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RADEC Learning Integrated with Artificial Intelligence: A Quasi-Experimental Study on Elementary Students' Critical Thinking Skills

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ABSTRACT

Purpose: This study aimed to examine the effectiveness of the Artificial Intelligence (AI)-integrated RADEC (Read, Answer, Discuss, Explain, and Create) learning model in improving fifth-grade students' critical thinking skills on natural disaster topics. **Methods**: This study employed a quasi-experimental approach using a nonequivalent control group design. The research was conducted at SD Negeri Tegalkalong I, Sumedang Regency, Indonesia, involving 60 fifth-grade students divided into an experimental class (n = 30) and a control class (n = 30). The experimental class used the AI-integrated RADEC model, while the control class used the Problem-Based Learning (PBL) model. Data were collected through a HOTS-based critical thinking test consisting of 19 essay items, observations, and documentation. Data were analyzed using descriptive statistics, t-tests, and N-Gain analysis. **Findings**: Both learning models improved students' critical thinking skills. However, the AI-integrated RADEC model produced significantly greater improvement than the PBL model, as indicated by the independent-sample t-test result ($p = 0.001 < 0.05$) and a higher N-Gain score in the experimental class (0.8152, high category) than in the control class (0.6013, medium category). **Research Implications**: Integrating AI into RADEC learning can support the development of critical thinking skills and strengthen disaster education in elementary schools. However, the findings should be interpreted cautiously because the study was limited to one school, a relatively small sample, and two learning sessions. Further research with larger samples and longer implementation periods is recommended. **Originality**: The novelty of this study lies in integrating AI into the Read and Discuss stages of the RADEC model as a tool for information evaluation and reflection rather than a direct answer provider.

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INTRODUCTION

With the rapid advancement of science and technology, the field of education is required to continuously adapt to the various challenges of the 21st century. The development of science and technology has provided significant benefits to human life by overcoming limitations of space and time, making it seem as though no barriers exist between one place and another (Sujana & Rachmatin, 2019). This condition has brought changes to various aspects of life, including educational and learning processes in schools. Therefore, improving the quality of education in a country is the responsibility of all parties involved, including both students and teachers (Ismail, 2021). Efforts to improve educational quality should be realized through learning processes that are capable of adapting to the demands of contemporary developments and students needs. Educational transformation in the 21st century requires fundamental changes in the learning process. Learning is no longer merely a one way transmission of knowledge but must focus on developing critical thinking, collaboration, communication, and creativity skills (Aeni et al., 2026).

Critical thinking skills are among the essential competencies that students must possess in the 21st century (Novandi et al., 2025). These skills are necessary for students to analyze information, solve problems, evaluate events, and make logical and systematic decisions. Critical thinking skills are particularly important because they help students understand various real world problems occurring in their surrounding environment, including disaster-related issues

(Kusuma et al., 2024). The results of the Programme for International Student Assessment (PISA) indicate that Indonesian students' critical thinking and scientific literacy skills remain relatively low compared to those of students in other countries (OECD, 2024). This condition suggests that learning processes in schools have not yet fully optimized the development of students higher order thinking skills. Furthermore, learning that focuses solely on content delivery causes students to be less accustomed to developing critical thinking skills when dealing with real life problems in their environment (Mazidah, 2024).

As a result, students still experience difficulties in analyzing information, evaluating problems, connecting concepts with real world conditions in their surroundings, and expressing reasons or opinions logically. Students also tend to understand learning materials only at a basic level without being able to develop deeper thinking skills regarding the events or issues being studied. In addition, learning processes that are insufficiently supported by innovations in the development of engaging and interactive instructional materials constitute another factor contributing to suboptimal student engagement in learning (Kemaliah et al., 2023). Students are also not yet accustomed to Higher Order Thinking Skills (HOTS) based questions that require critical thinking abilities. In fact, science and social studies learning (IPAS), particularly on the topic of natural disasters, requires critical thinking skills so that students can accurately understand the causes, impacts, and mitigation efforts related to disasters (Vitasari & Berlian, 2025).

This issue becomes increasingly important in areas with relatively high disaster risks. Sumedang Regency is one of the regions with the potential for landslides, floods, and earthquakes (RPMJ, 2025). These geographical conditions make disaster education essential from the elementary school level so that students develop an understanding of and preparedness for disaster risks (Bachri et al., 2024). Therefore, a learning model is needed that can help students understand disaster-related materials while simultaneously improving their critical thinking skills.

One learning model that can be employed is the RADEC (Read, Answer, Discuss, Explain, and Create) learning model. The RADEC model was developed by Sopandi (2019) as a learning model oriented toward developing 21st century skills through activities of reading, answering questions, discussing, explaining, and creating products. This model encourages students to actively construct their own knowledge, thereby making the learning process more meaningful. Previous studies have reported positive impacts of the RADEC learning model on students higher order thinking skills. A systematic literature review conducted by Lami'ah et al. (2026) found that the implementation of RADEC contributes to the improvement of students analytical, evaluative, creative, and scientific communication skills. In addition, Utami et al. (2026) reported that the RADEC model assisted by student worksheets (LKPD) significantly improved elementary school students' critical thinking skills compared to RADEC implementation without LKPD support. These findings indicate that RADEC has strong potential to facilitate the development of higher order thinking skills in elementary school learning.

Technological advancements in education encourage teachers to create innovative and engaging learning experiences (Aeni, Rahmawati, et al., 2025). The development of digital technology has not only transformed how teachers deliver learning materials but has also changed how students acquire, understand, and process information during the learning process (Aprilia et al., 2025). When utilized appropriately, technology transforms the classroom into a center of active exploration. It helps students develop essential 21st century skills (4C: Critical Thinking, Creativity, Collaboration, and Communication) through highly contextualized learning experiences (Mardiana et al., 2024). Appropriate utilization of technology can facilitate more active, contextual, and student centered learning, thereby supporting the development of 21st-century skills, including critical thinking abilities. The use of technology can also facilitate students access to learning through more interactive approaches (Aeni, Lazuardi, et al., 2025).

Technological developments have also created new opportunities and potential in education through the utilization of Artificial Intelligence (AI). The use of AI in learning can help students obtain information quickly and comprehensively. In addition, AI provides opportunities to create learning experiences tailored to various learning styles and preferences (Aisyah et al., 2025). However, in this study, AI is not utilized as a tool that provides instant answers. Instead, it serves as a medium to assist students in building initial understanding during the Read stage and as a resource for evaluating and comparing answers during the Discuss stage. Consequently, students are still required to analyze and evaluate information critically based on their own understanding. Therefore, innovative and contextual learning that integrates technology, including Artificial Intelligence, is needed to help students understand information more comprehensively and enhance their critical thinking skills (Widiansyah, 2025).

Although previous studies have demonstrated the effectiveness of the RADEC model and the use of various learning supports such as worksheets and digital media, studies integrating AI into the RADEC learning syntax remain limited. Existing studies generally focus on the effectiveness of RADEC itself or on the use of AI as a standalone learning technology. Research examining the integration of AI within the RADEC stages to improve elementary school

students' critical thinking skills, particularly on natural disaster topics, is still scarce. Therefore, this study seeks to fill this gap by integrating AI into the Read and Discuss stages of the RADEC model.

This study contributes to the literature by integrating AI into the Read and Discuss stages of the RADEC model, where AI functions as a tool for critical evaluation rather than as a direct answer provider. Unlike previous studies that primarily utilized AI as a source of information, this study integrates AI into the Read and Discuss stages to encourage students to analyze, compare, validate, and reflect on information critically based on their own understanding. This approach is expected to contribute to the development of critical thinking skills while supporting meaningful learning about natural disasters.

Based on the identified research gap, this study addresses the question of whether the AI-integrated RADEC learning model is more effective than the Problem-Based Learning (PBL) model in improving fifth-grade students' critical thinking skills on natural disaster topics. Therefore, this study aims to determine the effectiveness of the Artificial Intelligence (AI)-integrated RADEC learning model in improving the critical thinking skills of fifth-grade students on the topic of natural disasters**.**

METHOD

This study employed a quantitative approach using a quasi-experimental research design, specifically the nonequivalent control group design. A quasi experimental design was implemented using two groups, namely an experimental class and a control class (Anantasia, 2025). The experimental class received instruction through the AI-integrated RADEC learning model, while the control class was taught using the Problem-Based Learning (PBL) model. Both groups were administered a pretest before the treatment and a posttest after the learning process to determine changes in students' critical thinking skills.

The study was conducted at SD Negeri Tegalkalong I, Sumedang Regency, Indonesia. The population consisted of fifth-grade elementary school students. The research participants comprised 60 students divided into two classes, with 30 students assigned to the experimental class and 30 students assigned to the control class. The sampling technique employed was purposive sampling, in which participants were selected based on specific considerations aligned with the objectives of the study (Subhaktiyasa, 2024). The selection criteria included students were enrolled at SD Negeri Tegalkalong I, which possesses adequate facilities and technological infrastructure to support technology integrated learning, students had not previously experienced the AI-integrated RADEC learning model on natural disaster topics, and students demonstrated critical thinking skills that required further development based on classroom observations, learning outcomes, and Higher Order Thinking Skills (HOTS) based tasks.

The primary research instrument was a HOTS based critical thinking test consisting of 19 essay items developed according to Ennis's critical thinking indicators, including elementary clarification, basic support, inference, advanced clarification, and strategies and tactics. The instrument was designed to measure students cognitive abilities at the C4 (analyzing), C5 (evaluating), and C6 (creating) levels of the revised Bloom's Taxonomy (Nisa & Chusni, 2026). Prior to implementation, the instrument was reviewed and validated by two experts in elementary education and educational assessment. The experts evaluated the relevance of the items to the research objectives, the alignment with Ennis's critical thinking indicators, the clarity of language, and the suitability of the items for fifth-grade students. Revisions were made based on the experts' suggestions before the instrument was administered. The validation results indicated that the instrument was appropriate for use in the study. Furthermore, the reliability analysis yielded a Cronbach's Alpha coefficient of 0.875, indicating high internal consistency and reliability. In addition, observation sheets were utilized to assess teacher performance and student activities during the learning process. Documentation in the form of photographs, learning materials, and other supporting documents was also collected to strengthen the research findings (Mardiana et al., 2024).

The research procedure consisted of three stages: preparation, implementation, and evaluation. During the preparation stage, lesson plans, learning materials, research instruments, and observation sheets were developed. Subsequently, a pretest was administered to both groups to determine students initial critical thinking abilities. During the implementation stage, the experimental class received instruction through the AI-integrated RADEC learning model, while the control class was taught using the PBL model. The RADEC learning model consists of five stages Read, Answer, Discuss, Explain, and Create. In this study, AI was integrated specifically into the Read and Discuss stages. During the Read stage, students utilized AI as an additional learning resource to build initial understanding of natural disaster topics. During the Discuss stage, students compared the results of their group discussions with AI generated responses prepared by the teacher to evaluate the accuracy, relevance, and completeness of information critically. The AI tool used in this study was ChatGPT (GPT-4). The prompts were developed by the teacher based on the learning objectives, key concepts of natural disasters, and discussion questions used during the learning process.

The AI-generated responses were reviewed and verified by the teacher before being used as reference materials during the Discuss stage to ensure their accuracy, relevance, and suitability for fifth-grade students. Meanwhile, the Answer, Explain, and Create stages were conducted independently without direct AI assistance, allowing students to develop critical thinking skills through their own reasoning and analytical processes. Following the implementation of the learning treatments, a posttest was administered to both groups to measure changes in students' critical thinking skills.

Data were collected through tests, observations, and documentation. The testing technique was employed to measure students' critical thinking skills before and after the implementation of the learning models using a HOTS based instrument (Huda et al., 2025). Observations were conducted to examine student activities and teacher performance throughout the learning process, particularly during the implementation of the AI-integrated RADEC learning model. Documentation was used to support the research findings through learning activity photographs, instructional materials, and other documents related to the study.

The research data were analyzed using descriptive and inferential statistical analyses with the assistance of SPSS software. Descriptive statistics were employed to describe students critical thinking scores through mean, minimum, maximum, and standard deviation values (Martias, 2021). Inferential statistical analyses included normality tests, homogeneity tests, paired sample t-tests, independent sample t-tests, and N-Gain analysis (Alhaaniyah et al., 2025). The normality test was conducted to determine whether the data were normally distributed, while the homogeneity test was used to examine the equality of variances between groups. Paired sample t-tests were employed to identify differences between pretest and posttest scores within each group, whereas the independent-sample t-test was used to determine differences in critical thinking skills between the experimental and control groups following the learning intervention. To measure the effectiveness of the learning models in improving students' critical thinking skills, N-Gain analysis was also conducted. The level of significance for all statistical analyses was set at 0.05.

RESULTS

This study aimed to determine the effectiveness of the Artificial Intelligence (AI) integrated RADEC learning model in improving fifth-grade students' critical thinking skills on natural disaster topics. The results are presented based on students critical thinking test scores, N-Gain analysis, observations of teacher performance and student activities, as well as statistical hypothesis testing. Table 1 presents the results of students' critical thinking skills tests in both the experimental and control classes.

Table 1. Students' critical thinking skills Test Results

Class	N	Score Range	Average score	
			Pretest	Posttest
Experimental	30	100	38.77	88.63
Control	30	100	40.63	76.20

Based on Table 1, the experimental class obtained a mean pretest score of 38.77, which increased to 88.63 on the posttest. Meanwhile, the control class achieved a mean pretest score of 40.63, which increased to 76.20 on the posttest. These results indicate that students in both groups demonstrated improved performance in critical thinking tasks following the learning intervention. However, the greater increase observed in the experimental class suggests a stronger improvement in students' critical thinking performance compared to the control class. Overall, both the AI-integrated RADEC learning model and the Problem-Based Learning (PBL) model contributed to the improvement of students' critical thinking skills, although the gains achieved by the experimental class were substantially higher. The increase in posttest scores suggests that students were better able to apply critical thinking skills when responding to disaster-related problems after participating in the learning activities. To further examine the effectiveness of the two learning models, an N-Gain analysis was conducted. The results are presented in Table 2.

Table 2. N-Gain Analysis Results

Learning Model	N-Gain	Category
AI-integrated RADEC	0.8152	High
Problem-Based Learning	0.6013	Medium

Based on Table 2, the experimental class that implemented the AI-integrated RADEC learning model obtained an N-Gain score of 0.8152, which falls within the high category. Meanwhile, the control class that employed the PBL model achieved an N-Gain score of 0.6013, categorized as medium. The results suggest that both learning models were effective in improving students' critical thinking skills. However, the AI-integrated RADEC learning model produced

a higher level of improvement than the PBL model. The higher N-Gain score in the experimental class indicates that students achieved greater improvement in critical thinking performance compared to those in the control class. This finding suggests that the AI-integrated RADEC model was more effective in facilitating the improvement of students' critical thinking skills throughout the learning intervention. The results are presented in Table 3.

Table 3. Teacher Performance Observation Results

RADEC Syntax	Meeting 1	Meeting 2
Read	3	4
Answer	3	4
Discuss	4	4
Explain	3	4
Create	-	4
Total Score	**13**	**20**
Percentage	**81.25%**	**100%**
Category	**Good**	**Very Good**

Based on Table 3, teacher performance improved from the first meeting to the second meeting. During the first meeting, teacher performance reached 81.25%, categorized as good, and subsequently increased to 100%, categorized as very good, during the second meeting. These results indicate that the teacher became more effective in implementing each stage of the AI-integrated RADEC model. The improvement was particularly evident in the teacher's ability to facilitate classroom discussions, guide students in evaluating AI-generated responses, and encourage evidence-based reasoning. This suggests that the learning procedures were implemented more consistently as the lessons progressed. It should be noted that the Create stage was not implemented during the first meeting because the learning activities were focused on introducing the natural disaster concepts and completing the Read, Answer, Discuss, and Explain stages. The Create stage was conducted in the second meeting after students had developed sufficient understanding of the learning material. Student activity during the implementation of the AI-integrated RADEC model was also observed, and the results are presented in Table 4.

Table 4. Student Activity Observation Results

RADEC Syntax	Meeting 1	Meeting 2
Read	3	4
Answer	3	4
Discuss	4	3
Explain	3	4
Create	-	4
Total Score	**13**	**19**
Percentage	**81.25%**	**95%**
Category	**Good**	**Very Good**

Based on Table 4, student activity increased from 81.25% during the first meeting to 95% during the second meeting, reaching the very good category. The data demonstrate that students became increasingly active and engaged throughout the learning process. During the discussion activities, students were observed comparing their own answers with the AI-generated references, identifying differences in information, and providing arguments to support their conclusions. Several students also demonstrated greater confidence in expressing opinions and asking questions during classroom discussions. These observations indicate that students were not only participating actively but were also engaging in reflective and analytical thinking processes. Similar to the teacher observation results, the Create stage was only implemented during the second meeting. Therefore, no observation score was recorded for this stage in the first meeting. Before conducting hypothesis testing, normality and homogeneity tests were performed to determine whether the data met the assumptions required for parametric statistical analysis. The results are presented in Table 5.

Table 5. Results of Normality and Homogeneity Tests

Statistical Test	Sig. Value	Description
Experimental Pretest Normality	0.186	Normal
Experimental Posttest Normality	0.298	Normal
Control Pretest Normality	0.143	Normal
Control Posttest Normality	0.432	Normal
Homogeneity	0.064	Homogeneous

Based on Table 5, all significance values exceeded 0.05, indicating that the data were normally distributed. Furthermore, the homogeneity test yielded a significance value of 0.064 (> 0.05), indicating that the variances of the experimental and control groups were homogeneous. After fulfilling the prerequisite assumptions, paired sample t-tests and an independent sample t-test were conducted to determine differences in students' critical thinking skills (Hastuti et al., 2024).

Table 6. Results of Paired-Sample t-Tests and Independent-Sample t-Test

Statistical Test	Sig.	Description
Experimental Paired Sample t-Test	0.001	Significant
Control Paired Sample t-Test	0.001	Significant
Independent Sample t-Test	0.001	Significant Difference

Based on Table 6, the paired-sample t-tests for both the experimental and control groups yielded significance values of 0.001 (< 0.05), indicating that both the AI-integrated RADEC learning model and the Problem-Based Learning (PBL) model significantly improved students' critical thinking skills after the learning intervention. Furthermore, the independent-sample t-test produced a significance value of 0.001 (< 0.05), confirming a significant difference between the two groups. These findings indicate that although both learning models were effective, the AI-integrated RADEC model demonstrated significantly greater improvement in students' critical thinking skills than the PBL model. Beyond the statistical results, classroom observations also revealed positive changes in students' critical thinking behaviors. Students increasingly provided reasons for their answers, evaluated the accuracy of information, and compared different sources before drawing conclusions. These behaviors were particularly evident during the Discuss stage, where students critically examined AI-generated responses rather than accepting them without question.

DISCUSSION

The results indicate that the Artificial Intelligence integrated RADEC learning model was effective in improving the critical thinking skills of fifth-grade elementary school students on natural disaster material. This effectiveness was reflected in the significant increase in students posttest scores, the results of the paired sample t-test and independent sample t-test, and the high N-Gain score achieved by the experimental class. The findings demonstrate that both the AI-integrated RADEC model and the Problem-Based Learning (PBL) model were effective in improving students' critical thinking skills. Nevertheless, the AI-integrated RADEC model produced higher learning gains than the PBL model, despite both models being effective in improving students' critical thinking skills.

The improvement in students' critical thinking skills can be explained through the characteristics of the RADEC learning model itself. According to Sopandi (2019), the RADEC model was specifically designed to develop 21st century competencies through the stages of Read, Answer, Discuss, Explain, and Create. These stages encourage students to actively construct knowledge, engage in collaborative learning, and develop higher-order thinking skills. Similarly, Yulianti et al. (2023) reported that the RADEC model positively influences students learning outcomes because it promotes active participation and independent learning. The findings of the present study support these previous results, indicating that the systematic implementation of RADEC can facilitate the development of critical thinking skills.

The significant improvement observed in the experimental class was particularly influenced by the integration of AI during the Read and Discuss stages. During the Read stage, students independently explored information regarding natural disasters through various learning resources supported by AI. This activity encouraged students to identify, analyze, and select relevant information before participating in classroom discussions. Such learning experiences align with constructivist learning theory, which emphasizes that knowledge is actively constructed by learners through interaction with information and learning experiences (Julia et al., 2024). Therefore, students were not passive recipients of information but became active participants in the learning process.

During the Discuss stage, students were encouraged to evaluate information critically through comparison and reflection activities. Students compared the results of their group discussions with AI generated responses prepared by the teacher and then analyzed the similarities, differences, and accuracy of the information obtained. This process required students to apply critical thinking skills, including interpretation, evaluation, analysis, and decision-making. Critical thinking skills enable students to evaluate information systematically and make logical decisions based on evidence (Kusuma et al., 2024). Similarly, Novandi et al. (2025) emphasized that critical thinking skills are essential competencies that should be developed from the elementary school level to prepare students for increasingly complex challenges in the future.

The findings of this study also support previous research regarding the educational potential of Artificial Intelligence. AI can provide broad and rapid access to information and create more personalized learning experiences (Aisyah et al., 2025). Likewise, Widiansyah (2025) argued that technology integration can facilitate students learning processes and support the development of higher order thinking skills. However, unlike many educational applications of AI that position technology primarily as a source of answers, the present study utilized AI as a medium for critical evaluation. Students were encouraged to assess and verify information generated by AI rather than simply accepting it as correct. This approach helped maintain students cognitive engagement and prevented excessive dependence on technology.

The effectiveness of the AI-integrated RADEC learning model was further supported by the observation results of teacher performance and student activities. Teacher performance improved from 81.25% during the first meeting to 100% during the second meeting, while student activity increased from 81.25% to 95%. These findings indicate that both teachers and students became increasingly familiar with the implementation of the learning model. Mardiana et al. (2024) emphasized that teachers play a crucial role as facilitators in 21st century learning environments by creating active and student-centered learning experiences. The observation results suggest that the teacher successfully fulfilled this role by guiding students through each stage of the RADEC model systematically. It should also be noted that the Create stage was implemented only during the second meeting after students had completed the preceding RADEC stages and developed sufficient conceptual understanding of the topic.

Although overall student activity increased throughout the implementation, a slight decrease was observed in the Discuss stage during the second meeting. One possible explanation is that students devoted more attention to evaluating AI-generated responses, resulting in less verbal interaction during group discussions. However, this finding may also indicate that some students experienced difficulties in sustaining collaborative discussion while simultaneously engaging in information verification activities. Therefore, the decrease should be interpreted cautiously and warrants further investigation in future studies involving longer implementation periods and more detailed observation procedures.

The results of the statistical analyses further strengthened the effectiveness of the learning model. The normality and homogeneity tests confirmed that the data met the assumptions required for parametric testing. Subsequently, the paired sample t-test results showed significant differences between pretest and posttest scores in both groups, while the independent sample t-test revealed a significant difference between the experimental and control groups. Similar findings have been reported in previous studies demonstrating that innovative and student centered learning models can significantly improve critical thinking skills (Hafid et al., 2025; Hastuti et al., 2024).

The N-Gain analysis also provided evidence of the effectiveness of the AI-integrated RADEC learning model. The experimental class achieved an N-Gain score of 0.8152, categorized as high, whereas the control class obtained a score of 0.6013, categorized as medium. According to Dewi and Yahya (2022), N-Gain analysis is useful for measuring the effectiveness of learning interventions by assessing the magnitude of learning improvement. The substantial difference between the two groups indicates that integrating AI into the RADEC learning process contributed significantly to students critical thinking development.

The findings of this study are also relevant to current educational challenges. Previous studies have highlighted that Indonesian students' critical thinking skills remain relatively low and that learning processes often emphasize content mastery rather than higher-order thinking development (Mazidah, 2024). Through the integration of AI within the RADEC framework, students were encouraged to engage in deeper analysis, evaluation, and reflection. This learning process not only improved students understanding of natural disaster concepts but also strengthened their ability to think critically when confronting real world problems.

These findings extend previous studies on RADEC and AI-assisted learning by demonstrating that AI can be integrated into elementary classroom activities as a tool for information evaluation and reflective thinking. The results suggest that the combination of constructivist learning principles and AI-supported activities may provide meaningful opportunities for developing students' critical thinking skills.

Despite the positive findings, this study has several limitations. First, the implementation of the AI-integrated RADEC learning model was conducted over only two learning sessions and involved participants from a single elementary school with a relatively small sample size. Consequently, the findings may not fully represent the long-term effects or broader applicability of the intervention. Second, ChatGPT was used as the sole AI tool in the learning process. Because AI-generated responses may vary across platforms and depend on prompt design, the results may have been influenced by the specific characteristics of ChatGPT. Therefore, future studies are recommended to involve longer implementation periods, larger and more diverse samples, and comparisons across different AI systems.

From a practical perspective, the findings suggest that the AI-integrated RADEC learning model can serve as an alternative instructional approach for developing critical thinking skills in elementary schools. Teachers may utilize AI strategically as a supporting tool that encourages students to evaluate information critically rather than rely solely on technology generated responses. From a theoretical perspective, this study contributes to the growing body of knowledge concerning the integration of artificial intelligence and constructivist learning approaches in developing 21st century competencies, particularly critical thinking skills.

CONCLUSION

This study concludes that both the Artificial Intelligence (AI)-integrated RADEC learning model and the Problem-Based Learning (PBL) model were effective in improving the critical thinking skills of fifth-grade elementary school students on natural disaster material. However, the AI-integrated RADEC learning model produced significantly greater improvements in students' critical thinking skills than the PBL model, as evidenced by the higher posttest achievement, the N-Gain score of 0.8152 (high category) compared to 0.6013 (medium category), and the independent-sample t-test result ($p = 0.001 < 0.05$).

The findings suggest that the effectiveness of the AI-integrated RADEC learning model was influenced by the implementation of the Read and Discuss stages, where AI functioned as a learning support tool that encouraged students to explore, compare, evaluate, and validate information critically rather than merely receive answers. This process enabled students to actively construct knowledge, engage in reflective thinking, and develop higher-order thinking skills. The study also provides empirical evidence regarding the integration of AI into the RADEC learning model in elementary disaster education, particularly through the use of AI as a tool for information evaluation and reflection rather than as a direct answer provider.

Nevertheless, the findings should be interpreted within the context of the study's limitations. The intervention was conducted in only one elementary school, involved a relatively small sample of 60 students, and was implemented over only two learning sessions, which may not fully capture the long-term effectiveness and consistency of the AI-integrated RADEC learning model. In addition, ChatGPT was used as the sole AI tool, which may limit the generalizability of the findings to other educational contexts and AI platforms. Therefore, the results cannot be generalized broadly without caution.

Future studies are recommended to investigate the implementation of AI-integrated RADEC learning across different subject areas, grade levels, and educational settings, as well as over longer intervention periods. Further research should also compare different AI platforms and examine their effects on critical thinking skills and other 21st-century competencies, such as creativity, collaboration, and communication.

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AUTHOR CONTRIBUTION STATEMENT

LK conceptualized the study, collected and analyzed the data, conducted the research, and prepared the original manuscript. AA contributed to the research design, supervised the study, and provided guidance in data interpretation and manuscript development. AS contributed to the research methodology, validated the findings, and reviewed and revised the manuscript. All authors read and approved the final version of the manuscript.

AI DISCLOSURE STATEMENT

The authors used generative AI tools for language refinement and grammatical editing during manuscript preparation. All intellectual content, data analysis, interpretation of findings, and final revisions were conducted by the authors, who take full responsibility for the accuracy and integrity of the manuscript.

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