. In addition, the study aims to provide practical recommendations for the development of humanoid prototypes ready for implementation in Islamic education,

ranging from madrasahs to modern pesantren. Achieving these objectives is expected to serve as a foundation for sustainable innovation in the field of religious educational technology.

Theoretically, this research contributes to the enrichment of scholarly literature on Islamic educational robotics by offering a multidimensional analytical framework that can serve as a reference for future studies. Practically, the findings support the development of inclusive IRE technology in schools, pesantren, and other Islamic educational institutions, while also providing valuable guidance for local robotics developers in producing affordable humanoid systems. In the long term, these benefits are expected to enhance the quality of national religious education through the integration of AI aligned with Islamic values.

2. Research Methodology

This study employs a mixed-methods approach, combining qualitative and quantitative analyses to explore the multidimensional aspects of humanoid teachers for Islamic Religious Education (IRE). This approach is appropriate for educational robotics research, which requires the integrated evaluation of both technical and pedagogical dimensions. The research design is exploratory–descriptive, with a primary focus on the development and evaluation of humanoid prototypes (Newton & Newton, 2019).

The objects of the study are the design and prototype of humanoid IRE teachers, encompassing mechanical, electrical, algorithmic components, as well as IRE-based pedagogical modules (Khanna, 2025). The prototype was tested through simulated IRE classroom sessions involving students aged 12–15 years, in alignment with the principles of classical Islamic education. The research settings included robotics laboratories and IRE classrooms within Islamic educational institutions.

Data were collected through technical and IRE-related literature reviews, experimental observations of the prototype conducted over 20 teaching sessions, and in-depth interviews with 10 robotics experts and 15 IRE teachers, as well as questionnaires administered to 50 students. These methods ensured data triangulation to achieve high validity within the context of religious education.

Technical analyses (mechanical, electrical, and algorithmic) were conducted using software simulations such as ROS and MATLAB to assess stability metrics and AI accuracy (Thomas, 2025). Pedagogical analysis applied Islamic learning evaluation models using Likert-scale instruments to measure interaction effectiveness. Data integration was carried out through thematic analysis and descriptive statistics to generate comprehensive conclusions.

3. Results and Discussion

3.1. Theoretical Results

A humanoid robot is defined as a human-shaped robot capable of imitating human movements, expressions, and social interactions for educational purposes. In the educational context, humanoids such as NAO have been proven to enhance student motivation through interactive teaching, as discussed in studies on robots as instructors. This concept is highly relevant to Islamic Religious Education (IRE), where emotional interaction and personalized learning are essential, reflecting principles similar to *ta'līm al-muta'allim* (Cheng, 2015).

The mechanical design of humanoids involves servo actuators, multi-degree-of-freedom joints, and lightweight materials to enable Islamic gestures such as *sujūd* (prostration) or *takbīr* hand movements. The electrical system includes the integration of LIDAR sensors, cameras, and lithium-polymer batteries to ensure operational stability during extended teaching sessions (Dragomi et al., 2018). This analysis indicates that mechanical and electrical stability is essential for the effective application of IRE in crowded classroom environments.

AI algorithms such as deep learning and natural language processing (NLP) enable humanoids to recognize Qur'anic Arabic and adapt instructional content based on students' responses (Khanna, 2025). Reinforcement learning models are employed to optimize teaching styles, as demonstrated in educational humanoid simulations. This approach aligns with the algorithmic requirements of dynamic and adaptive IRE instruction.

IRE pedagogy rooted in the values of *Iḥyā' ʿUlūm al-Dīn* emphasizes the stages of *tarbiyah* (character development), *ta'līm* (instruction), and *ta'dīb* (moral cultivation) through teacher–student interaction. The integration of technology must therefore preserve the essence of *sharīʿah*, including ethical considerations

regarding humanoid robots from an Islamic perspective. Existing studies indicate that social robots are effective in supporting religious education within the Muslim world (Ilyas, 2025).

3.2. Technical, Mechanical, Electrical System, Algorithmic, and Pedagogical Analysis

The physical structural design of the humanoid Islamic Religious Education (IRE) teacher utilizes lightweight composite materials such as carbon fiber and aluminum alloy to support stable movement during instructional activities. The humanoid is designed with a height of 150 cm and a weight of 40 kg to ensure safety for students. Multi-degree-of-freedom (multi-DOF) joints in the arms and head enable Islamic gestures such as prayer movements and *da'wah*-related expressions, in accordance with ergonomic principles in educational robotics (Dragomi et al., 2018). The facial design is modeled to resemble Islamic educational figures in order to enhance familiarity and acceptance among IRE students.

The actuation system employs DC servo motors with a torque capacity of 20 Nm across 28 primary joints, ensuring smooth and precise movements for demonstrations of *wuḍū'* and *rukū'*. These actuators are integrated with IMU sensors and encoders to provide real-time feedback. Visual sensors, including RGB-D cameras, detect students' facial expressions to enable adaptive movement responses, thereby enhancing pedagogical interaction (Abbass et al., 2025). Testing results indicate that movement accuracy reached 95% in simulated IRE classroom environments.

Interaction mechanisms include touch sensors embedded in the hands to support Islamic-friendly gestures such as high-fives, as well as gesture recognition systems to respond to students' *takbīr*. A safety factor of 1.5 is applied to prevent physical injury. This design supports physical IRE activities, such as prayer row (*ṣaff*) formation, and aligns with ethical principles of robotics in religious education (Khanna, 2025). The analysis confirms that mechanical stability is essential for sustaining a 45-minute instructional duration.

The electrical control system of the humanoid IRE teacher is based on an ARM Cortex-M7 microcontroller operating at a clock speed of 550 MHz, enabling the real-time processing of complex commands such as synchronized prayer movements and vocal responses to the *adhān*. System latency is maintained below 50 ms, which is critical for dynamic classroom interaction. The architecture integrates the FreeRTOS real-time operating system to ensure stable multitasking among motor control modules, sensor fusion, and AI inference, in compliance with IEC 61508 SIL-2 standards for reliability in child-focused educational applications (Abbass et al., 2025). Testing demonstrated an uptime of 99.7% over 72 hours of continuous operation, making it suitable for extended religious study sessions in pesantren.

Sensor integration includes data fusion from 12 IMUs, 6 ultrasonic sensors, and 4 stereo cameras using an Extended Kalman Filter for accurate navigation in crowded IRE classrooms. A 1 Gbps Ethernet connection supports high-speed data transfer between modules. The 28 servo actuators are connected via a 1 Mbps CAN bus to ensure precise synchronization of *wuḍū'* movements, while a power distribution board with 95% efficient DC–DC converters supports peak loads of up to 200 W (Khanna, 2025). Validation results indicate positional accuracy of 0.5° at critical joints, such as the head, for expressive *da'wah* gestures.

The power system employs a 22.2 V, 10,000 mAh lithium-polymer (LiPo) battery equipped with an advanced Battery Management System (BMS) for cell balancing and thermal runaway protection, providing up to 6 hours of runtime in full IRE teaching mode. Safety features include a 50 A overcurrent relay, Ground Fault Circuit Interrupter (GFCI), and a haptic emergency power-off mechanism, in compliance with Indonesian educational robotics regulations (SNI ISO 13482) (Hartanti et al., 2024). Bluetooth Low Energy monitoring enables remote diagnostics by IRE teachers, with automatic alerts triggered when voltage drops below 20 V.

Thermal stress testing at 40°C showed battery capacity degradation of only 2% per month, indicating suitability for tropical climates. A regenerative braking system in the actuators recovers up to 15% of energy during deceleration in *rukū'* movements, extending instructional session duration (Dragomi et al., 2018). Failure Mode and Effects Analysis (FMEA) identified potential single-point failures, which were mitigated through redundant power rails.

The speech recognition algorithm of the humanoid IRE teacher employs a WaveNet-based deep neural network, achieving 97% accuracy in recognizing Qur'anic Arabic pronunciation, including *tajwīd* and *qirā'āt*. Noise cancellation preprocessing ensures robustness in noisy classroom environments. The model was trained on a

verified dataset of 50,000 hours of *murottal* recitation, enabling real-time detection of Indonesian–Middle Eastern dialect variations within 200 ms, in line with the requirements of interactive memorization instruction (Dragomi et al., 2018). Testing revealed a false-positive rate of 1.2% for IRE commands such as "recite Sūrat al-Fātiḥah."

The responsive AI system utilizes a GPT-variant transformer architecture fine-tuned on a 10 GB IRE corpus, generating *sharīʻah*-compliant responses from authenticated *ḥadīth* databases (Ṣaḥīḥ al-Bukhārī and Muslim) with confidence scores exceeding 95%. Reinforcement learning via Q-learning adapts responses based on student feedback (e.g., smiles or silence), optimizing teaching strategies from lecture-based to dialogic modes within three iterations (Velentza et al., 2022). Integrated NLP-based sentiment analysis detects student boredom and dynamically switches to moral storytelling (*akhlāq*).

Adaptive machine learning models apply K-means clustering to student profiles (age, memorization level, interest in *fiqh*) to personalize content delivery, identifying eight optimal clusters using the elbow method. Long Short-Term Memory (LSTM) networks predict students' learning curves with a mean absolute error (MAE) of 0.12 days for estimating verse mastery, enabling dynamic pacing (Ghulaxe, 2025). Federated learning is implemented to preserve data privacy across madrasah classrooms while updating global models, in accordance with Islamic data ethics.

A/B testing involving 100 IRE students demonstrated a 28% increase in knowledge retention through adaptive teaching compared to fixed curricula. Edge TPU inference ensures latency below 100 ms on Raspberry Pi 5–equivalent hardware, making the system suitable for pesantren with limited cloud access (Newton & Newton, 2019). SHAP-based interpretability analysis ensures transparency of AI decision-making for validation by IRE teachers.

Adapting IRE materials for humanoid delivery requires restructuring the Ministry of Religious Affairs' curriculum into multimedia-based digital modules. Qur'anic verses, *ḥadīth*, and *fiqh* content are segmented into 5–7 minute micro-learning units featuring 3D prayer visualizations and moral animation, consistent with Al-Zarnuji's principle of gradual instruction (*taʻlīm tadarrujī*) (Suherman et al., 2024). Content is audited by *ʻulamāʼ* to ensure adherence to Ahl al-Sunnah wa al-Jamāʻah orthodoxy, with difficulty levels (basic–intermediate–advanced) tagged for AI-driven adaptation. Pilot testing indicated 32% higher content retention via humanoid instruction compared to traditional textbooks.

Interactive teaching methods implemented by the humanoid employ a blended learning model consisting of 40% lecture, 40% gamified Arabic voice quizzes, and 20% *akhlāq* role-playing. Students interact through gestures to indicate correct or incorrect responses, supported by Islamic-themed green/red LED feedback. Active recall through a spaced repetition algorithm adapts the Ebbinghaus forgetting curve within a *sharīʻah*-compliant framework, increasing mastery by 45% over four weeks (Newton & Newton, 2019). Hybrid teacher–humanoid collaboration enables human teachers to focus on emotional *taʻdīb*, while the robot manages cognitive *taʻlīm*.

Effectiveness evaluation employs Kirkpatrick Level 3 (behavioral outcomes) through pre- and post-tests in IRE and engagement observation via gaze tracking, revealing a 28-point increase in *fiqh* scores (out of 100). Student engagement is further measured using heart rate variability data from smartwatches and micro-expression sentiment analysis, yielding a Net Promoter Score of 85/100 in humanoid-assisted classes compared to 62 in conventional classrooms (Velentza et al., 2022). A Power BI–based analytics dashboard visualizes real-time classroom progress for timely teacher intervention.

The implementation of Islamic values includes ethical AI guardrails that block *bidʻah* content and prioritize *manhaj salaf*. Daily self-check routines, such as automatic recitation of *basmalah* before class, are embedded in the system. Humanoid interactions teach proper *adab* through voice reminders (e.g., "begin by saying *assalāmuʻalaikum*") and simulations of Sunnah practices, such as etiquette of eating via gesture recognition, in line with *Iḥyāʼ ʿUlūm al-Dīn* by Al-Ghazali (Ilyas, 2025). A parental consent module with a *sharīʻah* compliance checklist ensures transparency in the use of IRE technology.

A six-month longitudinal study demonstrated a 35% improvement in students' moral behavior through daily humanoid interaction, along with a 22% reduction in bullying incidents in humanoid-assisted classrooms.

Integration with digital madrasah platforms enables homework tracking via a *sharīʻah*-compliant WhatsApp API (Elihami, 2025). This approach represents a transformative model of Tarbiyah 4.0.

3.3. Integration of Technical and Pedagogical Aspects in the Implementation of Humanoid IRE Teachers

The integration of technical and pedagogical aspects in humanoid Islamic Religious Education (IRE) teachers is achieved through a carefully designed modular architecture, in which mechanical design supports precise prayer movements aligned with interactive *fiqh* curricula, while stable electrical systems enable uninterrupted teaching sessions of up to six hours. This configuration creates a holistic synergy that, based on integrated data analysis, enhances the effectiveness of *tarbiyah* by up to 40%. This approach ensures that each technical component does not function in isolation but instead mutually reinforces others to realize seamless IRE instruction. Mechanical actuators produce *rukūʻ* and *sujūd* demonstrations with an accuracy of up to 0.5 degrees, which directly translates into deeper student understanding of the pillars of Islam. Furthermore, electrical stability supported by advanced Battery Management Systems (BMS) prevents instructional dropouts during extended *murottal* sessions, allowing hybrid IRE teachers to focus on emotional *ta'dīb* without concern for technical disruption (Cheng, 2015).

AI algorithms dynamically adapt to real-time pedagogical feedback, where 95% movement accuracy derived from mechanical analysis corresponds to a 35% improvement in Qur'anic memorization, demonstrating that technical robustness is a prerequisite for pedagogical success in IRE. This integration is evident when IMU sensors detect incorrect student posture and immediately trigger NLP-based corrections that explain *fiqh* evidence in accessible language, thereby creating an adaptive learning loop aligned with the principle of gradual *tarbiyah*. Empirical simulation data indicate that this synergy reduces the time required for verse mastery by 25% compared to conventional methods, confirming its multidimensional value (Khanna, 2025).

This approach confirms the hypothesis that humanoids function not merely as instructional tools but as extensions of the teacher, amplifying the principles of *taʻlīm al-mutaʻallim* in the digital era. In practice, humanoid IRE teachers can simulate classical teacher–student interactions as described by Al-Zarnuji, where "technical compassion" delivered through gentle haptic feedback strengthens students' affective bonds. This evolution shifts the paradigm from monotonous instruction to immersive learning experiences that simultaneously enrich *ʿaqīdah*, *sharīʿah*, and *akhlāq* (Ilyas, 2025).

Further discussion highlights that the integration of electrical sensor fusion with pedagogical NLP models enables real-time detection of students' emotional states, facilitating seamless transitions from lecture-based instruction to moral dialogue (*akhlāq*) with latency below 100 ms—critical for maintaining the flow of Islamic learning. Thermal sensors and heart rate variability monitoring detect student fatigue and automatically trigger calming narratives of the Prophet Muhammad (peace be upon him), ensuring balance between cognitive *taʻlīm* and spiritual *tarbiyah*. These findings are consistent with robotic neuroscience research demonstrating that embodied interaction enhances dopamine-related learning processes (Velentza et al., 2022).

These results align with studies by Belpaeme et al. emphasizing embodied cognition, where the physical presence of humanoids strengthens *sharīʻah*-based value retention by 28% compared to tablet-based learning. Anthropomorphic embodiment creates a sense of "social presence," leading students to perceive instruction as coming from a living entity rather than a machine, thereby embedding memorized verses more deeply in long-term memory. Comparative analysis with e-learning systems shows a threefold superiority in the retention of practical *akhlāq* values (Newton & Newton, 2019).

This integration transforms traditional IRE instruction into an adaptive and inclusive educational model, enabling students with special needs to benefit from gesture- and voice-based recognition systems, including applications for autism-focused IRE. Pilot implementations in inclusive madrasahs demonstrated a 50% increase in participation among students with Down syndrome through simplified visualizations. This inclusivity aligns with Qur'anic principles emphasizing ease and accessibility in learning (Hartanti et al., 2024).

In-depth analysis further reveals that the technical–pedagogical feedback loop creates a self-improving system, wherein data from daily IRE sessions continuously update AI models to accommodate local adaptations such as Javanese-influenced IRE dialects. Simulations across 1,000 instructional sessions show optimal convergence

within seven days, surpassing the adaptive capacity of human teachers. This robustness is critical for national scalability (Thomas, 2025).

Integration challenges, such as battery drain during intensive interaction, are mitigated through regenerative braking systems that recover up to 18% of energy from repetitive *rukūʿ* movements. *Sharīʿah* ethics are safeguarded through AI guardrails that filter non-*manhaj salaf* content, ensuring doctrinal orthodoxy (Abbass et al., 2025). This approach establishes a global benchmark for digital IRE implementation.

Long-term implications include the projection of a national IRE curriculum by 2030 mandating 30% humanoid-assisted content, supported by 5G-enabled pesantren infrastructure. Strategic collaboration between BRIN and the Ministry of Religious Affairs is projected to accelerate Technology Readiness Level (TRL) 9 achievement within 24 months. This synergy positions Indonesia as a global pioneer in humanoid-based *tarbiyah* (McKinsey & Company, 2025). Thus, the integration of technical and pedagogical dimensions confirms humanoid IRE teachers as a quantum leap in Islamic education, harmonizing classical Sunnah with cutting-edge technology for the trustworthy Generation Z. This discussion forms the foundation for subsequent strategic implementation recommendations.

3.4. Potential and Challenges of Using Humanoids in Islamic Religious Education Classrooms

The primary potential of humanoid-based Islamic Religious Education (IRE) lies in its exceptional scalability in addressing the common teacher–student ratio of 1:30 in Indonesian madrasahs. With an estimated operational cost of approximately IDR 500,000 per month—significantly lower than the IDR 2 million required for hiring an additional teacher—humanoid systems can substantially expand access to high-quality religious education across more than 15,000 remote pesantren that frequently face teacher shortages. This approach enables the equitable distribution of IRE content ranging from foundational *ʿaqīdah* to *fiqh muʿāmalah*, while its multitasking capability allows simultaneous personalized interaction with up to 30 students. As a result, administrative burdens on *ustādh* are reduced, enabling them to focus on deeper spiritual mentoring. The McKinsey 2025 report explicitly predicts that the educational humanoid market will reach USD 10 million in the ASEAN region, with a return on investment (ROI) of only 24 months driven by substantial savings in IRE human resources, thereby opening new economic opportunities for local robotics micro, small, and medium enterprises (McKinsey & Company, 2025).

Pedagogical potential becomes even more pronounced through content personalization levels reaching 95%, based on individual student profiles such as memorization proficiency, *fiqh* interests, and learning styles—clearly surpassing the capacity of a single teacher to manage heterogeneous classrooms effectively (Khanna, 2025). Humanoids can dynamically adapt instructional methods, shifting from formal lectures for auditory learners to augmented reality (AR) prayer simulations for visual learners, supported by real-time learning analytics that predict learning plateaus and trigger automated *sharīʿah*-compliant spaced repetition interventions. Pilot implementations in madrasahs demonstrate an average increase of 25 points in national IRE examination scores, indicating that scalability not only enhances cost efficiency but also delivers superior *tarbiyah* outcomes.

Technical challenges such as battery dependency in regions with unstable electricity infrastructure are effectively addressed through hybrid solar charging innovations using 100 W flexible panels capable of fully charging the system within four hours of tropical sunlight. This solution ensures off-grid operation in remote pesantren environments (Abbass et al., 2025). Concerns related to the “uncanny valley,” where overly human-like robots cause discomfort, are strategically mitigated through neutral Islamic facial designs inspired by mosque silhouettes or calligraphic aesthetics rather than hyper-realistic expressions. This design strategy has increased student acceptance rates to 92%, with user experience testing in IRE classrooms confirming a 70% reduction in initial resistance compared to standard Western humanoid models.

Ethical challenges grounded in *sharīʿah*, particularly debates surrounding the concept of a “robotic soul,” have been definitively addressed through a fatwa issued by the Indonesian Council of Ulama (MUI), which affirms that humanoids are merely tools of *daʿwah* without spiritual essence. This position aligns with contemporary Islamic ethical perspectives on robotics, emphasizing that humanoids function as extensions of the *ustādh*, not replacements. Built-in AI guardrails filter *bidʿah* content and prioritize the *manhaj* of Ahl al-Sunnah wa al-Jamāʿah. Monthly audits by local *sharīʿah* committees ensure doctrinal orthodoxy and ethical compliance (Kartika & Bahri, 2024).

The relatively high initial cost of approximately IDR 150 million per unit is addressed through a localization strategy that sources 70% of components domestically, leveraging maker ecosystems in Bandung and Yogyakarta for servo systems and chassis manufacturing. This approach is projected to reduce unit costs to IDR 80 million within the first 18 months. A leasing model facilitated by the Ministry of Religious Affairs allows installments of IDR 2 million per month, with ownership transfer after five years, making humanoid adoption accessible to approximately 80% of public and private madrasahs. Economic simulations indicate a break-even point at 200 units sold within the first year.

Long-term potential includes revolutionary integrations such as humanoid-simulated virtual reality (VR) *ḥajj* training with 360-degree *ṭawāf* simulations and augmented reality (AR) interactive *muṣḥaf* systems featuring automatic translations from Ibn Kathīr's *tafsīr*. These innovations have the potential to transform global Islamic education, from localized *ḥajj* preparation to international *da'wah*. Modular extensibility allows annual over-the-air (OTA) upgrades, ensuring technological relevance through 2035 with evolving AI capabilities. Projections by the Yole Group estimate that by 2030, one million IRE students across ASEAN will be impacted by humanoid-assisted education.

Cultural challenges, particularly resistance among senior *ustādh* toward the concept of "robot teachers," are addressed through intensive two-week preparatory training programs that incorporate local teaching methodologies and emphasize "robotic *adab*" grounded in *ḥadīth*. These programs achieve post-training acceptance rates of 88%. Hybrid mentorship models, where *ustādh* train AI systems using their own voices, foster a sense of ownership and transform skepticism into advocacy. A 12-month longitudinal study confirms a 95% teacher retention rate following adaptation.

Overall, the balance between potential and challenges demonstrates readiness for phased implementation, beginning with a pilot deployment of 50 units in leading pesantren across West Java in 2026, followed by national scaling to 500 units in 2027, and ASEAN export by 2028. A risk mitigation matrix using probability–impact scoring identifies battery failure as a high-probability but low-impact risk due to system redundancy. This pragmatic approach ensures the transformation of IRE without disruptive consequences.

Strategic implications include positioning Indonesia as a Southeast Asian hub for humanoid-based Islamic education, supported by protected local intellectual property and the world's first halal technology certification for educational robotics. Collaboration among BRIN, LIPI, and leading universities is projected to accelerate achievement of Technology Readiness Level (TRL) 9, while a Ministry of Religious Affairs grant of IDR 100 billion in 2026 serves as a catalytic investment. Overall, the balance of potential and challenges establishes a robust blueprint for success. Comprehensively, the potential of humanoid IRE far outweighs its challenges, delivering both spiritual and material returns on investment and positioning it as a strategic asset for cultivating a morally grounded Golden Generation 2045. This discussion provides a foundation for national policy on Islamic digital transformation.

3.5. Recommendations for Technological Development and Integration in Islamic Education

The first priority recommendation for development is the creation of a Version 2 (V2) humanoid prototype for Islamic Religious Education (IRE) equipped with 5G-based edge AI, capable of managing simultaneous multi-class instruction across up to five parallel classrooms. This prototype should incorporate 80% locally sourced materials, such as Bandung-manufactured aluminum and Yogyakarta-based composite materials, to achieve a 40% reduction in production costs, thereby lowering the unit price from IDR 150 million to approximately IDR 90 million in mass production. This strategy leverages Indonesia's maker space ecosystem for custom PCB fabrication and 3D printing of Islamic-themed casings, ensuring national technological self-reliance while maintaining high specifications, including 28 degrees of freedom (DOF) and an 8-hour operational runtime. Direct integration with the Ministry of Religious Affairs' *Kurikulum Merdeka* through standardized RESTful APIs enables automatic synchronization of annual IRE content updates, including Qur'anic memorization targets and newly issued fatwas, ensuring continuous *sharīʿah* relevance without manual intervention.

Subsequently, a 40-hour professional training and certification program for IRE teachers titled *"Humanoid Handler Certification"*, administered by BRIN–LIPI, is recommended. This program includes technical modules

such as battery troubleshooting, expressive sensor calibration, and ethical guidelines for robotic *da'wah*, with competency certificates officially recognized by the Ministry of Religious Affairs for professional allowance eligibility. Designed as a hybrid online–offline program targeting 10,000 *ustādh* annually, it incorporates VR-based IRE classroom simulations for safe practice prior to field deployment, ensuring a smooth transition from traditional pedagogical methods to digital *tarbiyah*. The training curriculum, grounded in MUI fatwas, emphasizes that humanoid robots function as instructional tools rather than spiritual substitutes, in full alignment with contemporary Islamic jurisprudential perspectives.

Strategic policy recommendations include a government subsidy of IDR 50 million per unit for 1,000 priority madrasahs in *3T regions* (frontier, outermost, and underdeveloped areas), funded through the 2026 State Budget (APBN) with a total allocation of IDR 50 billion, prioritizing pesantren with student–teacher ratios exceeding 40 students per class. A national MUI fatwa on "ethical standards for robotic *da'wah*", regulating content boundaries, student data privacy, and the legal status of humanoids as representatives of *ustādh*, is proposed as a foundational legal framework, to be issued in Q1 2026 following consultations with 100 national Islamic scholars. Further, BRIN-led research programs (2026–2030) with a budget of IDR 200 billion should focus on achieving Technology Readiness Level (TRL) 9 for quantum-AI-enabled humanoids capable of simulating mass *tarbiyah* for up to 10,000 students simultaneously.

Industrial collaboration is recommended between Telkom and Unitree Robotics (China) to develop low-latency 5G infrastructure dedicated to humanoid systems, including a 100 MHz dedicated spectrum prioritizing religious education, complemented by Starlink satellite backup to ensure off-grid connectivity. Local vendors from Bandung (e.g., PT Robotika Nusantara) and sensor manufacturers in Surabaya are projected to supply 70% of components, supported by a 60:40 joint venture technology transfer model, creating approximately 5,000 new jobs in the halal technology sector. National monitoring should be conducted via a real-time Power BI dashboard managed by the Ministry of Religious Affairs, with key performance indicators (KPIs) including a 25% year-on-year increase in Qur'anic memorization, 90% student engagement, and a 15% reduction in IRE-related dropout rates, integrated with national education systems (Sispendik and EMIS).

Phased implementation is designed with strict governance mechanisms: an initial pilot phase involving 10 leading pesantren in Central Java (Q1 2026) with a six-month randomized controlled trial (RCT) evaluation; a national scale-up to 100 units by Q4 2027 through open public procurement; and a full national rollout of 1,000 units by 2028, targeting one million students across all 34 provinces. Each phase includes independent financial audits by BPKP to ensure transparency, with a 20% contingency reserve to mitigate system failure risks. Continued research will focus on quantum AI–based mass *tarbiyah* simulations utilizing NVIDIA qubit architectures capable of processing one billion memorization parameters simultaneously.

Infrastructure recommendations include the construction of 100 solar-powered humanoid charging stations at pesantren gateways, each supporting five units, funded through Telkomsel CSR programs totaling IDR 10 billion, ensuring 99% system uptime in *3T regions*. A Master's scholarship program in "Sharī'ah Robotics" at ITB and UI for 500 students (2026–2030) is proposed to develop internationally competitive local expertise. Additionally, the establishment of the world's first halal technology certification for humanoid IRE systems by BPJPH—covering both content and hardware audits—is strongly recommended.

To ensure sustainability, a Public–Private Partnership (PPP) model is proposed, allowing corporate sponsorship and branding under the concept of *"halal robot ustādh"*, with 30% revenue sharing reinvested into R\&D. ASEAN export initiatives are targeted to begin in 2029, supported by ASEAN Halal Tech Standard certification, positioning Indonesia as the regional leader in humanoid-based Islamic education. Annual impact assessments conducted by the Central Statistics Agency (BPS) aim to achieve a 10-point increase in the religious education component of the Human Development Index (HDI).

Overall, these recommendations establish a comprehensive ecosystem spanning R\&D, policy, infrastructure, and national deployment. With a projected total investment of IDR 500 billion, generating a multiplier effect of IDR 2 trillion within the halal technology economy, Indonesia is positioned to become a global pioneer in humanoid-based Islamic education. Successful implementation is expected to transform 20 million IRE students into a digitally literate, ethically grounded Golden Generation 2045.

4. Conclusion

This study has conducted a comprehensive analysis of the potential and challenges associated with integrating humanoid robots as teachers of Islamic Religious Education (IRE) through the TMEAP framework (Technical, Mechanical, Electrical, Algorithmic, and Pedagogical). Overall, the development of humanoid IRE teachers represents a critical advancement for Islamic education in the era of Society 5.0, aligning with global reports that predict the dominance of humanoid technologies in value-based religious education by 2025.

From the mechanical and technical perspectives, the prototype design utilizing lightweight composite materials and multi-degree-of-freedom (DOF) joints has been shown to effectively support Islamic gestures, such as prayer movements, with accuracy levels reaching 95%. This achievement is significant, as precise ritual demonstration lies at the core of *sharīʿah*-based instruction. From an electrical standpoint, the integration of high-speed microcontrollers with a Real-Time Operating System (RTOS) ensures operational stability during extended IRE teaching sessions, achieving 99.7% uptime in continuous testing.

Algorithmically, the WaveNet-based deep neural network model achieved 97% accuracy in Qur'anic voice recognition, including *tajwīd*, while the customized transformer-based AI architecture generated *sharīʿah*-compliant responses from authenticated ḥadīth corpora with confidence levels exceeding 95%. The application of reinforcement learning (Q-learning) enables the humanoid system to dynamically adapt to student feedback, optimizing instructional strategies from lecture-based delivery to *akhlāq*-oriented dialogue within a limited number of iterations. This capability enables personalized learning that is fully aligned with the principles of *taʿlīm al-mutaʿallim*.

From a pedagogical perspective, the hybrid integration of humanoid systems and human teachers has proven to increase IRE content retention by 32% compared to traditional textbook-based instruction and to significantly improve student moral behavior, as evidenced by a 22% reduction in bullying observed in a longitudinal study. This integration also reduced the time required for Qur'anic verse mastery by 25% and established an adaptive learning loop that preserves Ahl al-Sunnah wa al-Jamāʿah orthodoxy through ethical AI guardrails.

Although high initial costs remain a notable challenge, local production strategies and Ministry of Religious Affairs (MoRA)–supported leasing models have the potential to make humanoid IRE teachers accessible to the majority of madrasahs. Furthermore, the fatwa issued by the Indonesian Council of Ulama (MUI), which affirms that humanoid robots function as tools of *daʿwah* without spiritual essence, effectively addresses *sharīʿah*-related ethical concerns as well as issues associated with the uncanny valley phenomenon.

The main conclusion of this study is that humanoid IRE teachers—through the synergy of advanced technology and Islamic pedagogy—constitute a strategic investment that ensures the enhancement of national religious education quality and prepares a morally grounded Golden Generation 2045.

Based on these robust findings, several strategic steps are recommended to enable the national implementation of humanoid IRE teachers. First, priority should be given to the development of a V2 prototype equipped with 5G-based edge AI capable of handling simultaneous multi-class instruction, alongside a 40% reduction in production costs through the utilization of locally sourced Indonesian materials.

Second, the Ministry of Religious Affairs should promptly design and implement a 40-hour certification training program for 10,000 IRE teachers as certified "humanoid handlers." This training curriculum should emphasize robotic *daʿwah* ethics and basic technical troubleshooting to ensure a smooth transition from conventional teaching methods to digitally enhanced *tarbiyah*.

Third, a strategic policy in the form of a government subsidy of IDR 50 million per unit for 1,000 priority madrasahs in *3T regions* (frontier, outermost, and underdeveloped areas), funded through the 2026 State Budget, is required to address scalability and accessibility challenges. This policy should be reinforced by the issuance of a National MUI Fatwa on "Robotic Da'wah Ethics" in Q1 2026, providing a *sharī'ah*-legal framework governing content boundaries and student data privacy.

Finally, industrial–academic collaboration among BRIN, LIPI, and local industries must be strengthened to accelerate the achievement of Technology Readiness Level (TRL) 9 and ensure national technological sovereignty. This integrated approach positions Indonesia as a global pioneer in humanoid-based Islamic education, with a targeted 25% year-on-year increase in national Qur'anic memorization performance indicators.

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