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Enhancing Critical Thinking through AI and Simulation

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ABSTRACT

This study investigates the effectiveness of Artificial Intelligence (AI) and simulation-based learning in improving students' critical thinking skills in Information and Communication Technology (ICT) instruction at MTs Qur'aniyah Narmada, West Lombok. The research used a quasi-experimental design with nonequivalent control groups, involving 44 seventh-grade students divided into two experimental classes. One class was taught using AI-integrated applications, while the other employed simulation-based methods. Data were collected through critical thinking tests and student response questionnaires, then analyzed using descriptive statistics and independent t-tests. The results showed that the AI class achieved a higher average score (81.14) than the simulation class (73.41), with a statistically significant difference ($t = 2.267$, $p < 0.05$). These findings suggest that AI offers immediate feedback, adaptive learning, and deeper cognitive engagement, making it more effective than traditional simulation approaches in promoting critical thinking. The study concludes that integrating AI into ICT learning can significantly enhance digital literacy and higher-order thinking skills. This research contributes to the scientific discourse by offering a practical instructional model for madrasahs, especially in rural Indonesian settings. It supports the development of 21st-century competencies among students through innovative, technology-enhanced learning environments.

ARTICLE INFORMATION

Keywords:
artificial intelligence; community empowerment; critical thinking; ict learning; simulation

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INTRODUCTION

In the current era of rapid digital transformation, the integration of information and communication technology (ICT) literacy and critical thinking has become an indispensable necessity in education systems worldwide (Falloon, 2020; Thornhill-Miller et al., 2023; van Deursen & van Dijk, 2014). International institutions, such as UNESCO and the World Economic Forum (WEF), highlight digital literacy not merely as a technical ability, but as a core competency for surviving and thriving in the 21st century (Bravo et al., 2021; Martínez-Bravo et al., 2022; Nascimbeni & Vosloo, 2019). Digital literacy now encompasses accessing, interpreting, analyzing, and evaluating information across various platforms. This broad conception of literacy aligns with the growing complexity of global communication, where critical discernment is essential for distinguishing fact from misinformation (Maloy et al., 2022). Consequently, digital literacy should not be treated as a standalone technical subject but must be developed in parallel with critical thinking skills to foster reflective, informed, and responsible digital citizens (Pangrazio, 2016; Villar-Onrubia et al., 2022).

Critical thinking, as a cognitive and metacognitive skill, equips learners with the ability to question assumptions, analyze evidence, and construct reasoned judgments (Bean & Melzer, 2021; Dawson, 2025; Kurni & KG, 2024; Pherson & Pherson, 2020). Within education, it serves as a bridge between passive knowledge reception and active knowledge construction. Learners trained in critical thinking are more likely to question the validity of information, explore multiple perspectives, and make decisions based on logical reasoning. This skill set is increasingly vital in facing the demands of a knowledge economy and an era of information overload. Moreover, the synergy between ICT literacy

and critical thinking is crucial not only for academic achievement but also for enabling students to navigate a world that requires adaptive, creative, and analytical competencies (Gambrill, 2018; Pal et al., 2024; Vendrell-Morancho & Moya, 2025). These competencies are essential for students in under-resourced or peripheral educational settings where the challenges of access must be balanced by cognitive empowerment.

Empirical studies in Indonesia have revealed ongoing concerns about students' low critical thinking abilities. Nuryanti et al. (2018) found that most junior high school students still struggled to identify problems, analyse conclusions, or evaluate arguments, which are skills fundamental to critical reasoning. Similarly, Susilawati et al. (2020) emphasized that high school students often showed weaknesses in reflective and analytical thinking, particularly in evaluating information or drawing logical inferences. These findings highlight a systemic issue in the Indonesian education system, wherein students may excel at recalling facts but are not routinely trained to question or critique those facts. This gap in cognitive skill development has profound implications for the quality of education, especially in preparing students for higher education, employment, and civic engagement. Without interventions that deliberately target these shortcomings, students may remain ill-equipped for the complexities of contemporary life.

A similar condition is evident in madrasahs located in regional areas, such as MTs Qur'aniyah Narmada in West Lombok. Although the school is equipped with certified teachers and a functioning computer laboratory, these facilities are underutilized in ways that could develop students' critical thinking skills. Initial classroom observations indicate that ICT learning remains conventional, often involving only the passive viewing of educational videos or searching for information online, with little follow-up in the form of analytical discussion or reasoning-based tasks. Given the school's access to ICT infrastructure that could be mobilized for cognitive skill development, this represents a missed opportunity. The situation reflects a broader trend in which ICT is treated merely as a technical subject, detached from the pedagogical strategies needed to foster deeper thinking. There is a critical need to reorient ICT education toward active cognitive engagement through structured and innovative learning models.

ICT, when integrated meaningfully, has the potential to be a transformative medium for fostering higher-order thinking skills. Its contents, which include software manipulation and understanding system workflows, can serve as an ideal context for students to develop logical, reflective, and analytical capabilities (Bean & Melzer, 2021; van Rensburg & Rauscher, 2022; Reddy & Lakshmi, 2024). Noverdika (2021) demonstrated that using interactive multimedia in ICT education improved learning outcomes and stimulated student interest and understanding of abstract concepts. Through well-designed tasks, ICT can encourage students to troubleshoot, interpret digital data, and make strategic decisions. However, this potential often goes unrealized in practice. Many ICT classes still emphasize procedures over reasoning, where students follow steps without questioning why they matter. The challenge is not merely providing access to technology, but ensuring its use is embedded in learning designs that demand critical reflection.

In recent years, artificial intelligence (AI) and simulation methods have emerged as two instructional approaches with the potential to revitalize ICT education and integrate it with critical thinking development (Castillo, 2024; Jha & Singh, 2025; Moustaghfir & Brigui, 2024). AI can deliver adaptive learning experiences tailored to individual student needs, offering automated feedback and monitoring performance in real-time (Chen et al., 2020; Xu, 2024). Grace et al. (2023) noted that the application of AI in Indonesia could promote personalized learning paths and support higher-order thinking. Abidin (2023) applied AI in Madrasah Ibtidaiyah learning and found improvements in motivation and student independence, although the study did not directly measure critical thinking outcomes. These findings suggest that AI can function as a cognitive tool supporting reasoning and

self-regulated learning if aligned adequately with pedagogical goals. This opens up opportunities for shifting ICT from a tool-centered to a learner-centered domain.

Simulation, by contrast, offers a different but equally valuable pathway. It provides students with immersive experiences that mirror real-world challenges, encouraging them to apply theoretical knowledge in practical contexts. Mokoginta et al. (2022) illustrated the effectiveness of virtual simulation in enhancing vocational students' understanding of WAN network services. Nugraha et al. (2023) also reported improved learning outcomes through simulation combined with demonstration in practical courses. These environments compel learners to make decisions, reflect on consequences, and revise their understanding through trial and error. By replicating authentic problem-solving scenarios, simulation nurtures logical analysis, creative solution-making, and evaluative thinking skills. In contexts like madrasahs, where students may have limited exposure to real-world applications, simulations can serve as a crucial bridge between abstract knowledge and meaningful action.

Several Indonesian studies have affirmed the benefits of both AI and simulation, though rarely in direct comparison. Grace et al. (2023) reinforced the promise of AI in providing customized and responsive learning in local contexts. Abidin (2023) confirmed its motivational impact in madrasahs, while Rohmawaty et al. (2024) showed how AI-supported learning enhanced cognitive interaction in Arabic instruction, a foundational aspect of critical thinking. On the other hand, simulation-based methods have been praised for their ability to engage students contextually and interactively. Muzani et al. (2023) showed that ICT-based simulations improved student engagement in madrasahs, suggesting their value for Islamic educational environments. While AI and simulation offer clear strengths, the absence of comparative research leaves questions about which approach may be more effective in specific academic goals, such as developing critical thinking.

As reported by Nuryanti et al. (2018) and Susilawati et al. (2020), Indonesian students' persistent low performance in critical thinking requires urgent and innovative pedagogical solutions. Through a comprehensive meta-analysis, Pertiwi et al. (2023) confirmed the effectiveness of problem-based learning in enhancing students' reasoning abilities, highlighting the importance of well-designed instructional approaches. Despite these encouraging insights, only a few studies have explored how technology-enhanced strategies such as AI and simulation can be applied specifically within ICT instruction, especially in madrasah contexts. This represents a notable gap in the literature, considering that many madrasahs already possess ICT infrastructure but have yet to implement it in ways that deliberately target the development of higher-order thinking skills. MTs Qur'aniyah Narmada in West Lombok is one example, where facilities exist but are not optimally utilized to support critical thinking through innovative pedagogical methods. There is thus a pressing need to investigate how different instructional models can transform available ICT resources into powerful tools for cognitive development.

To address this gap, the present study aims to analyze and compare the effectiveness of two instructional approaches, AI-based learning and simulation-based learning, in fostering students' critical thinking skills during ICT instruction at MTs Qur'aniyah Narmada. This research seeks to identify whether significant differences exist in essential thinking outcomes between students taught using AI and those engaged through simulation methods. Furthermore, the study intends to examine how each approach influences different aspects of critical thinking, such as the ability to identify problems, analyze arguments, and evaluate information critically. By focusing on a madrasah setting with adequate technological infrastructure but limited cognitive integration, this study is expected to offer practical insights for designing effective ICT instructional models. The findings are also anticipated to provide a replicable framework for other educational institutions aiming to enhance students' digital literacy and critical thinking skills in a cohesive and pedagogically sound manner.

METHOD

This study employed a quantitative approach using a quasi-experimental design, namely the nonequivalent control group design (Miller et al., 2020; Stuart & Rubin, 2008). This type of design was chosen because it allows the researcher to apply different instructional treatments to two distinct groups within a natural classroom setting, even without complete randomization. Such a design is appropriate for educational research conducted in real school environments where fully randomized assignment is often difficult or impractical (Clark et al., 2021; Priadana, 2021; Sugiyono, 2017). Through this design, the study sought to examine and compare the effectiveness of two instructional models, namely ICT learning that integrates AI and ICT learning based on simulation, in developing the critical thinking skills of madrasah students.

The population in this study consisted of all seventh-grade students enrolled at MTs Qur'aniyah Narmada in West Lombok, totalling 66 students. From this population, a sample of 44 students was selected using random sampling to ensure fair and proportional representation. After the sample was determined, students were assigned to two experimental groups. The first group, comprising 22 students, received ICT instruction utilizing artificial intelligence-based applications. The second group, comprised of 22 students, was taught using simulation-based learning strategies. This sampling procedure was intended to reduce the risk of selection bias and to provide each student with an equal opportunity to be included in the study, thereby increasing the internal validity of the research outcomes.

Several instruments were used to collect data, including a test of critical thinking skills, a student response questionnaire, and supporting documentation. The critical thinking test consisted of essay items developed based on five indicators formulated by Ennis, covering essential aspects such as explanation, relevance, analysis, evaluation, and logical reasoning. The test was administered twice, as a pretest and a posttest, to measure the students' improvement in critical thinking before and after the instructional interventions. In addition, a questionnaire was distributed at the end of the treatment period to capture students' responses and attitudes regarding using AI and simulation in ICT learning. Documentation such as syllabi, lesson plans (RPP), and previous learning records was also collected to strengthen data triangulation and to provide contextual information regarding the implementation of each instructional model.

The treatment began with administering a pretest to both groups to assess their baseline critical thinking abilities. Following this, the first experimental group participated in a series of ICT lessons that incorporated AI tools designed to deliver personalized feedback and adaptive content. Simultaneously, the second experimental group engaged in ICT learning sessions that employed simulation-based scenarios, allowing students to explore real-life tasks and make decisions in a guided environment. Both groups received instruction for a minimum of four sessions. Upon completion of the treatment phase, a posttest was administered to both groups to evaluate changes in students' critical thinking skills. Subsequently, all participants were given a questionnaire to gather their perceptions of the learning process, and relevant teaching documents were reviewed to support the interpretation of the findings.

A series of testing procedures was conducted to ensure the reliability and validity of the instruments used. Content validity was assessed through expert judgment involving two academic supervisors and ICT subject teachers, who reviewed the appropriateness of each test item about the five indicators of critical thinking. Construct validity was further examined by analyzing the alignment between each item and the theoretical dimensions of critical thinking. Reliability testing was conducted using Cronbach's Alpha via SPSS version 25. The results showed that the instruments achieved alpha coefficients exceeding 0.70, indicating a high level of internal consistency and making them suitable for application in this study.

The data obtained from the pretest and posttest results were analyzed using descriptive statistical techniques to determine each group's means, standard deviations, and score distributions. Inferential analysis was conducted using an independent samples t-test with a two-tailed significance approach at the 5% level to test the research hypothesis regarding significant differences in critical thinking outcomes between the two groups. This test was performed using SPSS version 25. The results of this analysis were used to determine whether the AI-based instructional approach produced statistically different improvements in students' critical thinking compared to the simulation-based method in the context of ICT learning at the madrasah.

RESULTS AND DISCUSSION

This section presents the results obtained from the critical thinking tests administered before (pretest) and after (posttest) the instructional treatments. The analysis focuses on two experimental groups: one taught using AI-based ICT instruction, and the other through simulation-based learning. The pretest and posttest scores are compared to assess the improvement in students' critical thinking skills across both groups. The data are analyzed using descriptive statistics and inferential tests to determine whether significant differences exist between the two instructional approaches. This section is followed by a discussion that relates the findings to relevant educational theories and prior research. It also highlights the pedagogical implications for ICT instruction and the potential role of AI and simulation in strengthening students' higher-order thinking. Furthermore, the discussion emphasizes how these approaches can contribute to the empowerment of madrasah communities, particularly in rural educational settings.

The analysis of the pretest results indicated that both experimental groups had relatively balanced initial abilities in critical thinking. The group that received AI-based instruction recorded a mean pretest score of 65.14 with a standard deviation of 7.82. In contrast, the simulation-based group obtained a mean score of 64.77 with a standard deviation 8.05. These results suggest that, before the instructional intervention, there was no meaningful difference in students' critical thinking skills between the two groups. After the implementation of the respective instructional treatments, an increase in posttest scores was observed in both groups, although the improvement was more substantial in the AI group. This group achieved a mean posttest score of 81.14 with a standard deviation of 8.99, whereas the simulation group reached a lower mean of 73.41 with a standard deviation 13.22. These findings indicate that while both methods enhanced students' critical thinking, the AI-based instruction demonstrated greater effectiveness. The detailed results of the pretest and posttest are presented in Table 1 to provide a more precise comparison of the outcomes.

Table 1. Pretest and Posttest Results of Critical Thinking Skills

Group	Mean Pretest	SD Pretest	Mean Posttest	SD Posttest
AI	65.14	7.82	81.14	8.99
Simulation	64.77	8.05	73.41	13.22

The results suggest that AI-based learning and simulation methods improve students' critical thinking skills. However, the group that received instruction through AI demonstrated higher posttest scores than the simulation group, indicating greater improvement. This observed difference points to the potential advantage of AI in facilitating more adaptive, responsive, and cognitively engaging learning experiences. Further analysis was conducted using inferential statistical testing to determine whether the difference between the two groups was statistically significant.

The independent samples t-test conducted on the posttest scores indicated a significant difference in critical thinking skills between the students who received AI-based instruction and those

who learned through simulation methods. The AI group achieved a higher mean posttest score (81.14) than the simulation group (73.41), with standard deviations of 8.99 and 13.22, respectively. The computed t-value of 2.267 exceeded the critical value from the t-distribution table at the 5 percent significance level, and the p-value (Sig. 2-tailed) was less than 0.05. These statistical results led to rejecting the null hypothesis and accepting the alternative hypothesis, thereby confirming that the difference between the two groups was statistically significant. The findings suggest that AI-based learning is more effective than simulation in improving students' critical thinking skills in ICT instruction. Further details regarding the statistical output are presented in Table 2, which summarizes the means, standard deviations, and t-test results for both groups.

Table 2. t-Test Results of Posttest Critical Thinking Skills

Statistic	AI Group	Simulation Group
Mean Posttest	81.14	73.41
Std. Deviation	8.99	13.22
t-value	2.267	-
t-table (α = 0.05)	1.682	-

This finding can be explained through constructivist theory, which emphasizes the necessity of active mental engagement, reflection, and student involvement in processing information to achieve deep understanding. AI-based learning provides adaptive pathways and immediate feedback, enabling students to promptly evaluate mistakes, refine their thought processes, and build stronger arguments. Grace et al. (2023) demonstrated that AI can create intensive cognitive interaction by tailoring material to individual learning needs. Similarly, Abidin (2023) found that implementing AI in madrasahs could increase students' motivation and learning independence, which are essential foundations for critical thinking.

On the other hand, although simulation is not as adaptive as AI in adjusting learning challenges to each student's level, it remains a relevant method for training logical reasoning and problem-solving. Simulation offers structured experiences that mimic real-world situations, allowing students to apply their knowledge in practical and contextual scenarios. Studies by Mokoginta et al. (2022) and Nugraha et al. (2023) confirmed that simulation-based learning effectively improves systematic thinking and decision-making skills. These advantages make simulation an essential pedagogical tool, particularly in subjects that require process-oriented understanding. Thus, the t-test results not only highlight AI's analytical strengths but also emphasize the value of integrating both methods. Combining AI and simulation may better support the comprehensive development of students' critical thinking abilities by addressing individualized feedback and contextual learning experiences.

Analyzing each critical thinking skill indicator revealed meaningful variations in student achievement between the two treatment groups. The group that received AI instruction outperformed the group taught through simulation-based methods across nearly all indicators. The complete data showing the average percentage achievements for each indicator are presented in Table 3. At the same time, the comparative trend is further illustrated in Figure 1 for visual clarity and ease of interpretation. These two data sources offer insight into which aspects of critical thinking were most strongly influenced by the instructional models and serve as a basis for drawing more profound pedagogical implications.

Table 3. Average Percentage of Critical Thinking Skill Indicators

Indicator	AI Group (%)	Simulation Group (%)
Providing simple explanations	92.05 (Excellent)	80.68 (Excellent)
Focusing on relevant problems	90.91 (Excellent)	86.36 (Excellent)
Analyzing arguments	89.77 (Excellent)	70.45 (Good)
Evaluating information	77.27 (Good)	70.45 (Good)
Constructing logical reasoning	55.68 (Fair)	59.09 (Fair)

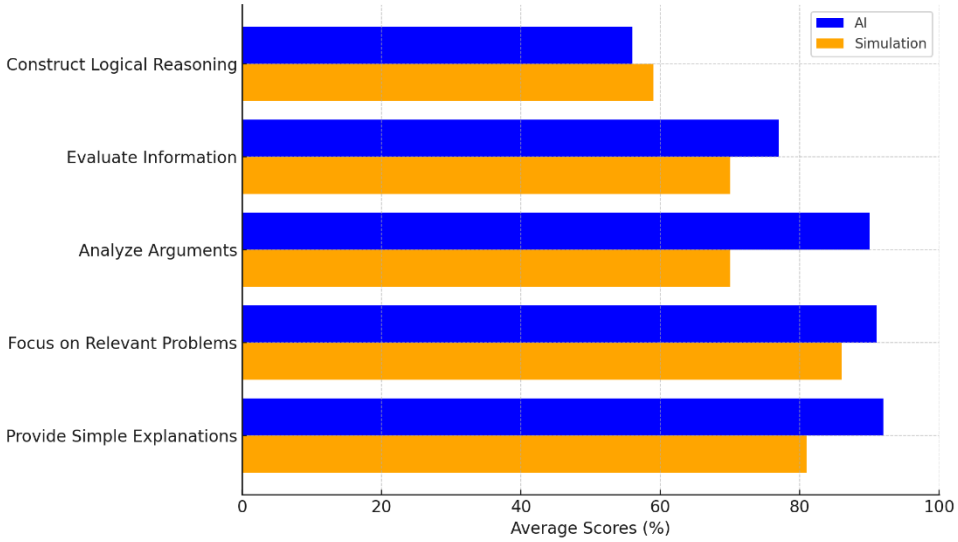


Figure 1. Comparison of Critical Thinking Indicator Profiles between AI and Simulation

From the table and figure, it is evident that in the indicator of providing simple explanations, the AI group recorded the highest achievement with 92.05 percent, categorized as “excellent”. The simulation group also reached the “excellent” category, with a lower percentage of 80.68. The AI group's superiority in this aspect can be attributed to its capacity to deliver adaptive content and interactive visualizations that simplify conceptual understanding. Grace et al. (2023) supported this by stating that AI enhances students’ comprehension of abstract concepts through personalized instruction that promotes cognitive engagement. Similarly, both groups attained high achievement for the indicator of focusing on relevant problems. The AI group scored 90.91 percent, while the simulation group achieved 86.36 percent, with both still classified as “excellent”. This demonstrates that both approaches were effective in helping students identify and focus on core issues, albeit through different mechanisms. AI-guided students used algorithmically structured questions, whereas simulations encouraged attention through immersion in real-world scenarios.

The most striking gap between the two groups was found in the indicator of analyzing arguments. The AI group obtained an average score of 89.77 percent, falling in the “excellent” category, while the simulation group reached only 70.45 percent, categorized as “good.” This significant difference may be explained by AI-based instruction offering structured reasoning pathways and immediate feedback, prompting students to compare alternatives and critique their logic. Rohmawaty et al. (2024) noted that AI systems enhance reflective analysis through adaptive interaction that strengthens critical reasoning. In evaluating information, the AI group again showed better performance with a score of 77.27 percent compared to the simulation group’s 70.45 percent, although both remained in the “good” category. Abidin (2023) explained that AI promotes evaluative thinking by allowing students to independently correct conceptual misunderstandings through diagnostic feedback, which plays a key role in critical evaluation processes.

Interestingly, a different pattern appeared in the indicator of constructing logical reasoning. In this category, the simulation group slightly outperformed the AI group, achieving a score of 59.09 percent compared to 55.68 percent. Both scores were categorized as “fair.” This result aligns with the inherent strengths of simulation-based learning, which places students in scenario-driven tasks that require them to formulate step-by-step solutions. Such learning experiences foster sequential thinking and decision-making. Nugraha et al. (2023) and Mokoginta et al. (2022) highlighted that simulations are particularly effective in training systematic thought processes, even though they may not support higher-order evaluative thinking as robustly as AI. Thus, while AI provides superior support for analytical and evaluative dimensions of critical thinking, simulations offer a more context-driven path to strengthening reasoning structure and procedural logic.

Overall, the data support the conclusion that AI-based instruction is more dominant in enhancing students’ analysis, explanation, and evaluation skills. On the other hand, simulation contributes uniquely to logical reasoning by simulating authentic problems that demand ordered and strategic responses. These findings indicate the potential value of combining both instructional approaches in a complementary framework. By integrating AI and simulation in ICT instruction, educators can address a broader spectrum of critical thinking dimensions, resulting in a more balanced and holistic development of students’ cognitive abilities. Such an integrated strategy is particularly relevant for madrasah contexts that seek to modernize instruction while fostering 21st-century skills through effective use of educational technology.

The findings of this study provide a comprehensive overview of how the application of AI and simulation methods in ICT instruction influences the critical thinking skills of madrasah students. Based on data analysis, AI proved to be more effective in enhancing analytical and evaluative aspects, whereas simulation showed strengths in reinforcing logical reasoning through contextual learning experiences. These differences highlight each method's distinct cognitive impacts when applied in classroom settings. Both approaches demonstrate valuable contributions depending on the targeted dimension of critical thinking. To further understand why these differences emerged and how the results align with or differ from previous studies, the following discussion elaborates on the advantages of AI and simulation, linking them to relevant learning theories and supporting prior research findings.

The superiority of AI in this study was evident in critical thinking indicators that require deep information processing, such as analyzing arguments and evaluating information. This is closely related to AI’s capability to provide adaptive learning pathways, where materials and questions are tailored to each student’s level of understanding. From the perspective of constructivist theory, learning processes become optimal when students are actively engaged in building knowledge through cognitive experiences that match their readiness. AI supports this process by automatically assessing students’ responses and adjusting the question difficulty level, continuously challenging students to develop their analytical and critical thinking abilities.

Figure 2 illustrates the adaptive learning mechanism applied in the AI-based instruction observed in this study, compared with the instructional flow of the simulation method. In the AI group, students began with a task input that triggered dynamic difficulty adjustments, automated feedback, and opportunities for individual reflection before progressing to deeper analysis. This process guided them through increasingly complex evaluations of arguments and data. On the other hand, the simulation group followed a learning path that started with realistic scenarios, which were processed collaboratively through group problem-solving and discussion. These discussions culminated in the formulation of practical conclusions, simulating real-world decision-making. Although not as personalized as AI, the simulation method supported critical thinking through authentic and socially interactive learning experiences.

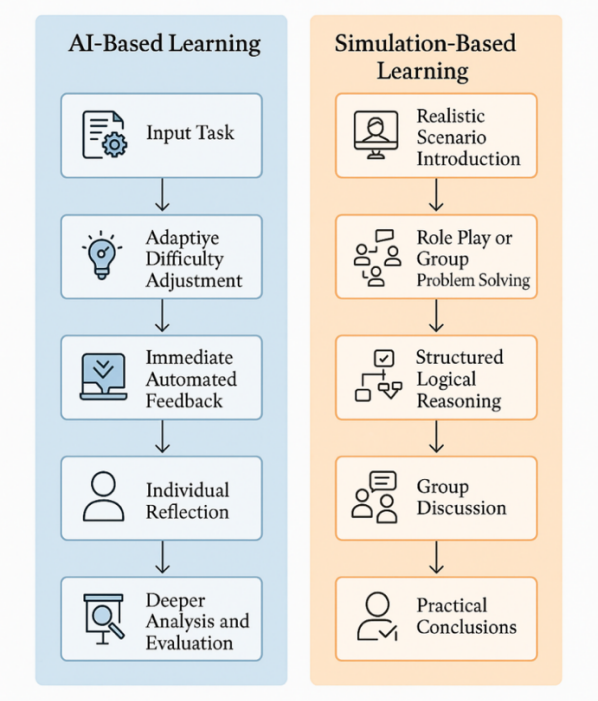


Figure 2. Comparison of AI-Based and Simulation-Based Learning Mechanisms

In addition, one of AI's key advantages is its ability to provide immediate and diagnostic feedback. Beyond indicating whether a student's answer is correct or incorrect, AI offers detailed explanations that guide learners in reflecting on their mistakes, reviewing flawed arguments, and refining their reasoning patterns. Grace et al. (2023) asserted that adaptive learning pathways combined with automated feedback promote intensive cognitive interaction between students and the learning material, pushing them to think at a higher evaluative level. Supporting this, research by Abidin (2023) in elementary-level madrasahs found that AI implementation facilitated students' understanding of the material and increased their confidence in testing their logical reasoning. Students felt more secure receiving feedback from the system, as it minimized the fear of being judged by teachers or peers. These findings align with the present study's results, which revealed that AI significantly outperformed the simulation group in analyzing arguments. Thus, AI should not be viewed merely as a tool for content delivery or practice, but rather as a strategic facilitator of systematic and reflective thinking, making it highly relevant for advancing critical thinking skills aligned with the demands of 21st-century education.

In addition to its role in supporting analytical and evaluative thinking, the implementation of AI in learning has been shown to enhance students' motivation and learning independence. In this study, students in the AI group demonstrated higher enthusiasm for exploring materials independently, mainly because the system provided challenges tailored to their individual ability levels. This personalization helped prevent students from feeling overwhelmed or disengaged due to tasks being too easy or difficult. When the difficulty level matched students' zone of proximal development, it stimulated an intrinsic desire to continue learning and improving their understanding. Furthermore, the immediate and adaptive feedback offered by AI was instrumental in fostering students' self-confidence. Upon completing tasks or answering questions, students received instant responses that identified errors and provided guidance on how to correct them. This reduced dependence on teacher intervention and contributed to developing a more autonomous learning environment where students could take risks and explore solutions without fear of criticism.

This psychologically safe space encouraged learners to experiment with different problem-solving strategies and engage more actively with the content. Abidin (2023), in his study at the elementary madrasah level, found that students who learned with AI felt more motivated and independent because they could study at their own pace with ongoing support from the system. Similarly, Rohmawaty et al. (2024) reported that postgraduate students using AI in Arabic language instruction were prompted to reflect more deeply on their arguments, recognize flawed reasoning, and draw critical conclusions. Although the educational contexts in these studies differ, the mechanism by which AI enhances reflective and independent learning appears consistent across levels. These observations align with the present study's findings, which showed improvements in critical thinking indicators, particularly in evaluation and analysis, due to increased student motivation and autonomy supported through AI-based instruction.

Although AI demonstrated a more decisive advantage in enhancing critical thinking skills in analytical and evaluative dimensions, the findings of this study also highlight the crucial role of simulation-based learning in supporting the development of students' logical reasoning abilities. On the indicator of constructing logical reasoning, the simulation group achieved a slightly higher score than the AI group, although both remained within the "fair" category. This result suggests that simulation uniquely fosters structured thinking, particularly through learning activities that immerse students in situations mirroring real-world problems. Students are encouraged to develop a step-by-step approach to solving problems by engaging with scenarios that require sequential analysis and decision-making. These findings emphasize that, while AI is more effective in advanced cognitive tasks, simulation has strengths in cultivating procedural and rule-based reasoning patterns.

Simulation-based learning involves direct student participation in guided problem-solving experiences. In such settings, students are tasked with identifying key information, organizing it logically, and forming coherent responses based on contextual clues. Through this process, they are exposed to cause-and-effect relationships and encouraged to consider multiple possible outcomes before concluding. Nugraha et al. (2023) noted that simulation effectively improves learning outcomes in subjects emphasizing procedures and processes. Unlike more abstract instructional approaches, the technique requires students to apply structured steps and logical sequencing, making it helpful in reinforcing foundational reasoning skills. Simulation grounds thinking in concrete examples, which helps students internalize logic patterns through experience.

Supporting this, the study by Mokoginta et al. (2022) found that vocational students who used virtual simulations better understood WAN network services by following systematic instructional stages, which helped them construct technical workflows with clarity. Similarly, Muzani et al. (2023) demonstrated that ICT-based simulations enhanced the learning engagement of elementary madrasah students, encouraging them to process tasks using logical but straightforward strategies. These findings reinforce the results of the present study, which positions simulation as a meaningful method for honing logical reasoning, especially in settings that require learners to navigate structured challenges. While simulation may not be as effective as AI in facilitating complex analysis or comparative evaluation, it is complementary to building students' sequential thinking capacity. Therefore, integrating simulation with AI holds strong potential for supporting the full spectrum of students' critical thinking development in ICT instruction.

The main findings of this study indicate that the implementation of AI in ICT instruction provides a significant advantage in critical thinking skill indicators that require analytical and evaluative abilities, such as analyzing arguments and evaluating information. The average achievements of the AI group on these two indicators were considerably higher than those of the simulation group, confirming that AI is more effective in stimulating students to think at a higher cognitive level. This occurs because AI does not merely present material in a static manner but also

delivers question scenarios that adjust to students' levels of understanding, compelling them to compare various alternative answers and critique their choices.

This advantage aligns with the findings of Grace et al. (2023), who discovered that AI could create intensive cognitive interaction through adaptive learning pathways directed at reflective and evaluative thinking processes. Similarly, Rohmawaty et al. (2024), in Arabic language learning among postgraduate students, found that AI facilitated more profound conceptual elaboration, helping students evaluate arguments and formulate conclusions based on systematic data analysis. Research by Abidin (2023) conducted at the elementary madrasah level also showed that AI-enhanced learning motivation and improved students' thought patterns in processing information. However, the focus was not directly on critical thinking skill indicators.

In comparison, while the simulation method effectively trains procedural reasoning, it is less adaptive in encouraging students to evaluate data in depth. Nugraha et al. (2023) emphasized that simulation improved students' understanding of practical material, while Mokoginta et al. (2022) and Muzani et al. (2023) highlighted how simulation helps to systematize learning steps within more realistic contexts. However, unlike AI, simulation does not offer automatic feedback that prompts students to revise their arguments based on individual data analysis. Thus, the findings of this study reinforce and extend the existing literature by providing empirical evidence in a new context, specifically through a direct comparison of AI and simulation in ICT instruction within madrasahs. Most prior studies have tended to investigate these two approaches separately. Therefore, this research's results confirm AI's superiority in supporting analytical and evaluative dimensions of critical thinking and contribute a new perspective by demonstrating the potential of combining AI and simulation as complementary methods in instructional design.

The findings of this study indicate that both AI and simulation possess distinct advantages in fostering students' critical thinking skills. AI demonstrated a more substantial impact in facilitating analytical and evaluative abilities, primarily due to its adaptive feedback mechanisms and personalized learning pathways. On the other hand, simulation made a valuable contribution in strengthening students' logical reasoning through context-based experiential learning that mirrors real-life situations. These results highlight the necessity of rethinking instructional strategies in ICT education within madrasahs. Rather than relying on a single instructional approach, educators are encouraged to adopt a more integrative model that combines AI's and simulation's unique strengths. This will ensure that students' critical thinking skills develop across multiple cognitive domains, making the learning process deeper and more balanced.

An integrated instructional design can be implemented by engaging students in simulation-based problem-solving activities that reflect realistic challenges, followed by AI-driven learning sequences that support reflection, adaptive feedback, and argument evaluation. This combination allows students to experience and respond to structured scenarios and refine their reasoning by receiving individualized input tailored to their cognitive needs. Through this approach, students are taught to formulate logical steps and to evaluate the quality of their decisions critically. The strategy supports a holistic model of critical thinking development that includes logical, analytical, and evaluative dimensions, all essential for 21st-century learning. Moreover, the complementary nature of these two approaches opens opportunities for differentiated instruction that caters to students with diverse learning preferences and readiness levels.

The relevance of this integrated approach is also supported by the findings of Pertiwi et al. (2023), whose meta-analysis demonstrated the effectiveness of problem-based learning in enhancing critical thinking. Although their study did not directly compare AI and simulation, the characteristics of structured, inquiry-driven learning in simulation-based activities align closely with the principles of problem-based instruction. These can be further enriched by incorporating AI technology to

facilitate personalized exploration and evaluation. In the context of madrasahs, this instructional innovation is particularly significant given the findings of Nuryanti et al. (2018) and Susilawati et al. (2020), who reported that critical thinking skills among junior and senior high school students in Indonesia remain relatively low. Addressing this issue requires more engaging learning experiences and intelligent systems that can guide students through complex reasoning processes.

Therefore, this study contributes to the empirical discourse on the effectiveness of AI and simulation in educational settings and offers practical implications for designing digital pedagogy in madrasahs and other similar institutions. An ICT instructional model combining AI and simulation provides a promising solution for strengthening digital literacy while fostering higher-order thinking. In doing so, it supports the development of human resources that are both intellectually capable and culturally grounded. Such a model holds great potential for transforming learning environments in religious schools, helping them meet modern education's challenges while preserving their distinctive values and traditions. The findings of this study offer significant contributions to the refinement of ICT instructional strategies in madrasahs. The demonstrated effectiveness of AI in enhancing critical thinking, particularly in the domains of analysis and evaluation, provides a strong foundation for educators to integrate adaptive technologies into their teaching practices with greater confidence. By leveraging AI features such as immediate feedback and individualized learning pathways, teachers can deepen students' understanding of subject matter and foster reflective thinking habits during problem-solving activities. This supports a more responsive, learner-centered environment that aligns with 21st-century educational demands.

In parallel, the study also reaffirms the continued relevance of simulation in supporting students' logical reasoning through experiential and contextual learning. Simulation-based activities allow students to engage with structured tasks that mirror real-world scenarios, reinforcing systematic thinking and procedural problem solving. These findings indicate that integrating AI and simulation into a unified instructional model may offer a comprehensive approach to nurturing all aspects of critical thinking. Madrasahs are therefore encouraged to design ICT programs that utilize simulation for collaborative problem solving and applied tasks, while also employing AI to strengthen individual reflection, feedback, and adaptive cognitive engagement. Implementing this approach at MTs Qur'aniyah Narmada demonstrates that enhancing digital literacy through AI and simulation has broader implications beyond academic outcomes. It contributes to positioning the madrasah as an agent of community development, where improvements in students' critical thinking translate into empowering the surrounding environment. As students become more capable of independent reasoning and informed decision-making, the institution helps shape a generation better equipped to face global challenges while rooted in local values. This model can be replicated in other madrasahs with similar contexts, offering a pathway for wider educational transformation driven by the strategic integration of technology into instructional design.

CONCLUSION

This study concludes that integrating AI into ICT instruction is significantly more effective than simulation in enhancing students' critical thinking skills, particularly in analysis and evaluation. While AI facilitates adaptive feedback and personalized learning paths that push students toward higher-order thinking, simulation contributes meaningfully by developing logical reasoning through contextual, problem-solving tasks. These complementary strengths suggest that instructional models in madrasahs should not rely on a single method but instead combine both approaches to foster all aspects of critical thinking comprehensively. Conducted in the context of MTs Qur'aniyah Narmada in West Lombok, the study also addresses the practical challenge of underutilized ICT infrastructure in rural educational settings by offering an empirically supported model that promotes digital literacy

and cognitive engagement. The results of this study have practical implications for educators and policymakers, as they demonstrate how integrating AI and simulation can improve not only academic performance but also students' readiness to face complex real-world challenges. By applying this integrated instructional approach, madrasahs and similar institutions can position themselves as agents of educational transformation, enhancing the quality of human resources and empowering communities through the development of reflective, independent, and critically minded learners.

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