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Artificial Intelligence in Islamic Religious Education: Enhancing Critical Thinking through AI Feedforward Feedback Models

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Abstract: Integrating the AI Feedforward Feedback (AI-FF) Model into Islamic Religious Education to Enhance Students' Critical Thinking Skills. This study aims to analyze the effectiveness of the AI-FF model in enhancing the critical thinking skills of Islamic Religious Education students, explore students' and lecturers' experiences during implementation, and evaluate the extent to which AI integration can be applied without diminishing teachers' moral and spiritual roles. A mixed-method approach was employed. Quantitative data were gathered through a quasi-experimental pretest–posttest design, while qualitative data were collected through in-depth interviews and structured observations. Statistical analyses were used to determine the model's effectiveness, and thematic analysis was applied to interpret learning experiences. The findings demonstrate that AI-FF effectively improves students' critical thinking skills, especially in analysis, argument evaluation, and metacognitive reflection. Qualitative results indicate that AI-FF provides cognitive scaffolding without replacing the teacher's moral guidance. Students reported improved confidence and more structured reasoning, while lecturers perceived AI as an augmentative tool. AI-FF can be ethically integrated into Islamic Religious Education when positioned as a supportive tool that strengthens cognitive processes while preserving the teacher's authority in moral and spiritual guidance. The study highlights the need for educators to develop AI ethics literacy and for integration models that maintain teacher primacy while leveraging AI as a cognitive facilitator.

Keywords: AI feedforward feedback, critical thinking, islamic religious education, AI ethics, technology-enhanced learning.

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INTRODUCTION

The use of Artificial Intelligence (AI) in Islamic Religious Education (Pendidikan Agama Islam, or PAI) in recent years has opened new opportunities to address long-standing challenges. Rather than radically reforming the education system with new technologies, AI applied in this context may help address low levels of Aqidah and Akhlak engagement among students, the lack of personalization in instruction, and the difficulty in diagnosing higher-order thinking skills in teachers. For example, it has recently been shown that AI-based learning systems enable adaptable teaching, facilitating students' learning of religious concepts at their own pace and with prompt feedback (Khalidi et al., 2025). Consequently, the role of AI in PAI education must be recognized not just as a technological intervention but as a pedagogical innovation designed to improve students' motivation, critical thinking, and ethical development by helping to individualize this learning field within Islamic education.

The advancement of Artificial Intelligence (AI) in the last decade has significantly transformed numerous educational areas, especially PAI. Multiple studies indicate that AI holds considerable promise for tailoring education, enhancing motivation, and reinforcing

cognitive processes that facilitate students' critical thinking (Abubakari et al., 2024; Nasir et al., 2025). In the realm of religious education, numer ous AI-driven applications have been employed to facilitate Quran memorization, comprehension of Islamic jurisprudence (fiqh), examination of religious texts, and learning evaluations through adaptive learning and immediate feedback (Suazo-Galdames & Chaple-Gil, 2025). Additional studies substantiate that AI has transcended its role as a mere tool and is evolving into a collaborative co-agent, fostering a supportive learning environment that promotes higher-order thinking (Katsenou et al., 2025).

In the domain of PAI, enhancing critical thinking skills is crucial, as religious instruction aims not only to disseminate knowledge but also to foster students' capacity to analyze, assess, and contextually apply Islamic ideals. AI-driven learning models, such as feedforward feedback models, offer significant potential by delivering predictive feedback to enhance future performance rather than merely assessing past outcomes. Research by Dann et al. (2024) substantiates that well-crafted AI models can enhance cognitive, affective, and psychomotor domains in Islamic education. Moreover, the incorporation of AI into PAI has not led to substantial improvements in learning outcomes compared with conventional lecture-based approaches (Ningsih et al., 2025).

Nonetheless, the implementation of AI in religious education presents ethical, technological, and pedagogical problems. Numerous studies underscore the possibility of algorithmic bias, the danger of theological divergence, and the constraints of AI in delivering moral and emotional guidance, which are fundamental to Islamic education (Papakostas, 2025). Infrastructure challenges and the technical precision of classical Arabic continue to pose significant barriers to the advancement of AI-driven Quran learning systems (Wedi et al., 2025). Moreover, apprehensions about overreliance on AI, which could undermine students' critical thinking abilities, have drawn the attention of cognitive scientists (Kumar et al., 2023). These results indicate the significance of a hybrid integration model between AI and educators, alongside the enhancement of teacher competences to empower them to employ AI critically, ethically, and successfully (Siregar et al., 2025).

Despite rapid advances in research on the incorporation of Artificial Intelligence (AI) into PAI, numerous gaps persist. Prior research has predominantly focused on the application of AI in Quran memorization, Islamic jurisprudence (*fiqh*) education, and adaptive learning systems (Al-Zahrani, 2024). However, limited investigations have explored the potential of AI feedforward feedback models to enhance critical thinking abilities among students in PAI. Moreover, current studies predominantly regard AI as a technological instrument, rather than as a pedagogical collaborator that fosters introspection, ethical reasoning, and discourse on Islamic principles(Bearman & Ajjawi, 2023; Steinert et al., 2024; Zhang & Zhang, 2024) Literature reveals contradictory findings concerning the efficacy of AI in enhancing higher-order cognitive skills, and practical studies contrasting AI with traditional learning methods in fostering critical thinking remain few (Ningsih et al., 2025). Conversely, matters concerning the incorporation of Islamic values, algorithmic bias, and AI ethics have yet to be articulated within a definitive pedagogical framework, despite numerous studies emphasizing the dangers of data bias and the difficulties in AI's interpretation of religious language (Ifenthaler et al., 2024; Rojas & Chiappe, 2024; Ruwe & Kuklick, 2025). Consequently, empirical and pedagogical research is required to investigate how AI feedforward feedback models can facilitate the enhancement of critical thinking in religious education while ensuring adherence to Islamic ideals.

The novelty of this study lies in the empirical examination of how AI-based feedforward feedback can be systematically integrated into PAI, thereby enhancing students' critical thinking and moral reasoning. Unlike other research (e.g., Al-Zahrani, 2024) that predominantly used AI merely as a technology tool for content delivery or memorization tasks, this study conceptualizes AI as an engaging pedagogical assistant in the context of Islamic education. More specifically, the current study views feedforward feedback as a formative activity to inspire reflection on students' learning processes, encouraging them to reflect on this type of input in an ethical manner that continuously promotes development in alignment with Islamic values. Theoretically, this study contributes by integrating constructivist learning theory and Islamic pedagogy, presenting AI's mediating role in reflection and learning dialogues without compromising religious authenticity. For Islamic teachers and course designers, this research provides a framework for responsible AI practices that increases students' analytical and moral engagement while maintaining ethical integrity and spiritual depth. By combining technology with moral pedagogy, the present research contributes to the reconstruction of 21st-century Islamic Religious Education into an education that integrates intellect and ethics: intelligent and ethical, yet spiritually rigorous. Based on this background, this study aims to:

1. Analyze the effectiveness of the AI feedforward feedback model in improving critical thinking skills in Islamic Religious Education students.
2. Explore the experiences of students and teachers in using the AI model,
3. Evaluate the extent to which AI integration can be implemented without diminishing the role of teachers as moral and spiritual educators.

In line with these objectives, this study formulates the following research questions:

1. How effective is the AI feedforward feedback model in improving critical thinking skills in Islamic Religious Education students compared to traditional learning methods?
2. How do students and teachers interpret the AI-based learning process, particularly in the context of developing critical reasoning and Islamic values?
3. What is the ethical and balanced form of AI pedagogical integration in Islamic Religious Education learning?

By formulating these questions, this study makes theoretical and practical contributions to the development of an AI-based pedagogical framework for Islamic religious education, while also offering an innovative learning model that can address the needs of 21st-century education without neglecting the principles of values, morality, and spirituality.

METHOD

Type of Research

This study used a quantitative approach with a mix-method design. The aim was to test the effectiveness of the AI Feedforward Feedback Model in improving critical thinking skills in PAI students. A non-equivalent control group design was used to compare learning outcomes between the experimental group using the AI-based feedforward feedback model and the control group using conventional learning methods. This approach was chosen because it allowed researchers to evaluate the impact of the AI intervention in a real classroom context while maintaining control over relevant variables.

Research Timeline and Location

The study was conducted over three months, from February to April 2025, at a State Islamic Senior High School (Madrasah Aliyah) in Riau Province that had implemented digital learning technology. The school selected based on its readiness for digital infrastructure and the availability of classes that met the research criteria.

Research Subjects

The study subjects included 80 grade XI PAI students. The study sample was determined using a purposive sampling technique, taking into account equivalence in academic ability across classes and the availability of digital devices. Two classes were selected as samples: one class as the experimental group (n=40) and one class as the control group (n=40). The sample composition was designed to be relatively homogeneous in terms of age, religious education background, and access to digital devices, to minimize bias.

All participants had sufficient access to digital learning devices primarily Android smartphones and demonstrated familiarity with basic educational applications. To avoid sampling bias and improve comparability among the participants, this homogeneity in terms of age, religious education background, and digital accessibility was intentionally maintained. The data for the study were collected using a purposive sampling method, which is considered appropriate given the specific inclusion criteria. The participants were determined by considering the following:

Table 1. Demographic characteristics of participants (N = 80)

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	36	45
	Female	44	55
Age Range	16 years	32	40
	17 years	48	60
Previous Education Background	Islamic Junior High (Madrasah)	70	87.5
	General Junior High	10	12.5
Access to Digital Device	Android Smartphone	80	100

They were Grade XI students enrolled in the PAI (Islamic Religious Education) class. They possessed Android smartphones capable of supporting the AI-based learning intervention employed in the study. They had adequate digital literacy skills to engage effectively in technology-integrated learning activities. Because not all students in the population met the technological access requirement, random sampling was not possible. Using this purposive sampling approach, only those with full capacity to participate in AI-assisted feedback tools were selected to enhance the study's internal validity. Although the results of this study may not be generalizable, this sampling approach was suitable as the study was designed to evaluate AI-assisted feedback in a digitally mediated Islamic education context.

Research Procedure

The research procedure was conducted in three stages. First, the preparation phase, which included preparing learning materials, developing an AI feedforward feedback module, conducting instrument trials, and training the teachers involved. Second, the intervention implementation phase lasted six meetings, in which the experimental group received AI-based learning that provided predictive feedback and recommendations for improvement before assignments were submitted. In contrast, the control group participated in PAI learning using lectures, discussions, and written exercises without AI assistance. Third, the evaluation phase involved administering a post-intervention critical thinking test, collecting AI interaction log data, and observing the learning process in both groups.

Research Instruments

Instrumental critical thinking is the active process of analyzing, evaluating, and reflecting on information to reach reasonable and ethical judgments. He insists that critical thought is not simply a cognitive capacity but a moral and reflective consciousness of one's own thinking processes (Fisher, 2011). In reference to designing a critical thinking tool, Fisher's model is solid and theoretical at the juncture of logical analysis, evidence assessment, conclusion drawing, and ethical decision-making responsibility. The five domains: Problem Clarification, Argument Analysis, Evaluation of Evidence, Inference, and Reflection & Ethical Decision-Making, comprehensively represent the stages of critical thinking.

The instrument is based on Fisher's (2011) critical thinking framework to enable assessment of five main domains: Problem Clarification, Argument Analysis, Evaluation of Evidence and Values, Inference and Drawing Conclusions, and Reflection and Ethical Decision-Making. It comprises 20 items that represent the key indicators of critical thinking skills in the PAI domain and is designed to assess students' ability to think critically about the issue at hand.

The first of these domains, Problem Clarification, focuses on the ability to understand and interpret problems clearly. Students identify the major problem in a situation, decompose it into elements, and explain the purpose of the analysis. For example, a prompt might ask students to determine the main issue in a sample text about students' low involvement in religious learning or to enumerate the factors leading to a lack of interest in Qur'an memorization.

The second part, Argument Analysis, assesses students' ability to scrutinize assumptions, connect evidence to arguments, organize rational thought, and develop inductive reasoning. For example, students could examine the implicit condition behind the statement "Obedience to parents guarantees success" or determine whether an argument uses a deductive model of reasoning. The third domain, Evaluation of Evidence and Values, assesses one's judgment of the power, relevance, and ethical aspects of an argument. Students will determine the legitimacy of Islamic claims (dalil), assess the strength of the evidence supporting them, and identify bias, such as values in texts or biases related to gender and/or moral subjects.

The fourth domain, Inference and Drawing Conclusions, assesses the capacity to reach logical conclusions, propose alternative interpretations, and make well-reasoned recommendations. Consider that students might decide Qur'an reading is beneficial for their ethical behavior, or suggest digital tools to support an interactive approach to learning the Qur'an. Lastly, we reflect on ourselves and make ethical decisions by exploring how our choices may reflect our ethical views, reasoning about our choices through Islamic constructs of ijtihad and maqâcid al-sharî'ah, and demonstrating self-regulation.

The sample items encourage students to consider the ethics of employing AI in Islamic education or to try to improve their reasoning in light of its weaknesses. In summary, the study has fully incorporated the cognitive and ethical aspects of critical thinking and has correlated the logical analysis with Islamic values. These methods assess not only students' reasoning skills but also their reflective awareness and ethical responsibility to engage in critical thinking in religious and educational settings.

The main instruments in this study included a critical thinking ability test based on Fisher's model indicators, adapted to the context of Islamic Religious Education; observation sheets of student learning activities; and recordings of AI-generated feedback. The critical thinking test was developed based on indicators of analysis, evaluation, interpretation, and reflection, with

content validation through expert judgment by three Islamic Education lecturers and an educational technology expert. The instrument's reliability was assessed using Cronbach's Alpha in a pilot test with 30 students outside the research sample.

Table 2. Validity and reliability test results of the critical thinking instrument (n = 30)

Indicator (n items)	Sub-Indicator / Item	r item–total	Validity	Cronbach's α (indicator)
A. Problem Clarification (20 Items)	A1. Identifying the main problem statement	0.68	Valid	α = 0.82
	A2. Breaking down components of the problem	0.59	Valid	
	A3. Formulating clear analytical goals	0.54	Valid	
B. Argument Analysis (20 Items)	B1. Identifying assumptions within religious texts	0.71	Valid	α = 0.85
	B2. Linking evidence to claims	0.63	Valid	
	B3. Explaining the reasoning structure in a text	0.57	Valid	
C. Evaluation of Evidence & Values (20 Items)	C1. Assessing the strength of the evidence	0.62	Valid	α = 0.78
	C2. Evaluating the relevance of Islamic arguments/dalil	0.48	Valid	
	C3. Identifying potential value-based bias in a text	0.42	Valid	
D. Inference & Drawing Conclusions (20 Items)	D1. Formulating logical conclusions from data/text	0.66	Valid	α = 0.80
	D2. Presenting plausible alternative interpretations	0.55	Valid	
	D3. Using premises to formulate recommendations	0.45	Valid	
E. Reflection & Ethical Decision-Making (20 Items)	E1. Reflecting on the moral implications of an argument	0.59	Valid	α = 0.76
	E2. Linking reasoning with Islamic principles (ijtihad, maqāṣid)	0.72	Valid	
	E3. Demonstrating self-regulation and improvement planning	0.61	Valid	
TOTAL				Cronbach's α total = 0.91

All items were found to be valid, with 100 items showing a correlation coefficient of r e" 0.30, thereby meeting the validity criteria. The Cronbach's á values each indicator ranged from 0.76 to 0.85, indicating adequate good reliability.

Data Collection Techniques

Data were collected using several techniques: (1) a critical thinking ability test to measure students' cognitive achievement before and after the intervention, (2) recordings of AI interactions to examine the quality of feedback provided, (3) observations of the learning process to assess classroom dynamics, and (4) documentation of student learning activities. All data were collected systematically following established learning procedures.

Data Analysis Techniques

Data analysis was conducted using the Analysis of Covariance (ANCOVA) test to examine differences in critical thinking ability

between the experimental and control groups, controlling for pretest scores. This technique was chosen because it is effective for analyzing the intervention's effects while accounting for students' baseline variables. Additionally, qualitative data from observations and AI logs were analyzed descriptively to provide context for the quantitative results. Interpretation of the analysis results is carried out by linking the findings to the problem formulation and research objectives, and by ensuring that the conclusions drawn are relevant to the effectiveness of the AI feedforward-feedback model in developing critical thinking skills among Islamic Education students. The report includes a detailed account of the assumption tests, particularly the homogeneity of regression slopes. Reporting the results of these assumption checks is essential to ensure the validity of the ANCOVA findings, as violations could compromise the accuracy and interpretability of the results.

■ RESULT AND DISCUSSION

This section presents comprehensive research results to answer the three main objectives of the study, namely: (1) analyzing the effectiveness of the AI Feedforward Feedback (AI-FF) model in improving the critical thinking skills of Islamic Religious Education students, (2) exploring the experiences of students and lecturers during the implementation of the model, and (3) evaluating the extent to which AI integration can be implemented without reducing the role of teachers as moral and spiritual educators.

Quantitative results are presented through pretest–posttest analyses and ANCOVA tests to determine differences in critical thinking skills between groups, with initial-value controls. Meanwhile, qualitative data are analyzed using thematic analysis to explore the dynamics of user experience, the quality of AI feedback, and the alignment of technology with Islamic pedagogical values. The integration of these two data sources provides a comprehensive picture of the pedagogical effectiveness, user acceptance, and ethical implications of AI use in religious learning.

Effectiveness of the AI Feedforward Feedback Model in Improving Critical Thinking Skills

Quantitative Analysis Results

Before performing any main statistical analyses, assumption tests were conducted to confirm that the data met the assumptions of parametric testing. More precisely, assumptions concerning normality and homogeneity of variance were scrutinized. The Shapiro–Wilk test was used to test for normal distribution, while Levene's Test was used to test for equality of variances between groups. The results of both tests are listed in Tables 3 and 4. Based on the Shapiro–Wilk test results, the Sig. The values for both groups are greater than 0.05, indicating that the posttest data are normally distributed.

Table 3. Tests of normality (shapiro–wilk test)

Group	Statistic	df	Sig.
AI-FF Group (Posttest)	0.972	40	0.325
Traditional Learning Group (Posttest)	0.968	40	0.284

Table 4. Test of homogeneity of variances (levene's test)

Levene Statistic	df1	df2	Sig.
0.742	1	78	0.392

The Sig. value of 0.392 (> 0.05) indicates that the variances between the two groups are homogeneous, thus fulfilling the assumption of homogeneity. Both assumption tests indicated that the data met the requirements for parametric analysis. Shapiro–Wilk test results indicated that the distributions of posttest scores were normal in both groups, as reflected by p-values greater than 0.05. Similarly, Levene's Test indicated that the variances between the experimental and control groups were homogeneous ($p > 0.05$). These results indicate that the dataset meets the statistical requirements for further analysis using parametric tests, namely the Independent Samples t-test and Paired Samples t-test. Therefore, the statistics obtained from the follow-up analyses are statistically valid and reliable.

This study aims to assess the effectiveness of the AI Feedforward Feedback (AI-FF) model in improving the critical thinking skills of PAI students compared to traditional lecture- and assignment-based learning. The study used a pretest–posttest control-group design, in which both groups received a critical thinking test before (pretest) and after (posttest) the treatment. The experimental group received an intervention of AI-generated feedforward feedback at each stage of completing the analytical task, while the control group learned without AI intervention.

Table 5. Results of pretest and posttest of critical thinking skills (N = 80)

Group	N	Pretest Mean (SD)	Posttest Mean (SD)	Mean Gain	t-value	p-value	Cohen's d	Interpretation
AI-FF Group (Experimental)	40	67.45 (5.92)	85.32 (5.78)	17.87	12.14	< 0.001	1.6	Large effect
Traditional Learning Group (control)	40	66.88 (6.05)	73.54 (6.72)	6.66	4.55	< 0.05	0.7	Moderate effect
Between Groups (Posttest)	80				7.21	< 0.001		Significant difference

Statistical results indicate that the implementation of AI-FF had a significantly greater impact on improving critical thinking skills. As shown in Table 5, the experimental group increased their mean score from 67.45 in the pretest to 85.32 in the posttest (gain = +17.87). Meanwhile, the control group only experienced an increase in mean score from 66.88 to 73.54 (gain = +6.66). These findings indicate that students who received prospective, specific, and targeted AI feedback demonstrated greater development of analytical skills than those who received only traditional instruction.

Student data analysis shows a statistically significant difference in learning trajectories among students exposed to AI-FF and in traditional instruction. Instead of merely making small changes, the AI-FF intervention seems to have acted as a catalyst, accelerating the development of students' critical thinking skills. This suggests that prospective, specific, and targeted feedback can help learners engage more with metacognitive tasks, e.g., evaluating reasoning, identifying logical gaps, and refining arguments. Conversely, the relatively modest improvement in the control group suggests that conventional teaching approaches support surface-level understanding but are less effective at promoting higher-order cognitive development. Together, the results reinforce the pedagogical merit of AI-FF as a feedback strategy that moves beyond information delivery toward sustained cognitive transformation.

A paired-sample t-test confirmed that the improvement in the AI-FF group was highly significant ($t = 12.14$, $p < 0.001$), with a Cohen's

d effect size of 1.60, categorized as a large effect. This indicates that AI-FF's contribution to the development of critical thinking is not only statistically significant but also pedagogically substantial. In contrast, the control group showed significant improvement, though with a moderate effect size ($t = 4.55$, $p < 0.05$, $d = 0.70$), indicating that traditional learning still had an impact, albeit much smaller.

Furthermore, a test of group differences in posttest scores revealed a significant difference ($t = 7.21$, $p < 0.001$), indicating that AI-FF was more effective than traditional learning in improving students' critical thinking skills in Islamic Religious Education.

The indicator-based analysis provides a richer picture of how the AI-Feedforward (AI-FF) model uniquely fosters particular aspects of

Table 6. Effectiveness of the AI-FF model on each indicator of critical thinking

Critical Thinking	Pretest Mean (SD)	Posttest Mean (SD)	Mean Gain	t-value	p-value
A. Problem Clarification	66.82 (6.10)	84.91 (5.84)	18.09	11.85	< 0.001
B. Argument Analysis	67.13 (5.94)	85.46 (5.79)	18.33	12.26	< 0.001
C. Evaluation of Evidence & Values	67.78 (6.02)	85.01 (5.67)	17.23	11.94	< 0.001
D. Inference & Drawing Conclusions	67.24 (5.88)	85.68 (5.74)	18.44	12.38	< 0.001
E. Reflection & Ethical Decision-Making	68.28 (5.67)	85.52 (5.86)	17.24	12.09	< 0.001
Overall Critical Thinking (Aggregate)	67.45 (5.92)	85.32 (5.78)	17.87	12.14	< 0.001

critical thinking. A significant uplift in the Inference & Drawing Conclusions domain (Mean Gain = 18.44; $t = 12.38$; $p < 0.001$) indicates that AI-FF can indeed improve students' logical reasoning and inferential judgments. This finding indicates that the feedforward mechanism promotes foresight and constructiveness rather than retrospective feedback, thereby enhancing learners' ability to anticipate future consequences, connect evidence to claims, and reason.

The inference encompasses the top of the critical reasoning cascade and entails all prior cognitive work; accordingly, this improvement in this domain indicates a holistic improvement in students' higher-order thinking. Considerable progress was also made in Argument Analysis and Problem Clarification, demonstrating that AI-FF supports students in analyzing the argumentative stance, specifying assumptions, and forming a clear problem statement. Such gains might result from the model's iterative nature, which prompts students to reconsider their reasoning methods during task assignment. The programmed AI prompts seem to encourage metacognitive awareness and analytical precision, which are important components of critical discourse and academic reasoning.

The Evaluation of Evidence & Values and Reflection & Ethical Decision-Making domains also greatly improved, though slightly lower than inferential and analytical skills. This suggests that although AI-FF is effective for improving cognitive reasoning, its impact on moral and ethical reflection is more indirect.

Improving student learning outcomes is currently one of the main research topics of the 20th century; in this case, instructional practices that actively integrate higher-order thinking skills in students are the focus. For example, traditional teacher-centered approaches can be successful for content-oriented instruction. However, in practice, they don't typically guarantee the most

effective way to engage students or help them understand the material. It is for this reason that experimental work contrasting traditional teaching with innovative, student-centered interventions has received greater attention in academic discourse. Within this environment, the current study tests the efficacy of an experimental approach to teaching by analyzing posttest performance differences between the control and experimental groups, using learning achievement as an indicator of the instruction's impact. The comparison of posttest scores between control and experimental groups is presented in Figure 1.

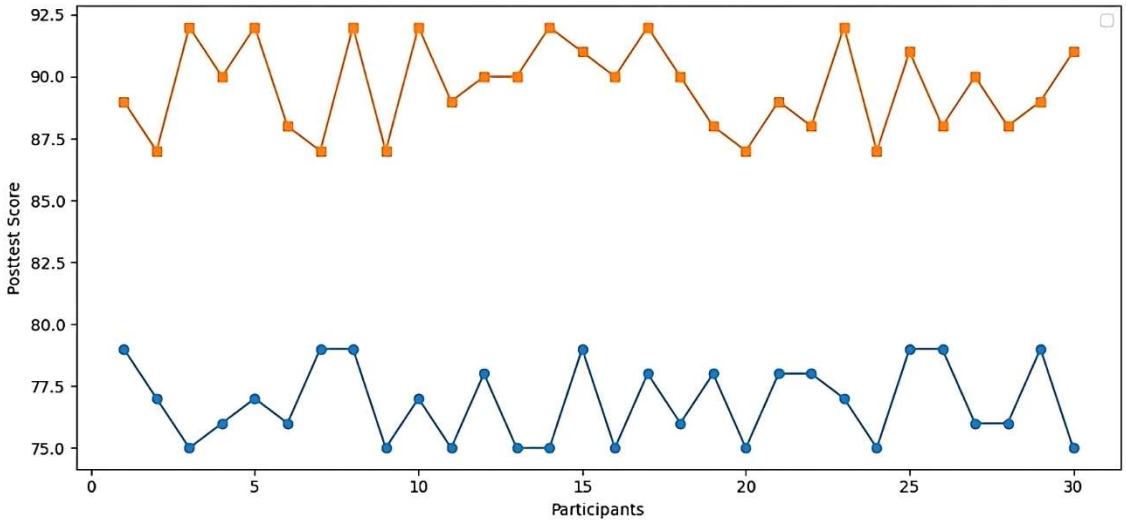

Figure 1. Comparison of posttest scores between control and experimental groups

Overall, the findings indicate that students in the experimental group consistently achieved higher posttest scores than those in the control group, demonstrating the effectiveness of the instructional device. These findings indicate that learning structures that support activities and structured interaction can positively impact students' success. The study adds to a growing body of empirical evidence supporting new pedagogical approaches in educational contexts. Further research is warranted to investigate these interventions in the long term and their generalizability to alternative educational settings and content.

ANCOVA Analysis Results

To ensure that the posttest differences were truly due to the AI-FF intervention, and not to variations in students' baseline abilities, an ANCOVA was conducted with the pretest as a covariate. The ANCOVA results are shown in Table 7.

Table 7. ANCOVA results for critical thinking skills by learning group

Source of Variation	SS	df	MS	F	p-value	η^2	Interpretation
Pretest (Covariate)	512	1	512.46	9.82	0.003	0.11	The covariate significantly influences the outcome
Group (AI-FF vs. Traditional)	768	1	768.21	14.73	< 0.001	0.19	Strong and significant effect
Error	3248	77	42.18				
Total	4528	80					

The ANCOVA test results showed F(1, 77) = 14.73, p < 0.001, confirming a statistically significant difference in posttest scores between the AI Feedforward Feedback group and the traditional learning group, after controlling for pretest scores. This finding indicates that the improvement in critical thinking skills was significantly influenced by the AI-FF model, rather than by variations in students' initial abilities. In addition, the effect size ç² = 0.19 indicates a strong effect, accounting for approximately 19% of the variance in improvement in critical thinking skills. The covariate (pretest score) also made a significant contribution (p = 0.003), confirming that ANCOVA is appropriate for analyzing group differences and that controlling for initial abilities is necessary to produce more accurate interpretations. The distribution of pretest and posttest scores in experimental and control group is presented in Figure 2.

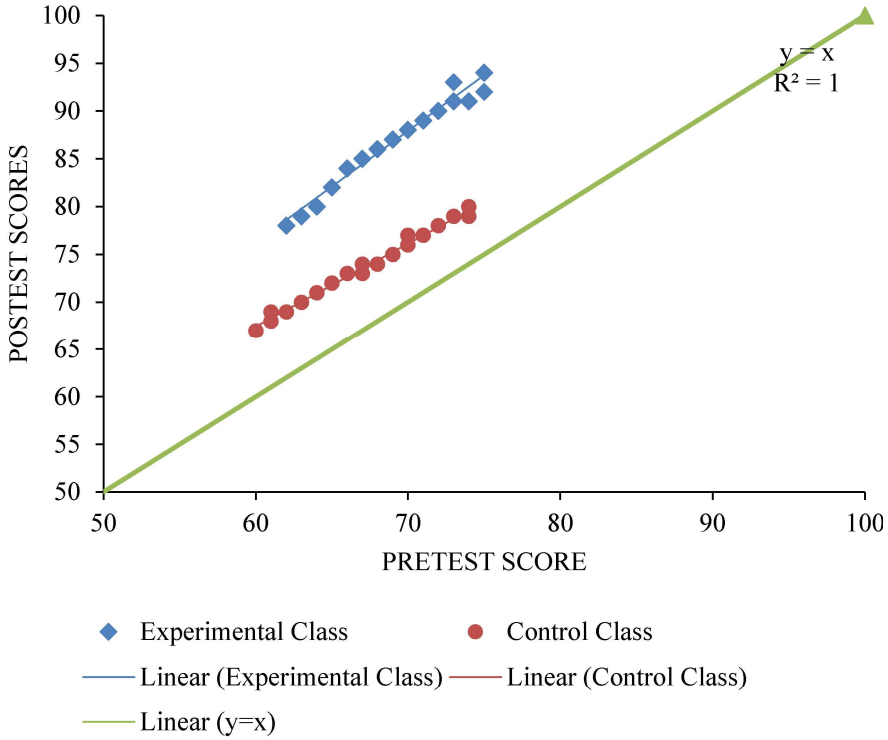

Figure 2. Distribution of pretest and posttest scores

Several recent studies confirm that artificial intelligence can strengthen higher-order thinking skills through a feed-forward mechanism, helping students predict and correct errors before they occur. For example, a study by Liu et al. (2025) showed that forward-looking AI-based feedback can improve analytical reasoning and self-regulated learning. They found that students who received feedback demonstrated a more systematic argument structure than those who received only conventional feedback.

This finding also parallels research by Li et al. (2024), which reported that AI anticipatory guidance can strengthen students' argument construction in academic writing contexts. This occurs because AI not only corrects errors after they occur but also identifies potential weaknesses early, enabling students to modify their thinking processes. This principle aligns with the characteristics of AI-FF found in this study.

From an educational theory perspective, the effectiveness of AI-FF can be understood within

Vygotsky's social constructivism framework, specifically the concept of the zone of proximal development (ZPD). According to Vygotsky, the most effective learning occurs when students receive scaffolding from more experienced individuals to achieve higher levels of ability(Afzaal et al., 2024). In the digital era, Weng et al.'s (2024) research found that AI systems can function as more capable peers, providing adaptive and consistent cognitive assistance. This strengthens AI-FF's position as a metacognitive scaffolding that helps students organize logic, refine argumentative flow, and independently evaluate propositions.

From a Vygotskian perspective, AI-FF is not just a technological tool; it can be better understood as a dynamic scaffolding agent that occurs in students' own zones of proximal development (ZPD). With complex PAI critical-thinking tasks (e.g., ethical reasoning, Qur'anic interpretation, socio-religious problem analysis), students frequently find difficulty not because of incomplete information about the content presented, but because of challenges in structuring arguments and aligning evidence with Islamic principles alongside competing moral positions. AI-FF bridges this gap as it offers immediate task-oriented signals that allow learners to engage in successive rounds of cognitive exercises such as (1) clarifying assumptions, (2) identifying logical inconsistencies, and (3) refining evaluative judgments. Unlike static instructional support, AI-FF adjusts feedback to reflect where students are in their output, thereby maintaining cognitive challenge while preventing overload. This adaptive feedback operates as contingent scaffolding: students benefit from expanded support when they approach the edge of their proficiency and are less likely to need it as they gain more autonomy in their reasoning. Consequently, AI-FF facilitates learners' self-study of analytical frameworks typically modeled by expert instructors, enabling autonomous critical inquiry in the absence of external guidance. AI-FF here does not simply function as a "more capable peer" in the ZPD framework; rather, AI-FF serves as a metacognitive mediator of doctrinal understanding and higher-order moral reasoning in Islamic education.

In the context of Islamic Religious Education, critical thinking has more complex dimensions than in other fields. Critical thinking in Islamic Religious Education encompasses the ability to understand Quranic and Hadith arguments, assess the authority of scholars, apply the maqâcid al-syarî'ah (the principles of Islamic law), and relate Islamic ethical values to contemporary phenomena. Siregar et al.'s (2025) research confirms that Islamic Religious Education learning requires a model that encourages the analysis of arguments rather than simply the repetition of text. Thus, the findings of this study extend conclusions by demonstrating that AI-FF provides a scaffolding pattern that is not only logical but also supports ethical-religious reasoning.

Several other studies also support this argument. The study by Sailer et al. (2021) revealed that AI-based scaffolding significantly improved evaluation and synthesis skills. Meanwhile, Zheng and Wang (2023) confirmed that feedforward guidance increased the depth of argumentation in academic discussions. This pattern appears similar to the effectiveness of AI-FF found in this study.

Thus, a review of previous literature demonstrates that improvements in critical thinking through AI-FF are not a unique phenomenon. These improvements are supported by a broad international research base across general pedagogy and educational technology studies. This study makes a novel contribution by placing AI-FF in the context of Islamic Education (PAI), a field rarely explored by AI-based research, yet in dire need of approaches that balance cognitive and moral aspects.

This is consistent with prior research (e.g., Al-Zahrani, 2024) that highlighted that algorithmic

scaffolding tends to favour logical and evidential reasoning before addressing the affective-moral facets of decision making. However, the upward trend across all five indicators underscores that AI-FF encourages an integrative style of critical thinking where analytical rigor, logical inference, and reflective judgment coalesce into a complete cognitive skill set. Hence, in conclusion, the analysis of each indicator highlights that the AI-Feedforward model's greatest strength is in strengthening students' inferential and analytical reasoning while adding meaningful reflection and ethical dimensions. These findings support AI-FF as a transformative approach to instruction, capable of promoting critical thinking and the cognitive and moral-intellectual components.

Research claims based solely on context are unlikely to be sufficient in the face of research and policy. Therefore, we have arranged a discussion to dispel the explicit claim that novelty lies solely in introducing AI-FF into Islamic Education (PAI). Instead, we have beefed up the dialogue by emphasizing the philosophical and pedagogical contributions of this research, particularly by explaining how AI-FF operates differently in knowledge systems characterized by revealed sources, normative authority, and moral reasoning.

The updated discussion focuses on AI-FF as a mediator of epistemic tensions between authoritative religious knowledge and student-driven intellectual inquiry. It serves as a conceptual extension of AI-mediated feedback across value-laden educational contexts. Instead, this research provides a more subtle theoretical insight into how AI-based feedforward feedback operates in systems rooted in revealed knowledge, normative authority, and moral responsibility, where novelty lies less in the contextualized use of AI-FF in Islamic Education than in other settings. PAI, in contrast to general pedagogical domains where critical thinking is primarily epistemic and procedural, requires learners to interpret the text in a manner consistent with authoritative sources (i.e., the Qur'an, Hadith, and established scholarly consensus [ijma¿]). The results support the notion that AI-FF does not substitute or undermine the effectiveness of a particular epistemic source; that is, it is a mediating instrument that facilitates the analytical involvement of the students in a form of critical engagement with the religious text by structuring their argumentation, providing ethical justification, and encouraging reflective evaluation while retaining the integrity of the doctrinal space. This interplay unveils a unique model of bounded critical thinking in which analytical autonomy evolves in relation to specified theological parameters. In theory, this extends AI-feedback literature by showing that AI-FF can be adopted for value-driven, authority-related educational contexts without compromising epistemic legitimacy. Methodologically, the study contributes to this body of work by conceptualizing critical thinking within PAI as the interaction between cognitive analysis and moral reasoning, thereby providing a framework for future analysis in normatively grounded fields such as ethics, law, and religion.

Student and Teacher Experiences in Using the AI Feedforward Feedback (AI-FF) Model

The qualitative analysis in this study used a thematic analysis approach based on the six stages outlined by Braun & Clarke (2021): data familiarization, initial coding, theme formation, theme review, theme naming, and interpretation. Six students (S1–S6) and two Islamic Education teachers (G1–G2) were interviewed in depth to broadly explore how the AI Feedforward Feedback (AI-FF) model is used, perceived, and experienced in the context of PAI learning. The coding and in-depth analysis yielded three main themes: AI as a thinking partner, AI as a tool for integrating Islamic values, and ethical boundaries and the risks of dependency. This section presents a comprehensive narrative of the findings,

accompanied by verbatim quotes from the participants.

The qualitative data were analyzed using reflexive thematic analysis, following the six-phase framework proposed by Braun & Clarke (2021), which includes data familiarization, initial coding, theme construction, theme review, theme definition and naming, and interpretation. To improve analytical rigour and inter-rater reliability, two authors independently coded the interview transcripts using an inductive procedure. They subsequently proceeded to iterative comparison sessions, analyzing coding discrepancies, refining code definitions, and reaching consensus on emerging themes. Inter-coder agreement was examined at a preliminary coding phase, yielding a high level of consistency and thus bolstering the credibility of the coding framework. Any remaining disagreements were resolved through reflective discussion, ensuring that the final themes reflect the participants' views rather than the researchers' biases. This collaborative and reflexive method serves as the basis for best practice in maintaining trustworthiness in qualitative educational research.

AI as a Cognitive Companion

One of the most consistent findings from the interviews was students' perception of the AI-FF as a thinking partner that provided instant cognitive support without judgment. Most students stated that the AI †provided a safe space for them to test ideas, examine arguments, and correct errors without feeling embarrassed or fearing being perceived as incompetent. Although participants' descriptions of AI-FF as a "personal tutor" underscore AI's role in decreasing anxiety and enhancing confidence, this sense of psychological safety deserves scrutiny. A lack of social judgment and emotional risk can invite repeated practice and self-disclosure, but extended exposure to such a secure feedback environment may reduce students' resilience to direct critique, particularly when it occurs in a classroom or professional setting. Excessive insulation from interpersonal feedback may limit students' ability to negotiate alternative points of view constructively, given the scholarly tradition's emphasis on dialogical engagement and respectful disagreement, such as *adab al-ikhtilâf*. Thus, AI-FF should be viewed as a preparatory scaffold to support early-stage confidence and cognitive rehearsal, and not a permanent substitute for human-mediated discourse. The gradual infusion of peer and instructor feedback following AI-supported practice may ensure that they hone not only critical reasoning skills, but also socio-emotional abilities required for authentic intellectual exchange. Student S4, who was previously known to be passive in class discussions, revealed how the AI-FF changed the way he expressed his opinions:

"*The AI is like a personal tutor. I can repeat things without feeling embarrassed. I feel more confident practicing before speaking in class*." (S4)

This statement demonstrates that the AI provides a private practice space that helps students build self-efficacy before participating in class forums. Another student, S3, highlighted how the AI not only points out errors but also explains why they occurred:

"*The AI doesn't just say I'm wrong, but shows me how to correct them. It then gives me reasons why my argument is weak."* (S3)

This demonstrates the AI-FF's function as metacognitive scaffolding, providing a structure for thinking that helps students assess the quality of their arguments. Student S1 expressed a similar experience, particularly when the AI encouraged her to consider different perspectives:

"Sometimes I feel like my answer is the most correct. But the AI tells me to look at it from another person's perspective or the other side of the issue." (S1)

In the context of PAI learning, the ability to view moral issues or Islamic law from multiple perspectives is an important element in developing critical thinking. Students S5 and S6 also described how the AI-FF helped improve their ability to construct religious arguments. S5 said:

"I often get confused about how to start. The AI helps me create an outline first, then I fill it in myself." (S5). Meanwhile, S6 added:

"*What I like most is that the AI gives logical examples without providing a final answer. So I still have to think for myself."* (S6)

These two statements indicate that the AI-FF does not provide instant answers but rather offers thought guidance that students can follow to develop independent answers. From a teacher's perspective, the presence of the AI-FF has shown positive changes in academic engagement. Teacher G1 stated that before the AI intervention, most students tended to "stay quiet and wait for direction." However, after using AI-FF, he noticed an improvement in students' readiness for discussion:

"*The students are more prepared to come to class. They've practiced their arguments with AI beforehand. The discussions are more lively."* (G1)

Thus, AI in this context does not replace the teacher, but rather functions as a cognitive companion that prepares students to become more active and confident discussion participants.

Integration of Islamic Values in Critical Reasoning

The second theme demonstrates how AI-FF helps connect students' critical thinking processes with Islamic values, evidence, and intellectual traditions. Students view AI as a quick reference source, providing Quranic verses, hadith, the views of Islamic scholars, and current examples of Islamic ethics. S1 stated that AI was very helpful in understanding Islamic ethical concepts:

"For example, if I ask about justice, AI gives me the verses, hadith, and examples of current situations. So I can immediately see the connection." (S1). A student added how AI makes Quranic texts more applicable to case reasoning:

"*Usually, when I read a verse, I don't immediately know how it relates to modern issues. AI explains the context*." (S2). S3 also appreciated how AI was able to provide the opinions of classical and contemporary scholars:

"*AI gives me Imam Ghazali's opinion, then compares it with contemporary scholars. I understand that scholars' opinions can differ*." (S3).

This statement indicates that AI-FF enhances students' ability to understand the diversity of Islamic scholarship and to apply it in argumentative analysis. However, teachers play a central role as grade curators. Teacher G2 emphasized that although AI is capable of providing evidence quickly, filtering and verification are still necessary:

"AI can provide evidence, but I still ensure that the evidence is appropriate, because the context must be appropriate." (G2).

Teacher G1 added that AI often provides evidence "literally," and teachers are still needed to provide an understanding of ushul fiqh and maqasid sharia:

"*AI is sometimes too textual. I have to explain the meaning or the value to be taken. That's part of our job as educators."* (G1)

However, not all experiences are positive or without challenges. S5 said that sometimes AI

provides lengthy and difficult-to-understand evidence:

"*Sometimes AI gives long texts, and I get confused. I need a teacher who explains the important parts."* (S5)

Thus, AI-FF helps enrich Islamic reasoning, but the presence of teachers remains fundamental in guiding Islamic understanding and ensuring ethical compliance.

Ethical Boundaries and Risks of Dependence

Although AI-FF brings significant benefits, teachers and some students expressed concerns about a tendency toward over-reliance. Teacher G2 expressed concern that some students are beginning to view AI as a source of instant answers:

"*Some students, when they get an assignment, immediately open AI. They don't try it first*." (G2). Teacher G1 added that this phenomenon has the potential to diminish the authenticity of students' thinking:

"*Sometimes their answers are too perfect, too similar to AI. That's a sign they lack personal reflection*." (G1)

The teachers emphasized that Islamic Religious Education learning aims not only to develop technical thinking skills but also to foster moral reflection and spiritual maturity that cannot be represented by machines. G2 emphasized:

"*AI may help with analysis, but the formation of morals comes from the heart, not from a chatbot*." (G2).

Students also recognized this risk. S6 said: "*If I use AI too often, I feel like I can't think for myself. So I limit it.*" (S6). S4 revealed that he once felt "lazy to think" because AI was too accessible: "*Sometimes I just ask the AI without trying it first. But I realized that's not good*." (S4). S2 even touched on an emotional dependence on instant validation: "It feels good to get quick feedback. But if you're not careful, it becomes dependent." (S2). Another ethical concern arose regarding the risk of plagiarism. Teacher G1 provided a concrete example:

"*There was an essay assignment that was almost 80% similar to the AI's answers. That's dangerous if not supervised*." (G1)

Thus, the use of AI-FF requires strict pedagogical supervision and adherence to digital ethics to ensure that students continue to develop authentic thinking skills and intellectual independence. Overall, student and teacher narratives indicate that AI-FF serves as a powerful learning partner in developing critical thinking, connecting Islamic values with modern analysis, and enhancing academic self-confidence. However, AI is not without risks: the tendency toward dependency, the potential for plagiarism, and the weakening of moral reflection are important issues that require teachers to play an active role as spiritual and ethical guides. Therefore, effective implementation of AI-FF must position AI as a tool, not an authority, while teachers remain the guardians of values, context, and character development.

The experiences of students and lecturers using AI-FF align with previous research on user perceptions of artificial intelligence in the learning process. Students felt that AI-FF helped them construct arguments, improve logic, and reduce shyness about asking questions. This phenomenon has been widely described in the literature, particularly in relation to learner confidence, private learning space, and affective support.

Research by Ifenthaler et al. (2024) shows that AI systems capable of providing personalized learning can increase student confidence. They found that when students had a personal space to ask questions without fear of judgment, the quality of their participation in learning improved. This finding is relevant to the experiences of students in this study, who perceived AI as a "safe

space" to test their thinking. Furthermore, research by Ruwe & Kuklick (2025) explains that AI-based dialogic tutoring can improve students' dialogical reasoning skills. Students who used AI in analytical tasks were able to compare arguments, consider alternative perspectives, and independently correct logical errors. This dynamic also emerged in student interactions with AI-FF.

The experiences of lecturers who feel helped by AI are also consistent with related literature. Rojas & Chiappe (2024) demonstrated that integrating AI into learning can free teachers from routine technical correction tasks, allowing them to focus on values, character development, and depth of understanding. In the context of PAI, lecturers' workload related to moral development and interpretation of Islamic teachings is substantial, making the involvement of AI in basic cognitive tasks highly relevant. Research by Shao et al. (2024) further indicates that AI can amplify teachers' capacity, strengthening their ability to manage classes and provide personalized guidance. AI does not replace teachers; rather, it optimizes teachers' time and energy, allowing them to focus more on high-level interactions. This aligns strongly with the findings of this study, which show that lecturers feel AI-FF provides additional space to focus on spiritual values, rather than merely logical technicalities.

Therefore, the experiences of students and lecturers in this study extend the findings of previous research to a more specific context, namely the application of AI in religious education. This field has greater moral and spiritual sensitivity than other fields, making these findings an important contribution to the global discussion of AI in religious education.

Evaluation of AI Integration in Islamic Religious Education (PAI) Learning Without Reducing the Role of Teachers

Research findings indicate that integrating Artificial Intelligence Feedforward Feedback (AI-FF) into PAI learning offers significant opportunities to strengthen students' critical thinking skills. However, the success of this integration depends not only on technological capabilities but also on maintaining teachers' role as moral-spiritual educators. This section integrates theoretical analysis and empirical findings to explain the complementary and ethical roles of AI and teachers in PAI learning.

AI as Scaffolding, Teachers as Moralizers

Interviews with teachers indicate that AI-FF is viewed as highly beneficial as a cognitive scaffolding that helps students clarify argument structure, identify reasoning errors, and improve response quality. The first teacher (G1) described AI-FF as:

"A tool that helps students construct more coherent arguments without immediately providing answers."

This aligns with the feedforward function, which is designed to predict errors and provide alternative solutions before students submit their final assignments. AI also acts as a trigger for intellectual reflection through a simulated argument process. When students offer an answer or initial idea, the AI-FF responds with guiding questions that challenge their assumptions or logic. A student explained that

"AI often asks for feedback, such as 'What is the basis for your thinking?' It makes me think twice before confirming my answer."

Interactions like this demonstrate that AI-FF works not simply as an answer provider, but as a thinking partner, expanding students' reflective space. However, teachers remain key actors in the moral and spiritual realm. The second teacher (G2) emphasized in an interview that "AI can help with logic, but for values, morals, and religious evidence, the teacher still determines the context

" AI lacks spiritual sensitivity, does not understand the maqâcid al-shâri'ah (the principles of Islamic law), and is unable to provide comprehensive ethical considerations.

Therefore, the teacher's role as a moralizer, ensuring that every thought process aligns with the values of monotheism, noble morals, and scholarly etiquette, must be maintained. These findings are consistent with Bandura's self-regulated learning model, which emphasizes that the development of moral independence cannot be fully taught by machines but requires human role models.

The Need for "AI Ethics Literacy" in Islamic Religious Education Learning

The integration of AI into Islamic Religious Education learning cannot be separated from ethical issues. All students interviewed acknowledged that AI-FF facilitated the learning process, but two students (S4 and S6) revealed that they were sometimes tempted to simply copy AI recommendations without further thought. A third teacher (G3) cautioned that

"*AI is fast and practical, but that's precisely what makes some students lazy to think."*

Concerns about digital plagiarism, decreased moral reflection, and reliance on instant feedback were recurring themes in the interviews. Based on these findings, the need for AI ethics literacy becomes increasingly clear. Teachers need training to understand ethical standards for AI use, including mechanisms to verify the accuracy of arguments, filter out content bias, and ensure that AI does not provide erroneous or out-of-context religious information. As G1 stated: "*Sometimes AI provides correct arguments, but the context is inappropriate. Teachers must be curators*."

Students also need to be equipped with critical skills to: evaluate religious information provided by AI; distinguish between argumentative logic and Islamic truth; recognize that AI is not an authoritative source of religious knowledge; and develop independent thinking, rather than relying on instant answers. This ethical literacy is crucial so that the use of AI-FF not only improves cognitive abilities but also strengthens students' character and academic integrity.

Ethical AI Integration Models in Islamic Religious Education Learning

Based on the research findings, three AI integration models are deemed ethical and appropriate for Islamic Religious Education. AI is a ugmentation, not a substitution. AI should be positioned as an augmentative tool that strengthens, not replaces, the role of the teacher. An undergraduate student stated that

"*AI helps understand the material, but the ustadz's explanations are still more convincing."*

This shows that in the context of Islamic Education, the teacher's authority remains dominant, while AI functions as a complement to accelerate understanding. Discussions on integrating AI into Islamic Religious Education learning emphasize that while AI is highly helpful for cognitive tasks, it cannot replace teachers as moral and spiritual educators. This is supported by international literature on the moral, emotional, and epistemological limitations of artificial intelligence.

(2022) explain that morality cannot be learned solely through information or algorithms, but through the process of internalizing values through social experience. Therefore, while AI can provide logical advice, it lacks the moral capacity to guide students in understanding Islamic ethical values and morality.

Alqarni (2025) asserts that AI lacks moral sensitivity, making it incapable of understanding the social context surrounding an argument. AI operates solely on data patterns. Even in secular ethical contexts, AI struggles to understand moral

nuances. In religious contexts, this difficulty is compounded because Islamic ethical values are integrative, encompassing textual, contextual, and spiritual aspects.

This view aligns with the principles of human-centered AI advocated by UNESCO (2023), which emphasize that AI should be used as a tool to assist humans, not a substitute. In religious education, this principle becomes even more important because the learning process is not simply the transfer of knowledge, but also the formation of character and spirituality.

A study by Luckin (2022) emphasized that teachers have three roles that AI cannot replace: moral compass, emotional mentor, and role model. These three roles are at the core of PAI learning, so AI integration must be carried out ethically and proportionally. In Islamic education, research by Mursalim (2020) stated that religious learning centers on the concept of *ta'dib*, namely the formation of morals through intellectual and spiritual discipline. AI lacks the capacity to serve as a role model or to provide the emotional experiences necessary for ta'dib.

Feed-forward and feedback models are key mechanisms for describing information processing in artificial intelligence (AI) systems and biological neural networks, particularly in cognitive and sensory functions. Feedforward models represent a unidirectional information flow between the input and output layers, providing fast processing of stimuli when they are first input. Such architectures are useful for tasks that involve little or no context, where learning involves predicting patterns or labels, or performing implicit learning. However, human cognitive and perceptual processes rarely operate in a feed-forward manner (Alamia et al., 2020).

On the contrary, they are extremely dependent on feedback that enables higher-level representations to affect lower-level processing and support context-aware error correction and adaptive learning. This line of reasoning has gained particular prominence recently in AI research in fields including educational, perceptual, and cognitive modeling. Feedback models emphasize the differential roles of AI systems and human instructors in language learning. Su & Huang (2025) show that artificial intelligence-generated feedback has proven particularly useful for immediate, widespread error detection, serving primarily as a tool for learners' awareness of linguistic errors. In contrast, teachers provide more prominent feedback, often through criterion-based advice and future-oriented learning strategies.

This tripartite feedback framework demonstrates that even if AI performs optimally in immediate corrective processing, human educators offer interpretative and anticipatory scaffolding that facilitates learners' long-term development. This type of finding highlights that feedforward and feedback processes must be integrated as in educational design, not seen as an 'end in themselves' in comparison to an interrelated process (McDermott et al., 2020).

In addition to language learning, feedback mechanisms are also central to sensory processing and perceptual invariance. Neuroscience suggests that feedback modulation enables neural systems to sustain context-invariant representations despite changes in the external environment. Smooth, spatially diffuse modulation of feedback gain supports neural populations to flexibly adjust activity and preserve stable representational subspaces (via stable representational subspaces). It is a process necessary for robust perception (Schenker & Agarwal, 2017). In the area of visual cognition, feedforward processing instantaneously produces coarse representations of visual information, which are refined through successive iterations of feedback loops aimed at increasing accuracy and alleviating uncertainty (Kreiman & Serre, 2020).

These results indicate that feedback serves not only to correct but also to build perceptual accuracy. Feedback is also at the core of hierarchical information storage and categorical

processing. The push-pull feedback model, when applied to inhibitory and excitatory signals, reduces interference and enhances retrieval in hierarchical structures, closely matching known patterns of neural activity (Liu et al., 2019).

This shows that feedback processes matter in the complex, information-rich environment where selective activation and suppression of information are essential for cognitive function. In the same way, computational systems for visual perception based on novel generative adversarial autoencoders show that feedback processes reconstruct lower-level sensory information from higher-level abstractions, indicating a temporal hierarchy in which feedforward and feedback mechanisms dynamically cross over time (Al-Tahan & Mohsenzadeh, 2021). In cognitive modeling, the distinction between feedforward and feedback architecture further demonstrates their unique functional roles. Systematic data on artificial grammar learning suggest that feedback-driven recurrent neural networks are much more human-like, especially when tasks require rule extraction and conscious reflection (Frank & Goodman, 2025).

Moreover, feedforward networks remain useful for modeling implicit aspects that rely on statistical regularities rather than deliberate reasoning. Taken together, these results show that, in general, feedforward models are computationally efficient, while feedback methods are crucial for adaptive, context-dependent higher-order cognitive tasks. Therefore, the inclusion of feedback mechanisms in AI and neural network models is a crucial step towards integrating artificial systems with human-like levels of thought complexity.

■ CONCLUSION

This study confirms that integrating the AI Feedforward Feedback (AI-FF) model into Islamic Religious Education learning provides important conceptual and pedagogical contributions to the development of students' critical thinking skills, while also demonstrating that technology can be adopted ethically without displacing teachers' roles as moral-spiritual educators. AI-FF has been shown to strengthen higher-order cognitive processes by providing reflective and predictive support, but still requires human guidance from teachers who hold authority over values, interpretation of arguments, and the formation of morals.

These results contribute to the literature concerning technology-enhanced learning in Islamic education by establishing that an augmentation rather than a substitution approach to AI incorporation is more epistemologically and pedagogically appropriate. Rather than postulating a novel theoretical framework, this research proposes a practical framework for AI–teacher co-agency in Islamic Religious Education in which AI functions as a supportive feedback and scaffolding tool. In contrast, teachers retain interpretive, ethical, and relational authority. This framework highlights how AI can be strategically positioned to enhance cognitive engagement and formative feedback without undermining the humanizing values central to Islamic pedagogy. By articulating concrete roles for AI and educators, this research lays the groundwork for the construction of ethical implementation guidelines, AI literacy programs to equip teachers and students, and curriculum designs that leverage technological affordances while preserving the moral, dialogical, and relational foundations of Islamic education.

Research recommendations include developing standards for AI integration in Islamic education, implementing professional training for teachers on AI ethics and literacy, and conducting further studies to test the effectiveness of this model across various educational institution contexts and learning levels.

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