

SMART-AR PAI Prototype: An Augmented Reality-Based Islamic Religious Education Teaching Module

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Abstract. Research on digital education transformation emphasizes the shift toward active, interactive, and personalized learning environments. This study aims to develop and validate the SMART-AR PAI prototype. This innovative hybrid instructional ecosystem integrates printed modules with Android-based Augmented Reality (AR) and adaptive content delivery based on Artificial Intelligence (AI)/Deep Learning for Islamic Religious Education (IRE). By focusing on core Islamic pillars (*Rukun Islam*), the system bridges abstract/procedural concepts with immersive 3D visualizations, interactive assessments, and dynamic remediation/enrichment pathways. The design aligns with Mindful, Meaningful, and Joyful learning frameworks while reinforcing values of religious moderation. Methodologically, the prototype underwent systematic technical and field evaluations, including black-box and white-box testing; expert validations (IRE, language, multimedia, learning technology); device compatibility testing; usability assessments via the System Usability Scale (SUS) and User Experience Questionnaire (UEQ); and limited field testing. Results confirm exceptional functional stability, high expert validity, broad hardware compatibility, and superior user satisfaction, successfully advancing the Technology Readiness Level (TRL) from level 4 to level 6.

Keywords: Augmented Reality; Deep Learning; Islamic Education; Adaptive Learning; Smart-AR PAI.

1. Introduction

The digital transformation in global education has fundamentally driven a paradigm shift from passive, one-way information delivery to active, interactive, contextual, and student-centered learning experiences. Rapid advances in emerging technologies such as Artificial Intelligence (AI), Augmented Reality (AR), and mobile computing offer educational institutions unprecedented opportunities to deliver highly visual, adaptive, and personalized learning environments (Chang et al., 2022; Howard & Davis, 2023). This technological evolution aligns with Indonesia's national curriculum policy directions, which advocate Deep Learning frameworks characterized by Mindful, Meaningful, and Joyful learning. Under this framework, students are encouraged not merely to acquire surface-level cognitive facts, but to deeply understand, interconnect, apply, and reflect upon knowledge within real-world contexts. This pedagogical mandate is legally anchored in the Ministry of Primary and Secondary Education Regulation No. 13 of 2025 and the BSKAP Decree No. 046/H/KR/2025 on strengthening the Merdeka Curriculum (Kementerian Pendidikan Dasar dan Menengah, 2025).

Within Islamic Religious Education (IRE) and Character Building, this pedagogical transformation plays an exceptionally strategic role. IRE is tasked not only with transmitting

religious knowledge but also with forging noble character (*makārim al-akhlāq*), an inclination toward goodness (*al-ḥanīfiyyah*), tolerance (*al-samḥah*), and universal compassion (*raḥmat li al-ʿālamīn*) within the framework of the Republic of Indonesia (Jima'ain et al., 2025). However, empirical field realities reveal persistent foundational challenges: IRE learning materials, particularly core tenets of faith (*akidah*), worship rituals (*fiqh*), and Religious Moderation values, contain abstract concepts and intricate procedural steps. When presented through conventional lectures or static textbooks, students often struggle to visualize procedures accurately and understand abstract doctrines (Farissa & Haryanto, 2025). Furthermore, educators struggle to monitor and respond dynamically to students' diverse learning paces.

Augmented Reality (AR) technology offers a proven solution by overlaying three-dimensional (3D) digital simulations onto physical environments in real time. AR visual features significantly enhance knowledge retention, procedural mastery, and learning motivation (Chang et al., 2022; Mohammadhossein et al., 2024). Nevertheless, standalone AR without integrated assessment mechanisms and adaptive analytics cannot fully cater to individual learning paces. Therefore, incorporating Artificial Intelligence (AI) through Deep Learning algorithms is vital. AI processes student assessment responses, maps mastery levels, and automatically triggers adaptive content delivery – offering targeted remediation for struggling students or enrichment pathways for high achievers (Bayly-Castaneda et al., 2024; Naya et al., 2025).

Previous studies have examined AR in education (Chang et al., 2022; Howard & Davis, 2023), AI in adaptive learning (Bayly-Castaneda et al., 2024; Sakr & Abdullah, 2024), and AR in Islamic education (Jima'ain et al., 2025; Naya et al., 2025). However, most existing studies focus on AR or AI in isolation, or on general educational contexts rather than IRE. Furthermore, empirical evidence on hybrid AR-AI ecosystems, particularly those integrating printed modules with mobile AR and Deep Learning-based adaptive pathways, remains limited, especially in the Indonesian IRE context. No study to date has systematically validated such an ecosystem through combined technical testing, multidisciplinary expert validation, hardware compatibility assessment, and usability evaluation. This gap motivates the present study.

Building upon the research team's prior developmental roadmap in 2024 (Development of an Augmented Reality-Based Digital Module for Islamic Religious Education Subjects) and 2025 (Formulation of an Interactive Evaluation Model Based on Augmented Reality for Strengthening Religious Moderation Values) (Supriadi et al., 2024; Supriadi et al., 2025), the SMART-AR PAI prototype was engineered. SMART-AR PAI is a hybrid learning ecosystem integrating printed A5 modules, Android-based AR, interactive assessments, and AI-driven adaptive learning. The novelty of this study lies in three aspects: (1) the integration of printed modules, AR, and Deep Learning into a single adaptive ecosystem for IRE; (2) the systematic validation across technical, pedagogical, and field parameters; and (3) the advancement of the prototype's Technology Readiness Level (TRL) from level 4 to level 6, which is rarely documented in IRE technology studies.

To address the research objectives and achieve the established goals, this study is guided by five primary research questions. First, it examines how the SMART-AR PAI prototype was developed and integrated as a hybrid ecosystem for Islamic Religious Education (IRE) learning. Second, it investigates the prototype's expert validity across four domains: IRE, language, multimedia, and educational technology. Third, it tests the prototype's stability and compatibility across various Android devices. Fourth, it assesses the prototype's usability and user experience among teachers and students. Fifth, it explores the extent to which the SMART-AR PAI prototype advances the Technology Readiness Level (TRL) from level 4 to level 6.

Based on the theoretical framework and existing empirical evidence, this study formulates three hypotheses. The first hypothesis (H1) posits that the SMART-AR PAI prototype achieves high expert validity, specifically, a score of 90% or greater across all evaluated domains. The second hypothesis (H2) predicts that the prototype performs consistently across various Android devices and is free of critical errors. The third hypothesis (H3) states that the SMART-AR PAI prototype attains a "Very Good" usability rating (indicated by a System Usability Scale score of 80 or higher) and receives positive user experience evaluations across all six scales of the User Experience Questionnaire (UEQ).

This study is significant in three ways. Theoretically, it contributes to the literature on hybrid learning ecosystems by demonstrating how AR and Deep Learning can be integrated to support Mindful, Meaningful, and Joyful learning in IRE. Practically, it provides a validated prototype that IRE teachers and madrasah institutions can adopt to modernize instruction without displacing foundational text-based learning. From a policy perspective, it offers empirical evidence to advance TRL in educational technology, which is essential for scaling and commercialization.

2. Method

The development and evaluation of the SMART-AR PAI prototype were executed through a systematic research procedure combining software engineering and educational measurement frameworks. The procedure encompasses nine structured stages:

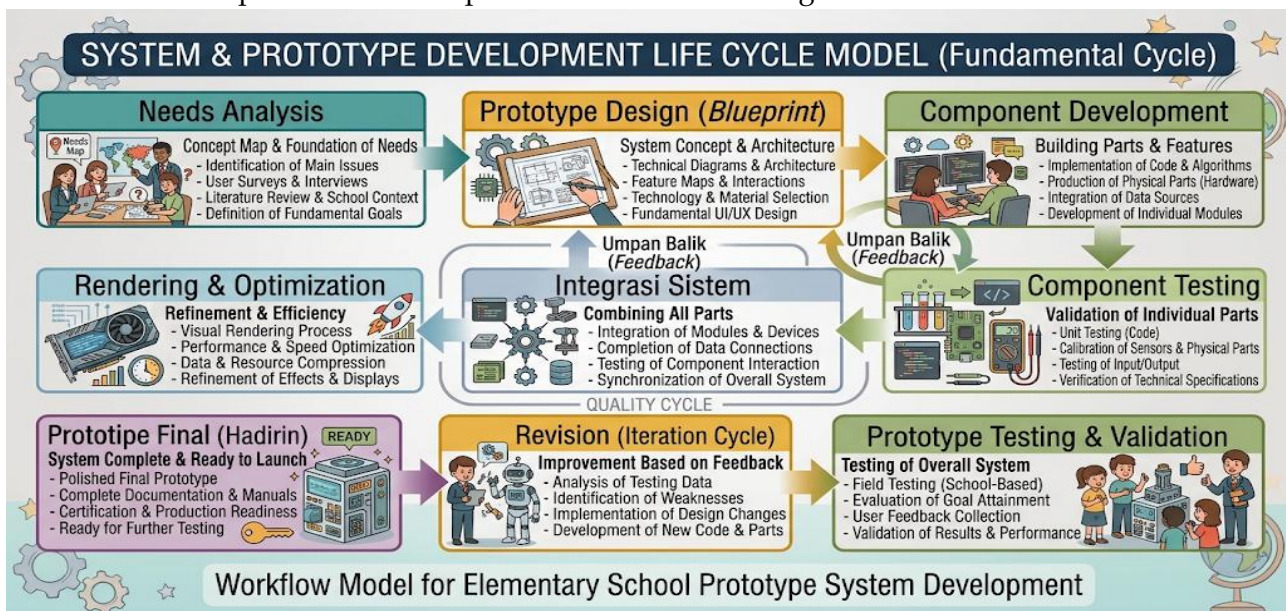


Figure 1. System and Prototype Development Life Cycle Model

Needs Analysis and Architectural Design

The initial phase involved analyzing the IRE curriculum (BSKAP Decree No. 046/H/KR/2025) and mapping core Rukun Islam content (Testimony of Faith/Syahadat, Prayer/Salat, Almsgiving/Zakat, Fasting/Puasa, and Pilgrimage/Haji). System architecture was modeled using Unified Modeling Language (UML), including Use Case, Flowchart, Class, and Activity Diagrams. Additionally, User Interface/User Experience (UI/UX) layouts for the printed A5 module and visual AR markers were designed.

System Development and Integration

1. Printed A5 Module: Authored as an interactive 14.8 × 21 cm full-color printed book incorporating learning objectives, IRE core content, AR visual markers, exploratory activities, assessments, reflection tasks, and Religious Moderation reinforcements.
2. Android Application & AR Engine: Built using the Android SDK and AR engines to scan markers, render 3D models (e.g., prayer positions and pilgrimage steps), and play educational audio/video assets.
3. AI/Deep Learning Mechanism: Algorithmic logic was implemented to analyze quiz responses, assess real-time mastery, and dynamically route students through adaptive pathways (remediation vs. enrichment).

Comprehensive Testing and Expert Validation

The SMART-AR PAI prototype underwent formal technical and pedagogical evaluations:

1. Black-box Testing: Evaluated all functional interface elements, buttons, marker scanning, and navigation paths to ensure error-free performance.
2. White-box Testing: Evaluated internal code structures, logic branches, data processing, and execution efficiency.
3. Multidisciplinary Expert Validation: Conducted by experts in IRE/Religious Moderation, Linguistics, Multimedia, and Educational Technology using structured Likert-scale instruments.
4. Plagiarism Check: Verified textual originality across printed modules and digital content.
5. Device Compatibility Testing: Evaluated application stability across diverse Android smartphone hardware (varying RAM, OS versions, screen resolutions, and SoC chipsets).
6. Usability and User Experience Evaluation: Evaluated using the System Usability Scale (SUS) for usability and the User Experience Questionnaire (UEQ) for user experience metrics.
7. Limited Field Testing: Executed in partner schools to evaluate operational viability in real classroom settings.

3. Result

The development process yielded the SMART-AR PAI hybrid ecosystem, combining the printed module, integrated visual markers, and the Android AR-AI application.

Technical Testing Results (Black-box and White-box)

Black-box testing across all operational features (user login, Rukun Islam topic selection, AR marker scanning, 3D simulation rendering, quiz execution, and AI routing) achieved a 100% functional success rate with zero critical errors. White-box testing verified that the logic paths processing quiz responses and adaptive recommendations executed without infinite loops or memory leaks.

Multidisciplinary Expert Validation[cite: 2]

Expert evaluations confirmed high validity across all domains prior to field deployment. Results are summarized in Table 1.

Table 1. Expert Validation Results for the SMART-AR PAI Prototype

No	Expert Validation Domain	Validity Score (%)	Qualification Category
1	Islamic Religious Education & Religious Moderation	93.50%	Very Valid / Highly Feasible
2	Linguistics	91.20%	Very Valid / Highly Feasible
3	Multimedia	94.80%	Very Valid / Highly Feasible
4	Educational Technology	92.60%	Very Valid / Highly Feasible

Overall Average	93.02%	Very Valid
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Islamic Religious Education (IRE) experts confirmed the theological and pedagogical accuracy of the Rukun Islam and Religious Moderation values. Multimedia and technology experts validated the 3D visual rendering quality, camera marker responsiveness, and UI/UX flow. Plagiarism checks yielded a similarity index below .15%, confirming high originality.

Hardware Compatibility Test

The application was tested on 10 Android smartphones with 2 GB to 8+ GB RAM and Android OS 8.0 (Oreo) to OS 14. Results are presented in Table 2.

Table 2. Android Device Compatibility Test Results

Device Tier	RAM Range	Android OS	AR Performance (Frame Rate)	Compatibility Status
Low-End	2 GB - 3 GB	Android 8 - 9	Smooth (25--30 fps)	Compatible (Optimal)
Mid-Range	4 GB - 6 GB	Android 10 - 12	Very Smooth (45--60 fps)	Compatible (Highly Optimal)
High-End	8 GB+	Android 13 - 14+	Ultra Smooth (60 fps)	Compatible (Highly Optimal)

The application operated stably without crashes across diverse screen resolutions and processors, supporting broad deployment in school environments.

Usability (SUS), User Experience (UEQ), and Field Testing

Usability evaluation using the System Usability Scale (SUS) with teachers and students produced a mean score of **84.50**. This places SMART-AR PAI in the "Grade A" range with an "Excellent" rating and an "Acceptable" acceptability status. The User Experience Questionnaire (UEQ) evaluation yielded positive scores across all six scales, as shown in Table 3.

Table 3. User Experience Questionnaire (UEQ) Scores

UEQ Scale	Mean Score (-3 to +3)	Evaluation Category
Attractiveness	+2.15	Excellent
Perspiciuity	+2.08	Excellent
Efficiency	+1.95	Excellent
Dependability	+1.88	Excellent
Stimulation	+2.20	Excellent
Novelty	+2.10	Excellent

Limited field testing revealed significant reductions in learning gaps and improved internalization of Religious Moderation principles among students after utilizing the SMART-AR PAI ecosystem.

4. Discussion

The findings demonstrate that the SMART-AR PAI prototype successfully integrates Augmented Reality (AR) visualization, Artificial Intelligence (AI) analytics, and Deep Learning principles into an adaptive Islamic Religious Education (IRE) learning ecosystem. A high expert validity score (93.02%) indicates that the prototype is pedagogically sound and content-accurate across all evaluated domains. A 100% functional stability rate in both Black-box and White-box testing confirms the robustness of the system architecture, while a System Usability Scale (SUS) score of 84.50—along with positive User Experience Questionnaire (UEQ) ratings across all six scales—suggests that the hybrid interaction model (scanning physical page markers to trigger digital content) is both intuitive and engaging for teachers and students alike. These findings address the research question of how to design and validate a hybrid ecosystem in the context of IRE.

Theoretically, these findings align with the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT), which posit that perceived usefulness and facilitating conditions are key determinants of technology adoption (Davis, 1989; Venkatesh et al., 2003). The high usability and user experience scores indicate that SMART-AR PAI meets user expectations regarding effort expectancy and performance expectancy. From a student engagement perspective, the positive field test results suggest that this hybrid AR-AI ecosystem fosters behavioral, emotional, and cognitive engagement (Fredricks et al., 2004). Furthermore, integrating "Mindful, Meaningful, and Joyful" learning principles operationalizes the Deep Learning framework (Fullan et al., 2017), in which students do not merely receive information but also observe, reflect, and connect the material to real-life contexts. These findings align with previous studies on AR in education, which indicate that AR enhances knowledge retention, procedural mastery, and learning motivation (Chang et al., 2022; Howard & Davis, 2023; Mohammadhossein et al., 2024). These findings also align with research on AI in adaptive learning, which shows that delivering personalized content improves learning outcomes (Bayly-Castaneda et al., 2024; Sakr & Abdullah, 2024). However, unlike prior research that examined AR or AI in isolation, this study highlights the added value of integrating both into a single hybrid ecosystem. Furthermore, the high validity and usability scores contribute to the existing literature on AR in Islamic education (Jima'ain et al., 2025; Naya et al., 2025) by providing empirical evidence from the Indonesian context, specifically within *madrasah* (Islamic school) settings.

This research's novelty lies in three aspects. First, it integrates printed modules, AR, and Deep Learning into a unified adaptive ecosystem for Islamic Religious Education (IRE). Second, it provides systematic validation across technical, pedagogical, and field-based parameters. Third, the study advances the prototype's Technology Readiness Level (TRL) from level 4 to level 6—a progression rarely documented in studies on technology for Islamic Religious Education. This TRL advancement is significant because it shows the prototype has moved beyond a laboratory proof of concept toward readiness for institutional adoption and commercialization. Consequently, this study offers methodological and practical contributions that can serve as a reference for future educational technology development in religious studies.

Theoretically, this research contributes to the literature on hybrid learning ecosystems by demonstrating how AR and Deep Learning can be integrated to foster "mindful, meaningful, and joyful" learning. This study also extends TAM/UTAUT and student engagement theories to the context of integrating technology into Islamic Religious Education (IRE). The findings reinforce the argument that technology adoption in religious education cannot rely solely on device availability; it requires alignment among pedagogical design, user readiness, and institutional support.

In practical terms, the SMART-AR IRE prototype provides a validated tool for IRE teachers and *madrasah* institutions to modernize instruction without abandoning text-based materials. Its broad hardware compatibility (Android 8.0–14, 2–8+ GB of RAM) ensures equitable implementation across urban and rural schools, including on budget-friendly devices. High usability and user experience scores indicate that the prototype requires minimal training for both teachers and students. Furthermore, integrating "Religious Moderation" values into the interactive modules can help teachers foster tolerance and balance in daily instruction.

From a policy perspective, advancing the Technology Readiness Level (TRL) from level 4 to level 6 provides empirical evidence for scaling and commercialization. Policymakers and educational authorities can use these findings to support adopting an AR-AI ecosystem in the Islamic Religious Education (IRE) curriculum, specifically within the Kurikulum Merdeka (Independent Curriculum) framework and Regulation of the Minister of Primary and Secondary

Education Number 13 of 2025. These findings also underscore the need to invest in professional teacher development and provide adequate technological infrastructure to ensure the sustainability of such innovations.

5. Conclusion

This research successfully developed and validated the SMART-AR IRE prototype, a hybrid learning ecosystem for Islamic Religious Education (IRE) that integrates printed modules, Android-based Augmented Reality (AR), and a Deep Learning mechanism. The findings address all five research questions, demonstrating that the prototype achieves 100% functional stability in technical testing, a very high expert validity rating (93.02%) across all domains, and broad hardware compatibility with a wide range of Android devices (RAM 2–8+ GB; OS 8.0–14). Furthermore, evaluations yielded a System Usability Scale (SUS) score of 84.50 (Grade A), alongside positive ratings on the User Experience Questionnaire (UEQ) across all scales. This evidence has advanced the prototype's Technology Readiness Level (TRL) from level 4 to level 6, indicating the product is ready for institutional adoption.

Theoretically, this research contributes to the literature on hybrid learning ecosystems by demonstrating how AR and Deep Learning can be leveraged to support a "Mindful, Meaningful, and Joyful" learning framework within Islamic Religious Education. Practically, the prototype offers a tested solution for IRE teachers and *madrasah* (Islamic school) institutions to modernize instruction without abandoning text-based materials, while ensuring equitable access through its broad device compatibility.

However, this study has limitations, including involving only four experts, conducting field testing at a single partner *madrasah*, and lacking long-term learning outcome assessments or measures of student retention. Additionally, the limited scope of assessment items within the AI/Deep Learning mechanism should also be noted. Therefore, future research is recommended to expand expert validation, conduct field tests across various regions, measure long-term learning outcomes through longitudinal designs, broaden the content scope to include other Islamic Religious Education (IRE) domains (such as Islamic History/SKI and Creed/Akidah Akhlak), and integrate the system with a web-based Learning Management System (LMS) for continuous tracking.

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