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Assessing the Impact of AI-Driven Tools on Qur'anic Literacy: A Quasi-Experimental Study in Islamic Higher Education in Indonesia

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ABSTRACT

This study investigates the effectiveness of artificial intelligence–driven tools in enhancing Qur'anic literacy among pre-service Islamic teachers in Indonesian higher education. Addressing the lack of empirical evidence on AI applications in Qur'anic learning, the research assessed how two tools, TajweedMate for pronunciation feedback and MyQuran.ai for comprehension and reflection, could strengthen students' recitation accuracy and understanding of Qur'anic meaning. A quasi-experimental design was applied involving 72 undergraduate participants divided into an experimental and a control group. Both groups undertook pre- and post-tests in recitation and comprehension. Quantitative data were analysed using paired-sample t-tests and ANCOVA. The results revealed a statistically significant improvement for the experimental group compared with the control group, with large effect sizes for both recitation and comprehension. These findings demonstrate that AI-driven tools can effectively integrate procedural and conceptual learning, offering personalized feedback, adaptive practice, and reflective engagement with Qur'anic texts. The study contributes to the growing field of AI-enhanced Islamic education by providing empirical validation of AI's pedagogical value. It also suggests practical implications for teacher education, highlighting the potential of technology to foster autonomous, reflective, and spiritually grounded learners within Islamic educational contexts.

Keywords: Artificial intelligence, Islamic higher education, Quasi-experimental study, Qur'anic literacy, Tajwid.

INTRODUCTION

The concept of Qur'anic literacy has taken on renewed significance in recent years, especially within Islamic higher education settings in Indonesia (Stimpson & Calvert, 2021). While historically the focus of Qur'anic literacy has centred on accurate recitation and memorization of the Qur'an (Sinai, 2017), contemporary educational discourse emphasises a broader view. This expanded view includes not only the correct articulation of Arabic letters and adherence to the rules of tajwīd, but also the comprehension of meaning, reflection on the text, and the capacity to apply Qur'anic teachings within one's life and future pedagogical practice (Hanafi, 2024). In teacher-education programmes for Islamic elementary school (Madrasah Ibtidaiyah) teachers, future educators are expected to move beyond rote learning to become autonomous learners and reflective practitioners who integrate Qur'anic literacy into their teaching and moral development. In this context, artificial intelligence (AI) offers a promising avenue to enhance personalised learning, provide immediate feedback, and support metacognitive strategies (Muslimin et al., 2024). AI-driven tools have begun to emerge in the domain of Qur'anic education, offering recitation correction, interactive chat-based comprehension, and self-paced learning companions (Ahmad & Ghafar, 2025).

Despite this promise, the integration of AI tools in Qur'anic literacy education remains under-researched and presents several unresolved issues. Systematic and bibliometric analyses show that while AI in Islamic education is rising, most research focuses on general Islamic studies or curriculum integration rather than specifically on Qur'anic literacy among teacher-education students (Salim & Aditya, 2025). Studies in Indonesia report that AI integration in Islamic education is still nascent, hindered by infrastructure readiness, teacher training, and cultural or ethical alignment with Islamic values (Marwa et al., 2025). Furthermore, while recitation-support applications exist, such as the Qara'a app, which uses AI to detect pronunciation errors (Abimanto & Sumarsono, 2024), there is limited empirical evidence on how AI tools promote deeper Qur'anic literacy, including meaning-making and reflexive learning. In addition, though some research has documented moderate but significant effects of AI on learning outcomes in Islamic religious education (Han et al., 2025), gaps remain around quasi-experimental investigations that specifically target combined recitation and comprehension dimensions within teacher-education programmes. Moreover, in the Indonesian higher-education context, qualitative studies indicate student experiences with AI but do not quantify the impact on Qur'anic literacy outcomes (Batubara et al., 2024). In sum, research has yet to convincingly demonstrate how AI-driven tools can support autonomous, metacognitively aware learners in Qur'anic literacy, particularly within Islamic teacher education.

In light of these gaps, there is a clear need for empirical research that examines the efficacy of AI-driven tools in supporting Qur'anic literacy among teacher-education cohorts in Islamic higher education institutions in Indonesia. Previous studies have yet to provide convincing evidence on whether AI technologies can simultaneously enhance the accuracy of Qur'anic recitation and the comprehension of Qur'anic meaning within the same instructional framework. The problem addressed in this study lies in the limited empirical evidence on how AI-driven tools can effectively strengthen both dimensions of Qur'anic literacy while promoting learner autonomy and metacognitive engagement. Therefore, this research aims to assess the impact of a dual-AI intervention, one tool focused on pronunciation and tajwīd feedback, namely TajweedMate AI, and another emphasizing comprehension, reflection, and interactive dialogue, namely MyQuran.Online, through a quasi-experimental design. Accordingly, this study addresses the following research question: "Is there a significant difference in the improvement of Qur'anic literacy between students who use AI-driven tools and those who learn through conventional methods?"

LITERATURE REVIEW

The notion of Qur'anic literacy has evolved considerably over the past decade, moving beyond phonetic recitation and rote memorization toward a multidimensional construct that includes accurate articulation (tajwīd), comprehension of meaning, reflective engagement, and the capacity to apply Qur'anic teachings in pedagogical and moral contexts (Hanafi, 2024). This broader conceptualization aligns with contemporary educational theories of literacies as socially situated and metacognitively oriented (Shi & Blau, 2021). In the teacher-preparation context, pre-service Islamic elementary school teachers are expected to become autonomous learners capable of integrating Qur'anic literacy into their future instructional practice and moral formation. Accordingly, the integration of digital tools and artificial intelligence (AI) invites new opportunities for supporting self-regulated learning, personalized feedback, and metacognitive strategy development.

Theoretical Foundations

From a pedagogical standpoint, self-regulated learning theory (Sinkkonen & Review, 2024) is relevant: when learners are given scaffolding, feedback, and opportunities for reflection, they become more metacognitively aware, strategic, and autonomous. In the context of Qur'anic literacy, tools that provide immediate corrective feedback (for example, on tajwīd) plus prompts for reflection (for example, on verse meaning) can support self-regulation. In parallel, technology-enhanced learning frameworks (Vygotsky, n.d.) suggest that adaptive, responsive tools can serve as "more capable others" in digital form, supporting scaffolded progression. Within Islamic education theory, the notion of taʿlīm al-Qur'an emphasises both mastering the form (qirā'ah, tajwīd) and internalising meaning (tafsīr, tazkiah) which must converge in teacher education. Thus, the conceptual framework anchoring this study posits that AI-driven tools can function not only as pronunciation tutors but as comprehension and reflection companions, thereby strengthening both the procedural and conceptual dimensions of Qur'anic literacy.

Empirical Studies on AI and Qur'anic/Islamic Education

Recent bibliometric research reveals a marked increase in scholarship on artificial intelligence in Quranic education, with deep-learning and AI-based applications for recitation, text recognition, and interactive learning emerging as key trends (Bajpai et al., 2025). For example, Lachheb et al. (2025) reported that machine-learning models (k-NN, ANN, BLSTM) were applied to Arabic text and recitation classification in Qur'anic studies and achieved high accuracy rates for detecting tajwīd errors. This shows the technical feasibility of AI in supporting

recitation accuracy. Prihatiningtyas et al. (2025) conducted a quasi-experimental study among female students of Qur'anic sciences and found that an AI-based electronic programme significantly improved mastery of articulation and recitation skills. These findings underscore that AI tools can enhance the procedural dimension of Qur'anic literacy. On the comprehension and reflection side, studies such as Salim and Aditya (2025) surveyed trends in AI integration in Islamic education and found that tools supporting Qur'anic and Hadith learning were increasing, yet most were descriptive and lacked rigorous efficacy data. Similarly, Lachheb et al. (2025) conducted a bibliometric analysis showing that while deep-learning and AI are gaining traction in Quranic education, the majority of studies remain technical or developmental rather than educational-outcome focused. In the Indonesian context, Ayanwale et al. (2022) and others documented teacher readiness and infrastructural challenges in implementing AI in Islamic education, emphasising that adoption alone does not guarantee improved learning outcomes. For instance, evaluation of ChatGPT-based AI in Qur'anic interpretation revealed concerns about accuracy, depth of interpretation, and alignment with scholarly tafsīr traditions (Dahia, 2024). Collectively, these studies highlight three major themes: (1) AI can support recitation and text recognition, (2) AI for meaning-making and reflective Qur'anic literacy is under-utilised, and (3) contextual factors (infrastructure, values alignment, teacher readiness) moderate the impact of AI in Islamic education.

METHODOLOGY

Research Design

This study employed a quasi-experimental design with a pre-test and post-test control group structure to examine the effectiveness of AI-driven tools in improving Qur'anic literacy among pre-service Islamic teachers in Indonesia. The design was chosen because it allows for the comparison of learning outcomes between students who received the AI-assisted intervention and those who experienced conventional instruction, while maintaining the natural classroom setting. The independent variable was the use of two AI-driven tools designed to enhance tajwīd accuracy and comprehension of Qur'anic meaning. The dependent variables included students' recitation accuracy, comprehension performance, and level of learner autonomy. The quasi-experimental approach is widely recognised in educational technology studies for its ability to measure intervention effects when random assignment is not fully feasible (Creswell & Cresswell, 2018).

PARTICIPANTS

The study was conducted at an Islamic higher education institution in West Nusa Tenggara, Indonesia, involving 72 undergraduate students enrolled in the Qur'anic Literacy and Teaching Practice course. Participants were pre-service teachers preparing to teach at Islamic elementary schools (Madrasah Ibtidaiyah). They were purposively selected because their curriculum explicitly includes Qur'anic literacy as a pedagogical competency. Two intact classes were used to form the groups: one experimental group (n = 36) and one control group (n = 36). Both groups were taught by the same instructor to ensure instructional consistency. Before data collection, participants provided informed consent, and the study followed institutional ethical guidelines concerning the responsible use of educational technology and data privacy.

Instruments

Two instruments were used to gather data are a Qur'anic recitation accuracy test and a Qur'anic comprehension test.

a. Qur'anic Recitation Accuracy Test.

This test measured students' ability to recite selected verses using correct tajwīd rules. Three certified Qur'an recitation experts independently rated the recordings using a validated tajwīd rubric adapted from https://www.rcampus.com/rubricshowc.cfm?code=JX5762X&sp=yes (RCampus, 2024), covering articulation, rhythm, and intonation. Inter-rater reliability reached 0.91 (Cronbach's alpha), indicating high consistency.

b. Qur'anic Comprehension Test.

The test assessed understanding of key vocabulary, thematic content, and moral reflection drawn from selected verses taught in the course. Items were adapted from existing Qur'anic literacy assessments developed by Supriadi et al. (2022) and validated by two experts in Qur'anic studies. The reliability coefficient was 0.87.

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Intervention Procedures

The intervention lasted for six weeks during the academic semester. Both groups followed the same curriculum and learning objectives, but their instructional modes differed.

- Experimental Group: Students used two AI-driven tools. The first was a Qur'an recitation tutor (Tajweedmate.ai) powered by speech recognition, providing instant feedback on tajwīd errors. The second was an AI comprehension assistant (MyQuran.ai) that generated meaning-focused questions and reflective prompts about the verses. Students interacted with both tools during class and independent study sessions. Instructors facilitated short discussions to connect AI feedback with pedagogical understanding.
- Control Group: Students received conventional instruction focusing on teacher modeling, peer recitation, and guided discussion without AI assistance. The teacher provided verbal feedback, and comprehension was supported through classical tafsīr explanations.

Both groups completed identical pre-tests and post-tests. The pre-test established baseline proficiency, while the post-test measured the impact of the learning interventions.

Data Collection and Analysis

Data were collected quantitatively and analysed using SPSS 24. Descriptive statistics were computed for all variables. Independent samples t-tests were used to examine differences between groups in pre-test scores to confirm equivalence. Paired samples t-tests compared pre- and post-test performance within each group, while ANCOVA was employed to determine the adjusted mean differences between groups, controlling for initial proficiency. Effect sizes were calculated using Cohen's d to indicate the magnitude of improvement.

Validity and Reliability

To ensure methodological rigor, the study applied both content and construct validation procedures. Expert panels reviewed all instruments before administration. Reliability coefficients above 0.85 for all measures indicated acceptable internal consistency. Procedural validity was maintained through consistent teacher training, identical materials, and equivalent instructional time across groups.

Ethical Considerations

This research was approved by the Institutional Review Board of the participating university. Participants were informed about the purpose of the study, their voluntary involvement, and the confidentiality of their data. The use of AI tools adhered to ethical principles in educational technology, ensuring that learners' data were anonymized and used solely for research purposes.

FINDINGS

This section presents the quantitative findings of the study, which investigated the impact of AI-driven tools on Qur'anic literacy among pre-service Islamic teachers. Data were collected from two groups of students, an experimental group using TajweedMate and MyQuran.ai, and a control group using conventional instruction. Both groups completed pre- and post-tests measuring recitation accuracy and Qur'anic comprehension. The data were analysed using descriptive statistics, paired-sample and independent-sample t-tests, and ANCOVA to determine the adjusted mean differences while controlling for initial proficiency.

Descriptive Statistics

The descriptive results show that both groups improved their Qur'anic literacy scores over six weeks, but the experimental group showed greater progress in both recitation and comprehension.

Table 1. Descriptive Statistics of Qur'anic Literacy Scores.

Variable	Group	N	Pre-test Mean (SD)	Post-test Mean (SD)	Gain Score
Recitation Accuracy	Experimental	36	68.14 (7.22)	85.47 (5.83)	17.33
Recitation Accuracy	Control	36	67.72 (6.89)	75.81 (7.56)	8.09
Comprehension	Experimental	36	64.89 (8.15)	84.17 (6.24)	19.28
Comprehension	Control	36	65.36 (7.88)	74.61 (7.47)	9.25

As shown in Table 1, both groups began with similar pre-test scores, indicating comparable initial proficiency levels. However, by the post-test stage, the experimental group achieved substantially higher means in both recitation accuracy and comprehension. The average improvement (gain score) for recitation was more than twice that of the control group, while comprehension gains were similarly pronounced.

Inferential Statistics

a. Independent Samples t-Test (Pre-Test)

An independent samples t-test confirmed no significant differences in the pre-test scores between the two groups for both variables (Recitation: t(70) = 0.25, p = 0.80; Comprehension: t(70) = 0.28, p = 0.78). This suggests initial equivalence of the groups before the intervention.

b. Paired Samples t-Test (Within-Group Improvements)

Paired samples t-tests revealed statistically significant improvements in both groups, though the experimental group recorded larger gains.

Table 2. Paired Samples t-Test Results.

Variable	Group	Mean Difference	t	p	Effect Size (Cohen's d)
Recitation Accuracy	Experimental	17.33	11.45	<.001	1.91
Recitation Accuracy	Control	8.09	6.28	<.001	1.05
Comprehension	Experimental	19.28	13.74	<.001	2.07
Comprehension	Control	9.25	7.32	<.001	1.16

Both groups demonstrated statistically significant improvements ($p < .001$). However, the effect sizes in the experimental group (Cohen's $d = 1.91$ and 2.07) indicate a very large impact compared to the control group.

ANCOVA Results

To test the main research question, whether there was a significant difference in the improvement of Qur'anic literacy between students who used AI-driven tools and those who learned conventionally, an ANCOVA was conducted using the pre-test as the covariate.

Table 3. ANCOVA Summary for Post-Test Scores.

Dependent Variable	Source	SS	df	MS	F	p	Partial η^2
Recitation Accuracy	Pre-test (covariate)	226.42	1	226.42	4.57	0.036	0.061
	Groups	1524.87	1	1524.87	30.79	<.001	0.307
Comprehension	Pre-test (covariate)	244.91	1	244.91	5.13	0.027	0.068
	Groups	1683.25	1	1683.25	35.21	<.001	0.336

The ANCOVA results revealed a statistically significant difference between the two groups in both recitation accuracy ($F(1,69) = 30.79$, $p < .001$) and comprehension ($F(1,69) = 35.21$, $p < .001$), even after controlling for pre-test differences. The partial eta squared values ($\eta^2 = .307$ and .336) suggest large effect sizes, indicating that the AI-driven intervention accounted for over 30 percent of the variance in post-test scores.

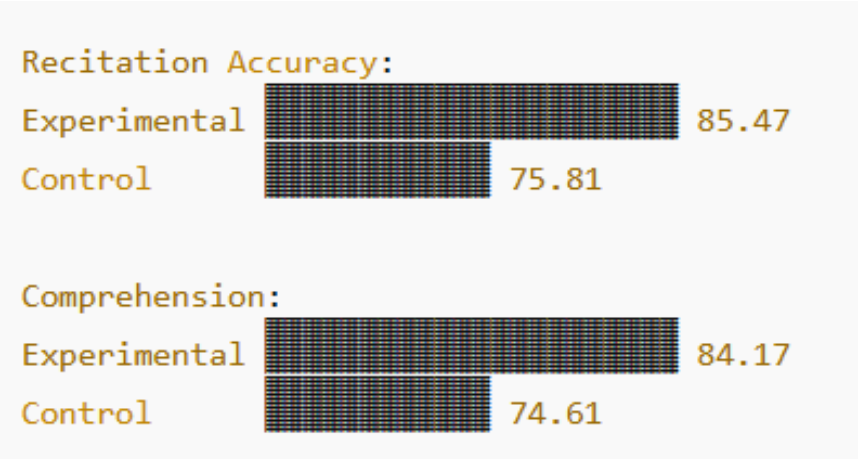

Figure 1. Comparison of Pre-Test and Post-Test Mean Scores.

Based on the described findings, the quantitative results support the conclusion that the use of AI-driven tools, specifically TajweedMate for pronunciation feedback and MyQuran.ai for comprehension and reflection, significantly enhanced both the procedural and conceptual dimensions of Qur'anic literacy (see Figure 1). Students in the experimental group not only demonstrated improved articulation and tajwīd accuracy but also reported better understanding and reflection on Qur'anic meaning. These findings affirm the dual benefit of AI-assisted

learning: providing precise corrective feedback for recitation while fostering self-regulated, meaning-focused engagement with the text.

DISCUSSION

The findings of this study provide empirical evidence that AI-driven tools, specifically TajweedMate and MyQuran.ai, significantly enhanced both the recitation and comprehension aspects of Qur'anic literacy among pre-service Islamic teachers. The improvement observed in the experimental group confirms that integrating artificial intelligence into Qur'anic education can effectively strengthen both the procedural and conceptual dimensions of literacy. These results align with the broader pedagogical argument that personalized feedback and adaptive learning technologies support more autonomous and metacognitively aware learning (Sinkkonen & Review, 2024).

The significant increase in recitation accuracy corroborates earlier findings by Prihatiningtyas et al. (2025), who demonstrated that AI-supported pronunciation tools enhance articulation and mastery of tajwīd rules. TajweedMate's feedback mechanism, based on speech recognition technology, enabled students to identify and correct pronunciation errors instantly, which is consistent with Lachheb et al. (2025), who found that AI-based recitation detection models, such as k-NN and BLSTM, achieved high precision in recognizing phonetic deviations in Qur'anic recitation. This result reinforces the argument that AI can function as a reliable digital tutor in supporting recitation accuracy and rhythm control. The large effect size in recitation improvement ($\eta^2 = .307$) shows that sustained AI-assisted feedback can provide a more consistent learning experience compared with conventional teacher-led correction, which may vary depending on instructional conditions.

Equally important is the improvement in comprehension scores, which demonstrates that AI tools can move beyond procedural correction toward facilitating deeper engagement with the meaning of Qur'anic text. MyQuran.ai, which provided reflection prompts and comprehension questions, encouraged learners to construct meaning through interactive dialogue. This finding resonates with the self-regulated learning framework (Sinkkonen & Review, 2024), where opportunities for reflection and feedback contribute to learner autonomy. The observed comprehension gains also reflect the conceptual expansion of Qur'anic literacy as proposed by Hanafi (2024), who defined literacy not only as accurate recitation but as understanding, reflection, and application of Qur'anic teachings. In this respect, the present study confirms that AI-mediated reflection can cultivate interpretive skills and personal connection with the Qur'an in ways that complement traditional tafsīr instruction.

The combined use of TajweedMate and MyQuran.ai also exemplifies how technology-enhanced learning can operationalize Vygotsky's concept of the "more capable other" in digital form. The tools functioned as scaffolding agents, supporting learners' progression from guided practice toward independent mastery. This dynamic reflects the dual structure of taʿlīm al-Qur'an, which involves both the mastery of form (qirā'ah and tajwīd) and the internalization of meaning (tafsīr and tazkiah). By integrating these two dimensions, the current study moves beyond prior works that addressed recitation or comprehension in isolation. As reported by Salim and Aditya (2025), most AI-related studies in Islamic education have been descriptive, focusing on technical development rather than educational impact. The present quasi-experimental findings contribute empirical validation by quantifying the pedagogical value of AI-driven Qur'anic learning.

Furthermore, the large effect sizes (Cohen's $d > 1.9$ for both recitation and comprehension) highlight the transformative potential of AI-based feedback when combined with reflective learning tasks. These results strengthen the view expressed by Muslimin et al. (2024) that adaptive learning environments can foster personalized, meaningful, and mindful engagement in Islamic education. The improvement in comprehension also addresses Dahia (2024) concern regarding the interpretive limitations of AI in Qur'anic studies. When used pedagogically rather than theologically, AI tools can serve as complementary supports for understanding, guiding students toward reflection rather than replacing scholarly interpretation.

The results also have contextual implications for Islamic higher education in Indonesia, where studies such as Marwa et al. (2025) identified infrastructure readiness and teacher training as barriers to effective AI integration. The present study demonstrates that even within a modest institutional setting, structured use of AI tools under guided supervision can produce measurable learning benefits. This suggests that the challenge lies not only in infrastructure but in pedagogical design and alignment with Islamic educational values. The dual-AI approach implemented in this research provided a balanced model that respects both the cognitive and spiritual aims of Qur'anic learning.

Overall, the findings fill the research gap identified in the introduction by providing quantitative evidence of how AI tools can simultaneously enhance accuracy and comprehension in Qur'anic literacy. The study extends previous qualitative observations (Batubara et al., 2024) by offering measurable outcomes through a controlled design. It also broadens the discussion on AI ethics and educational purpose, showing that technological mediation in religious learning can align with the goals of taʿlīm al-Qur'an when used thoughtfully.

From a theoretical perspective, the integration of AI in Qur'anic literacy education exemplifies the synergy between self-regulated learning theory and Islamic pedagogical principles. Immediate feedback from TajweedMate nurtured procedural self-monitoring, while reflective dialogue in MyQuran.ai promoted higher-order thinking and metacognitive awareness. This combination supported the development of autonomous learners capable of linking recitation practice with comprehension and moral application. Hence, AI-driven learning environments can be positioned as cognitive and affective partners rather than replacements for traditional pedagogy.

In conclusion, this study contributes to the growing field of AI-enhanced Islamic education by demonstrating the pedagogical efficacy of dual-AI intervention in improving Qur'anic literacy. It provides empirical validation to support curriculum innovation in teacher education programs and offers a replicable model for integrating AI ethically and effectively in Islamic higher education. Future research could expand on this work by exploring longitudinal effects, affective engagement, and the scalability of AI-driven Qur'anic learning in diverse educational contexts.

CONCLUSION

This study set out to examine whether AI-driven tools could effectively enhance Qur'anic literacy among pre-service Islamic teachers in an Indonesian higher education context. The research addressed a significant gap in the literature by empirically testing the dual dimensions of Qur'anic literacy, recitation accuracy and comprehension, through a quasi-experimental design involving TajweedMate and MyQuran.ai. The results showed that students who engaged with these AI tools demonstrated significantly greater improvement than those who learned through conventional methods. This indicates that AI technologies, when pedagogically integrated, can strengthen both the procedural and conceptual aspects of Qur'anic literacy. The findings affirm that adaptive feedback for pronunciation and reflective prompts for understanding create a dynamic learning environment that supports self-regulated and meaningful engagement with the Qur'an.

The study also highlights the potential for AI to bridge traditional Islamic learning and modern educational practices. The tools employed here did not replace human instruction but complemented it by providing individualized feedback and facilitating personal reflection. Such integration aligns with the principles of taʿlīm al-Qur'an, which emphasize both mastery of form and understanding of meaning. These results contribute empirical support to the growing field of AI-enhanced Islamic education, demonstrating that properly designed digital interventions can be harmonized with spiritual and pedagogical values.

Despite its promising results, the study has several limitations. It was conducted with a relatively small sample from a single institution, which may restrict the generalizability of the findings. The six-week intervention period also limits insights into long-term retention and transfer of learning. Additionally, while the study focused on cognitive and procedural outcomes, affective variables such as motivation and spiritual engagement were not measured in depth. Future studies should adopt larger samples, longitudinal designs, and mixed-method approaches to capture the broader pedagogical and emotional dimensions of AI-assisted Qur'anic learning.

The findings have several practical implications for curriculum developers, educators, and policymakers in Islamic higher education. Incorporating AI tools such as pronunciation tutors and comprehension assistants can enhance personalized learning and encourage autonomous engagement with the Qur'an. However, institutional readiness, teacher training, and ethical supervision must be prioritized to ensure that the use of technology remains aligned with Islamic educational principles. Pedagogical frameworks that integrate AI should emphasize reflection, authenticity, and balance between technological innovation and religious values.

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