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Transforming Primary Science Learning with AI-Based Interactive Multimedia: Impacts on Critical Thinking Skills in Primary Education

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Abstract: This study aims to develop AI-based interactive multimedia and evaluate its feasibility and effectiveness in enhancing the critical thinking skills of elementary school students. The research employed a Research and Development (R&D) method using the ADDIE model, consisting of the Analysis, Design, Development, Implementation, and Evaluation phases. The participants were 52 elementary school students. The instruments used in this study included expert validation questionnaires, user response questionnaires, and critical thinking test sheets. Data were analyzed through expert validation analysis, teacher and student practicality response analysis, and critical thinking test analysis of students in the experimental and control groups using the t-test and N-Gain test. The expert validation results showed average scores of 93.7% from material experts, 94.8% from media experts, and 95% from linguists, all categorized as "very valid," indicating that the AI-based interactive multimedia is highly appropriate for use. The effectiveness test, conducted by comparing pretest and posttest results of 26 control-class students and 26 experimental-class students, revealed that the control class obtained an average pretest score of 58.85 and a posttest score of 75.00, whereas the experimental class obtained 60.05 and 86.08, respectively. The t-test yielded a Sig. (2-tailed) value of 0.000 < 0.05, indicating a significant difference in students' critical thinking abilities between the experimental and control classes. The N-Gain score of 65 indicated a moderately effective category. In conclusion, the AI-based interactive multimedia developed for science learning content is feasible and effective in improving elementary students' critical thinking skills.

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Introduction

Critical thinking is shown by the individual's ability to criticize various phenomena that occur around him and assess using his or her point of view. Then the individual is able to position himself from an inappropriate situation, to a situation that is in his favor. Critical thinking skills are abilities that must be possessed by students in learning (Mahanal et al., 2019). In science learning, students are expected to actively search for and find concepts, be able to analyze a problem, actively discuss, dare to speak to convey ideas, be able to write work results as reports, and be able to read and convey work results. Natural Sciences is one of the subjects presented from the elementary school level (Subali et al., 2019). Several learning problems arise in science learning in elementary school. There is often a perception that science material is material whose characteristics tend to be more abstract and oriented

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towards memorization. Learning science is often considered something boring because it only applies conventional methods with lectures and the use of textbooks (Clark & Mayer, 2024).

Science learning can also be more fun if teachers are able to see the complementary needs of students in the current digital era, namely *gadgets*. Science learning activities will be more interesting if teachers are able to combine learning with the desire to access *large gadgets* from students in the digital era. Science learning in elementary school should indeed be carried out in a fun way by using various approaches, media, and diverse learning resources (Widyaningrum et al., 2022). Teachers' explanations with digital-based media will make it easier for students to understand the concepts that are basic for science learning (Mansur et al., 2024). With the use of learning videos as a medium, it not only helps teachers in delivering material, but also makes it easier for students to understand the learning process in a more interesting and interactive way (Kusmaryono & Basir, 2024).

The documentation study in the form of the results of the critical thinking ability test for grade V students of Kedungsegog State Elementary School 01 showed that 63% obtained a score below average. This is the basis for researchers to find a solution in improving critical thinking skills in science learning. In addition to the documentation study, the researcher distributed a questionnaire to 5 elementary school teachers and the results showed that most teachers agreed that their critical thinking skills may be influenced by the limitations of the delivery of abstract science learning materials that are very difficult to teach to students. This is because the medium of delivery of the material is very monotonous. Supported by the results of interviews with 10 grade V elementary school students, it shows that 75% of students stated that not all science learning materials can be understood well. In addition, students' interest in learning in participating in science learning is still not optimal. Students tend to chat more and are bored during learning. Therefore, there needs to be a breakthrough and innovation that can spur the enthusiasm of students to participate in science learning activities.

In science learning, there are things that need to be considered, including connecting knowledge with practices and problems, using technology, and making it real (Meedya et al., 2019). Therefore, it would be good for science learning to have a medium that teachers can use to facilitate students to learn to understand abstract science concepts. There are also several relevant studies that prove that multimedia learning can be used in elementary school children (Maizura et al., 2021). The results of the study have proven that the role of multimedia has a positive significance applied to elementary school age students. This is because the integration of graphics, text, images, sounds, and animations makes learning more concrete, fun, and can increase student activity. Of course, this multimedia concept supports Piaget's theory related to the cognitive development of elementary school students still in the concrete operational stage. Thus, multimedia can be used in elementary school age students. Furthermore, the researcher also analyzed the role of interactive multimedia in science lesson content in elementary schools. In its development, the use of interactive media is increasing through the integration of artificial intelligence (AI) in interactive multimedia, thereby creating a more dynamic, adaptive, and responsive learning environment to student needs.

The development of artificial intelligence technology in the field of education opens up new opportunities in the development of more innovative and adaptive learning media. With its ability to analyze student learning data in a sophisticated way, AI allows for personalization and high adaptability in the educational process, aligning the material with the individual's level of understanding and learning style (Pamungkas et al., 2024). This not only optimizes the absorption of material but also prepares students with essential digital

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skills in the modern era (Firdaus et al., 2024). One form of utilization is the use of AI-based multimedia that is able to provide an interactive, responsive, and learning experience that meets the needs of students. The presence of this media is not only aimed at delivering material, but also serves as a smart learning environment that can encourage the development of students' cognitive abilities through the presentation of structured information, visualization of interesting concepts, and instant feedback mechanisms. *Artificial intelligence* helps students understand the material, in addition to being able to form characters and skills that will later be able to face developments or changes in the world. The application of AI in education also not only helps students to keep up with technological developments, but also provides advantages in facing future challenges (Anas, 2025)

In addition, AI also encourages the development of critical and creative thinking skills, which are in line with the demands of the ever-evolving technological era (DE SOUSA NUNES, 2024). The use of AI-based multimedia also has a strong connection with critical thinking theory.This is because problem-based multimedia can facilitate the development of various aspects of critical thinking skills, such as focusing questions, analyzing arguments, and evaluating the credibility of information sources. Moreover, engaging with interactive multimedia in a problem-based context encourages students to reflect critically on their decisions and the resulting outcomes, thereby sharpening their analytical and diagnostic capabilities (Ding et al., 2024; Hilmi et al., 2024) Thus, AI-based interactive multimedia is a potential means in developing students' critical thinking skills in a systematic, measurable, and relevant way to the demands of 21st century learning.

Current research is oriented towards the development of critical thinking skills of elementary school students in a science learning environment. One of the solutions that can encourage the improvement of critical thinking skills is through the use of AI-based interactive multimedia. This medium allows students to interact with abstract scientific concepts in a more concrete and interesting way. AI-based interactive multimedia students can visually see and understand scientific processes, such as in magnetic matter, electricity and technology for life, with this multimedia can stimulate their critical thinking and analytical skills. This research aims to develop AI-based interactive multimedia and evaluate its feasibility and effectiveness in enhancing the critical thinking skills of elementary school students. Through this approach, it is hoped that students will not only memorize facts, but also be able to develop critical thinking, creative and problem-solving skills, which are key in creating more meaningful and relevant learning in this digital era.

Research Method

This study employed a research and development (R&D) method using the ADDIE model—Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). The research produced AI-based interactive multimedia and examined its feasibility and effectiveness. Sampling was carried out using a purposive sampling technique, involving 26 students from Kedungsegog 01 State Elementary School and 26 students from Kedungsegog 02 State Elementary School. The research instruments consisted of teacher and student interview sheets, expert validation questionnaires, teacher and student response questionnaires, and critical thinking skills tests. The validation process involved expert evaluations using structured validation questionnaires, with results categorized according to predetermined criteria.

Table 1. Questionnaire Validation Criteria

Average Percentage of Total	Validity Level
$80\% < P \leq 100\%$	Very Valid

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60% < P ≤ 80%	Valid
40% < P ≤ 60%	Fairly Valid
20% < P ≤ 40%	Less Valid
0%< P ≤ 20%	Not Valid

Source: Arikunto (2004)

The following are the effectiveness criteria based on the interpretation category of the N-Gain value used to determine the level of effectiveness of improvement, from the results of the critical thinking ability test of students in the control class and the experimental class shown in Table 2.

Table 2. N-Gain Effectiveness Interpretation Categories

Percentage (%)	Interpretation
< 40	Not Effective
40 – 55	Less Effective
56 – 75	Quite Effective
> 76	Effective

(Hake, 1999:1)

Result and Discussion

The results of the study show that the developed AI-based interactive multimedia effectively enhances the critical thinking skills of fifth-grade elementary school students. This improvement is attributed to the adaptive, exploratory, and feedback-based learning experiences provided through the multimedia. By presenting realistic learning contexts, the AI-based system encourages students to solve complex problems using evidence and logical reasoning. The implementation of the multimedia aligns with several modern learning theories. From a constructivist perspective, it supports active learning by enabling students to build knowledge through hands-on activities and problem-solving. Consistent with Vygotsky's theory, AI facilitates scaffolding that helps learners construct their understanding more effectively (Maulani et al., 2022). Additionally, the use of AI follows Mayer's Cognitive Theory of Multimedia Learning, which highlights the importance of multimedia design in optimizing cognitive load to enhance comprehension (Musyafak & Subhi, 2023; Willis, 2023).

The presentation of evaluations contained in AI-based multimedia with a Problem Based Learning (PBL) approach can encourage students to look for evidence, use logical reasoning, and make decisions independently. This process also includes the development of critical thinking skills, considering that students are required to analyze information, evaluate alternative solutions, and construct understandings based on strong arguments. The preparation of problem-solving steps provided on AI-based interactive multimedia helps students understand how to reason systematically. AI-based interactive multimedia works through a blend of theory, cognitive mechanisms, and effective instructional design, resulting in a significant improvement in students' critical thinking abilities.

The results of the study explain the process of developing AI-based interactive multimedia starting from needs analysis, design processes, development, implementation, and evaluation, as well as testing the effectiveness of AI-based interactive multimedia products in science lessons. Furthermore, the discussion section describes the results of the analysis of research and development findings.

Analysis

a) Analysis of Learning Media Needs

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Analysis by conducting interviews with 2 class V teachers to obtain information about students' learning conditions in the classroom, the use of learning media, and the learning media needed. The results of teacher interviews rarely use learning media during the learning process. In addition, the learning media that is often used by teachers are textbooks from the government and companion books purchased independently as well as learning media in the form of PPT or videos that are already available on the platform. The selection of learning media needs to be adjusted to the learning characteristics of students and relevant materials that can improve students' critical thinking skills, which are relatively low. This condition can be seen when students are given questions that require critical thinking skills and are unable to answer these questions according to the indicators of critical thinking ability. The use of AI-based science learning media is a medium that is considered appropriate to be used in elementary school student learning.

b) Learning Environment Analysis

The results of the analysis of the learning environment show that in the learning process carried out it shows that (1) the ability to formulate questions by students is still lacking, (2) the ability to plan problem-solving strategies is still not good. It is seen that students still need help from teachers in solving a problem in learning, (3) the ability to evaluate students in the category is still not able to solve problems, that is, students have not been able to calculate correctly and make conclusions from solving the problem completely.

Design

a) Development Design

In the initial design of the development of AI-based learning media, the steps taken by the researcher at this stage are, a) Data collection of materials, layouts, and images, b) *Storyboard*, c) AI-based learning media framework.

b) AI-based interactive Multimedia development

At the development stage, the researcher uses an *articulate story line application* which is an application to create learning media. Materials and assets are obtained from *cancva* and *freepic*. The creation of media products begins with creating an *articulate story line PPT display* consisting of learning materials, watching videos, games/games and practice questions. The components of the media are; 1) introduction; 2) curriculum; 3) instructions for use; and 4) material.

Development

Subject Matter Expert Validation

Validation of material experts is useful for assessing the suitability of material in AI-based interactive media. Aspects assessed by subject matter experts include the content of the material, the accuracy of the material and the feasibility of the material. The results of the material validation of science learning media are presented in the following Table 3.

Table 3. Results of Validation of Subject Matter Experts

Aspects	Validator		Score	Percentage		Average	Criterion
	1	2	Maximum	1	2		
Contents of the material	11	12	12	92	100	96	Very valid
Material accuracy	15	14	16	94	88	91	Very valid
Material Availability	7	8	8	88	100	94	Very valid
Critical thinking	22	23	24	92	96	94	Very valid

Based on Table 3, it is shown that the analysis of material validation of AI-based interactive media shows that the content of the material, the accuracy of the material, and the feasibility of the material are classified as very valid. However, it needs to be revised in accordance with criticism and suggestions so that it is worth using.

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Media expert validation

Media expert validation is useful for validating the ease of use, writing, display, and use of AI-based learning media. The validation aims to ensure that the developed media can be used and applied in the field without any obstacles in the learning process The results of the validation of AI-based science learning media are presented in Table 4 below

Table 4. Media Expert Validation Results

Aspects	Validator		Score Maximum	Percentage		Average	Criterion
	1	2		1	2		
Substance	8	7	8	100	88	94	Very valid
User	11	12	12	92	100	96	Very valid
Writing	15	14	16	94	88	91	Very valid
Display	16	15	16	100	94	97	Very valid
Media quality	11	12	12	92	100	96	Very valid

Based on Table 4, it is shown that the media validation analysis of the ease of use, writing, display, and use of AI-based learning media shows very valid criteria, but needs to be revised in accordance with criticism and suggestions to be valid for use.

Linguist Validation

Linguists provide assessments related to grammatical aspects in AI-based learning media. The assessment aspect is language clarity and communication. The results of linguists' assessments of AI-based social studies learning media are presented in Table 5 below.

Table 5. Linguist Validation Results

Aspects	Validator		Score Maximum	Percentage		Average	Criterion
	1	2		1	2		
Language Clarity	23	22	24	96	92	94	Very valid
Communicative	12	11	12	100	92	96	Very valid

Based on Table 5, it shows that the analysis of language validation on language clarity and communicability of AI-based learning media shows very valid criteria, but needs to be revised according to criticism and suggestions to be valid for use.

Implementation

The application of AI-based science learning media for Class V in Chapter 3 magnetism, electricity, and technology for life and focus on improving the critical thinking skills of grade V students in elementary school in the product trial field test stages are as follows.

The field-scale trial aims to find out whether AI-based interactive media in science subjects developed is effective and can improve students' critical thinking skills. Field-scale trials were carried out using *pretest* and *posttest.*

Table 6. Student Responses

Student	Aspects	item	Maximum score	Scores obtained	Percentage	Criterion
26	Material	4	104	98	94	Very valid
	Language	2	52	47	90	Very valid
	Display	5	130	122	93	Very valid
	Implementation	4	104	97	93	Very valid

After learning using AI-based interactive media in science subjects is completed, teachers provide responses related to the use of AI-based interactive media in science subjects. The results of the teacher's response were used to assess the ease and implementation of media in learning. The results of teachers' responses to AI-based interactive media in science subjects can be seen in Table 7 below.

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Table 7. Teacher Responses

Aspects	Item	Respond		Maximum score	Percentage		Average	Criterion
		1	2		1	2		
Content quality	8	30	31	32	94	96	95	Very valid
Language	5	19	18	20	95	90	92	Very valid
Implementation	6	22	21	24	92	88	90	Very valid
Display	6	22	23	24	92	96	94	Very valid

The visualization of learning outcomes is presented in the following bar chart, which illustrates the difference between pretest and posttest scores in the experimental and control classes as a basis for assessing the effectiveness of the treatment.

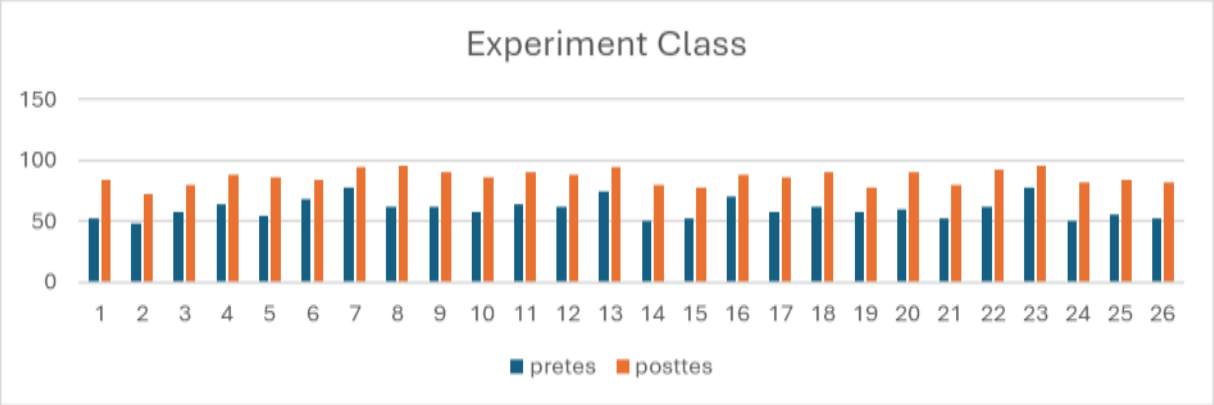

Figure 1. Pretest-posttest experiment graph

The graph shows a comparison of pretest and posttest scores in the experimental class. It can be seen that almost all posttest scores are higher than the pretest scores, indicating an improvement in learning outcomes after the implementation of learning media. To illustrate the score changes in the control class, Figure 2 presents a comparison of the students' pretest and posttest results.

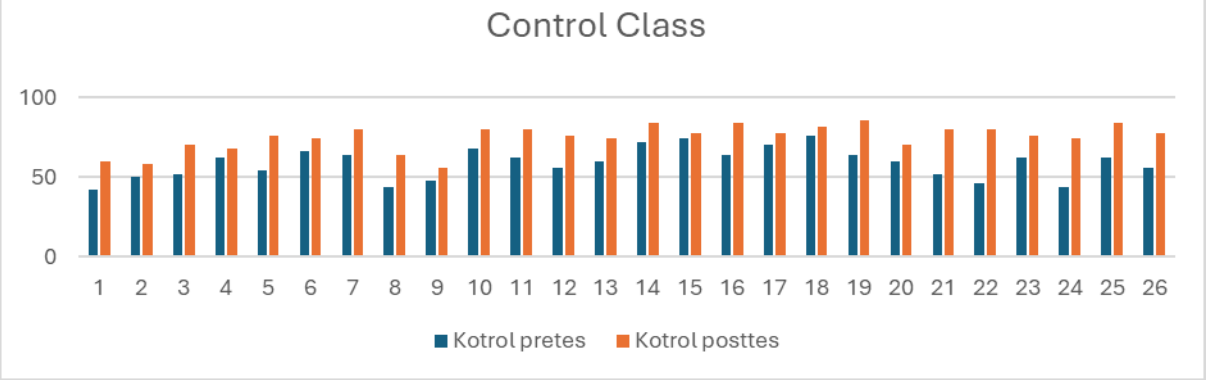

Figure 2. Pretest-posttest control graph

The graph for the control class shows that the posttest scores are slightly higher than the pretest scores, indicating an increase in students' abilities, although not a substantial one. When compared to the experimental class, this improvement is considerably lower. These initial observations were then reinforced through descriptive statistical analysis to provide a clearer picture of the distribution of scores, averages, and overall performance of students in both the control and experimental classes, as shown in Table 8.

Table 8. Descriptive Statistic

	N	Minimum	Maximum	Mean	Std. Deviation
Pretesteks	26	48,00	78,00	60,1538	8,31236
Postesteks	26	72,00	96,00	86,0769	6,05259

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pretestcotrol	26	42,00	76,00	58,8462	9,58621
postestcotrol	26	56,00	86,00	75,0000	8,16333
Valid N (listwise)	26				

The results of the descriptive analysis show that the experimental group experienced an increase in scores from a pretest average of 60.15 to 86.08 on the posttest. The control group also experienced an increase in scores from a pretest average of 58.85 to 75.00 on the posttest, although the increase was not as large as that of the experimental group. The data shows that both groups experienced an increase in learning outcomes, but the increase in the experimental group was higher, to ascertain whether there is a difference in the increase, it is necessary to carry out an independent sample t-test as the next analytical step, the following are the results of the independent sample t-test

Table 9. Independent Sample t-test

		t-test for Equality of Means		
		t	df	Sig. (2-tailed)
Postest	Equal variances assumed	5,558	50	0,00

Based on the results of the Independent Sample t-test, a significance value (Sig. 2-tailed) of 0.000 < 0.05 was obtained, so it can be concluded that there is a statistically significant difference between the experimental group and the control group. Thus, the treatment or intervention given to the experimental group was proven to have a significant effect compared to the control group. The results of the independent t-test, which showed a significant difference between the two groups, formed the basis for continuing the effectiveness analysis through the calculation of N-Gain scores in the experimental and control classes.

Table 10. N-Gain Score Test Results

No	**Class**	**N-Gain Score**	**N-Gain Percent**	**Interpretasion**
1	Experiments	0.65	65	Quite Effective
2	Control	0.39	39	Ineffective

Based on the table 10, it shows that the N-Gain percent in the experimental class is 65 with quite effective interpretation. This means that the use of AI-based interactive multimedia in experimental classrooms is quite effective in improving the critical thinking skills of elementary school grade V students. The percent N-Gain in the control class was 38 with an ineffective interpretation. This means that the use of media that teachers usually give to students in the control class is not effective in improving the critical thinking skills of grade V elementary school students. Thus, it can be concluded that the use of AI-based interactive multimedia is quite effective in improving the critical thinking skills of grade V elementary school students

Evaluation

The evaluation results of AI-based interactive multimedia in science learning show excellent quality based on expert assessments, which state that the media is highly valid and suitable for use in the learning process. From the educators' perspective, teachers' response to the use of AI-based interactive multimedia reached a percentage of 98%, including the very interesting category; teachers assessed that the attractive appearance of the media, clarity of language, and ease of use were able to help improve students' understanding and motivate them to be more active in learning. Student responses also showed that the media was very interesting, with students feeling enthusiastic, finding it easier to understand the material, and considering the learning process to be more enjoyable, interactive, and free from boredom.

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After examining the feasibility and user response, a t-test was conducted to determine its effectiveness on students' critical thinking skills, and the results showed a significant difference between the experimental class that used AI-based interactive multimedia in the context of problem-based learning models and the control class that used conventional media; the average critical thinking score of the experimental class was statistically higher than that of the control class. These results were reinforced by the N-Gain test, which showed that the experimental class obtained an average score of 65% and was categorized as quite effective, while the control class only obtained 39% and was categorized as ineffective. Thus, it can be concluded that AI-based interactive science multimedia is not only valid and preferred by teachers and students, but also proven to be significantly effective in improving the critical thinking skills of elementary school students.

Discussion

Learning conditions in elementary schools have various problems, including teacher-centered learning, so that students do not play an active role and learning goals have not been achieved optimally, because teachers still do not use more interactive learning media. Through the use of AI-based interactive media in science subjects, it can help learning goals to be achieved optimally and be able to create active learning.

This ability is very important to develop because it functions to formulate or solve problems and also make decisions in daily life. In addition, the objectives of science learning that require students to be able to think critically have not been optimally implemented until now(Sutiani et al., 2021). Finally, many learning activities in schools are surrounded by the problem of low student understanding and the level of students' critical thinking skills.(Y. Sari et al., 2025) stated that a learning is said to be successful if students really understand the material given by their teachers, not how good the grades obtained by the students.

The design of AI-based interactive media in science subjects was developed with the aim of improving students' critical thinking skills. AI-based interactive media science learning media developed by the researcher has an attractive appearance, clear material, and media design is adjusted to the level of student development. This media is able to involve students to be active in learning (Tan & Caleon, 2022). The unique appearance of educational games or quizzes can foster a sense of enthusiasm for students in the teaching and learning process. Learning in this way helps to make learning more enjoyable. (Abidin, 2024), stated that student activeness is all positive student activities during the learning process, both physical and non-physical and can be accounted for so that it has a good impact on the learning process and the end of learning.

The results of the validation include suggestions and comments from material experts on AI-based interactive media in science subjects, namely the material contained in AI-based interactive media in science subjects needs to be shortened or points made to make it easier for students to understand the material presented. Furthermore, suggestions and comments from media experts, namely changes in the appearance of the media, include image size, image captions, and symbols or icons on the media. In the writing section, it is necessary to re-select the color, typeface and font size to make it easier to read. Meanwhile, suggestions and comments from linguists are the choice of words that must be adjusted to the characteristics of students. Then, suggestions and comments from practitioners, namely media displays, should be equipped with instructions so that they are easy to use. Based on the results of assessments by material experts, media experts, linguists and practitioners on AI-based interactive media in science subjects, the criteria are very valid. So it can be concluded that AI-based interactive media in science subjects that are developed meet the category of being very valid for use in learning.

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Based on the N-Gain test results, the researcher obtained an average N-Gain score in the quite effective category. This finding indicates that the use of AI-based interactive media in science subjects improved elementary school students' critical thinking skills by 65%. The results of the T test were known to have a Sig. (2-tailed) value of 0.000 < 0.05 there was a significant difference between the average critical thinking ability of students between the experimental class and the control class.The hypothesis test results also show that H_0 was rejected. This result indicates that students' average critical thinking skills differed significantly before and after the treatment. Therefore, this study confirms that AI-based interactive media has an effect on students' critical thinking skills. These results are consistent with a systematic review concluding that multimedia interactivity in learning strengthens higher-order cognitive processes, including critical thinking (Saputra et al., 2023). Conceptually, this study supports the idea that integrating AI in learning such as adaptive support and feedback builds a more responsive learning experience and encourages students to analyze and evaluate more deeply (Kosmas et al., 2025). Practically and pedagogically, teachers can use AI-Based Interactive Multimedia to shift science learning from teacher-centered to student-centered through interactive activities and feedback, while also increasing students' motivation and engagement in learning (Balalle, 2024; Özdemir, 2025).

Conclusion

Based on the results of the research and discussion, the conclusions of this study on the use of AI-based interactive multimedia in science learning are as follows. The AI-based interactive multimedia developed in this study is designed to provide an engaging and interactive learning experience for fifth-grade elementary school students. Expert validation results show that the product is highly valid for use, with an average score of 93.7% from material experts, 94.8% from media experts, and 95% from linguists. Therefore, the AI-based interactive multimedia is considered very valid as a science learning medium. The effectiveness test using a pretest–posttest design involving 26 students in the control class and 26 students in the experimental class indicates that the average pretest scores were 58.85 in the control class and 60.05 in the experimental class, while the average posttest scores were 75.00 in the control class and 86.08 in the experimental class. The independent samples t-test produced a Sig. 2-tailed value of 0.000, which is lower than 0.05, indicating a significant difference in students' critical thinking skills between the experimental and control classes. The percent gain in the experimental class was 65 with a fairly effective interpretation, while the control class obtained a percent gain of 38 with an ineffective interpretation. In conclusion, AI-based interactive multimedia is feasible for use and effective in improving the critical thinking skills of fifth-grade elementary school students in science learning.

Recommendation

The AI animation based interactive media developed in this study currently focuses on energy concepts in science, so it has strong potential to be expanded to cover broader science topics. For teachers, this media is recommended as a student-centered tool that can be paired with guided questions, short discussions, and formative checks to strengthen students' critical thinking and engagement, while allowing teachers to adjust tasks and pacing to students' ability levels. For future researchers, it is recommended to broaden the content and add more AI-driven adaptive features such as personalized feedback and differentiated tasks, then test the media with larger and more diverse samples across schools and grade levels.

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Future studies should also examine longer-term effects, such as learning retention, motivation, and other 21st-century skills, and compare the effectiveness with other digital learning interventions.

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