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Augmented Reality Media: Development and Validation to Improve Critical Thinking Skills of Elementary School Student

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ABSTRACT

This study aims to determine the validity, practicality, and effectiveness of Augmented Reality media in improving the critical thinking skills of fourth-grade students in IPAS subjects in elementary schools. This study uses the Research and Development method with the ADDIE model, which has five stages, namely analyze, design, development, implementation, and evaluation. The study employed a Control Group Pretest-Posttest design with fourth-grade students at Muhammadiyah 1 Ngimbang Lamongan Elementary School. Data analysis was conducted through prerequisite tests and hypothesis testing. The results of the study indicate that: (1) The Augmented Reality learning media was found to be highly valid based on the validation results: media experts 3.80, design 3.84, content 3.86, and learning devices 3.80. (2) The media is considered practical based on student responses in small-group trials (3.46), large-group trials (3.57), and student activities (3.22 and 3.55). (3) The media is also effective, as evidenced by the T-test (0.000) and N-Gain scores of 40.62% (experimental class) and 68.09% (control class). It is concluded that Augmented Reality media can enhance elementary school students' critical thinking skills.

Keywords: media, augmented reality, critical thinking skills

1. Introduction

The curriculum plays a crucial role in education because it determines the direction, content, and learning process that impact the quality of graduates from an institution (Anggraini et al., 2022). In this context, the Merdeka Curriculum emerges as one of the efforts to align the national education system with contemporary developments, emphasizing the importance of character development, competency enhancement, and lifelong learning (Susandi et al., 2025). The Merdeka Curriculum is the government's initiative to address educational challenges, particularly in the post-pandemic “new normal” era (Mulyasa, 2023). This curriculum directs the learning process to not only focus on teachers and materials but also on students as active and reflective subjects of learning. One of the key competencies in the implementation of the Merdeka Curriculum is critical thinking skills (Kemendikbudristek, 2022). The Merdeka Curriculum creates an appropriate space for developing critical thinking skills by balancing the roles of teachers and students (Waruwu et al., 2024).

Critical thinking is an integral part of 21st-century competencies, alongside communication, collaboration, and creativity skills. Critical thinking skills are important as a scientific foundation and key to problem solving (Azzahra & Putri, 2025). These skills enable students to think logically and analytically, as well as to assess and solve problems based on valid information (Apriliani et al., 2021). However, the results of various studies indicate that the critical thinking skills of elementary school students are still

relatively low. This is due to various factors, one of which is the use of conventional teaching methods and media that have not been able to maximize the stimulation of students' cognitive activities (Sofri et al., 2020). Research by (Khasanah et al., 2025) states that the lack of critical thinking skills is caused by the conventional nature of the media used by teachers. In fact, students' critical thinking skills encompass several important aspects, such as identifying problems, analyzing data, drawing conclusions, constructing arguments, and designing solutions (Adisty et al., 2021).

In the learning process, media plays an important role as a means of delivering material, attracting students' attention, and helping to improve their understanding of the concepts being taught. In today's digital era, media is not only used as a tool, but also as an interactive element that can create a more comprehensive learning experience. Research by (Yuliana & Sari, 2021) explains that educational media designed appropriately can encourage increased motivation, creativity, and learning outcomes among students through appealing and needs-based presentations. As information and communication technology (ICT) continues to evolve, the forms of educational media also continue to innovate from conventional to digital and more interactive formats. According to (Prasetyo & Haryanto, 2022), the integration of technology in learning media can create a learning environment that is more responsive to the challenges and demands of the 21st century. Therefore, technological advancements present a strategic opportunity to develop learning media that not only conveys content but also provides a more contextual and in-depth learning experience.

Learning media is a means of conveying information or lesson material to support the teaching and learning process (Anindyah et al., 2024). Learning in the digital age requires media that aligns with students' needs, environment, and development, making it crucial to develop media that supports digital learning in elementary schools (Huda et al., 2025). One promising technology to apply in the learning process is Augmented Reality (AR). Augmented Reality (AR) technology can combine visual elements from the virtual world into the real world in real-time in two-dimensional or three-dimensional formats. This allows students to see, hear, and even interact directly with digital learning objects (Iqliya & Kustijono, 2019). According to (Wahyuningtyas et al., 2022), Augmented Reality (AR)-based learning enhances conceptual understanding, strengthens memory, and promotes critical thinking through engaging and realistic visualizations.

Several studies have shown that the application of Augmented Reality (AR) media in learning has a significant impact on improving student learning outcomes and cognitive skills. Research by (Najib, 2024) proves that the development of Assemblr EDU-based media combined with IPAS material has been proven to significantly improve critical thinking skills and retention in MI/SD students. Similar findings were also reported by (Kharisma et al., 2023), who stated that Augmented Reality (AR) media with the theme “7 Wonders of the World” is effective in improving students' conceptual understanding, active participation in learning, and interest in the material. Not only in Indonesia, but global research by (Kartiko et al., 2020) also shows that the use of Augmented Reality (AR) in elementary school can foster more intense emotional and cognitive engagement among students.

Augmented Reality (AR) is considered a technology that is not only visually appealing but also pedagogically effective, as it enables contextual, exploratory, and constructivist learning. A learning environment that supports the use of Augmented Reality (AR) media can encourage students to actively engage in the learning process, discuss, ask questions, and develop problem-solving strategies based on the digital objects they explore (Kharisma et al., 2022). The integration of this media is also seen as aligned with the spirit of the Merdeka Curriculum, which supports the use of technology in creating adaptive and relevant learning experiences (Putra & Purnama, 2023).

Based on this background, this study aims to develop Augmented Reality (AR)-based learning media for IPAS subjects for fourth-grade elementary school students. This media is designed using the Assemblr EDU platform and developed through the ADDIE (Analyze, Design, Development, Implementation, Evaluation) model. The novelty of this study lies in the systematic integration of fourth-grade IPAS material into AR media based on the ADDIE model, which has been validated by multiple experts and tested for effectiveness through a Control Group Pretest-Posttest design to enhance elementary school students' critical thinking skills. The primary focus of this study is to test the validity, practicality, and effectiveness of the Augmented Reality (AR) media in enhancing students' critical thinking skills. The hypothesis proposed in this study is that the use of Augmented Reality (AR) media can significantly improve students' critical thinking abilities compared to conventional teaching methods.

2. Methods

The type of research used is research and development (Research and Development). The development model used in this study employs the ADDIE model developed by Dick and Carry in 1996. The ADDIE development model consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Sugiyono, 2021). This research was conducted at SD Muhammadiyah 1 Ngimbang, Ngimbang District, Lamongan Regency, during the 2024/2025 academic year. The subjects used in this study were 24 students from grade IV, consisting of 12 students in the experimental group and 12 students in the control group. The instruments used in this study were validation sheets, student response questionnaires, student activity questionnaires, and critical thinking skills tests. Data analysis techniques used prerequisite tests and hypothesis tests.

3. Result and Discussion

Result

The analysis stage began with an initial survey through observation, interviews, and documentation studies of fourth-grade students and teachers at Muhammadiyah 1 Ngimbang Elementary School to identify existing needs in the field. This process included analyzing student needs, formulating learning objectives, and assessing student characteristics in terms of abilities, interests, and learning styles. The analysis results show that:

1. Teachers still use traditional learning media, so students only receive material in abstract form without real or concrete learning experiences.
2. Students have difficulty concentrating during learning because the classroom atmosphere and media used are not conducive to understanding the material.
3. Learning tends to be passive because teachers only rely on textbooks, which makes the learning process monotonous and uninteresting, resulting in low student participation.
4. Although SD Muhammadiyah 1 Ngimbang has adequate technological facilities, their utilization in learning activities is still not optimal.

During the design stage, product design was carried out systematically. This activity included designing the Augmented Reality (AR) media structure using the Assemblr Edu application, compiling IPAS material in 3D display format, and designing research instruments in the form of validation questionnaires and critical thinking skills tests.

Figure 1. Augmented Reality Media design

The development stage is the stage of creating and developing Augmented Reality (AR) media. The development stage can be described as follows:

The Augmented Reality media developed aims to improve critical thinking skills among elementary school students. This media has undergone a review and validation process by a number of experts, covering media validation, design, materials, and learning tools. The barcode can be seen in Figure 2.

Figure 2. Augmented Reality Media

Figure 3. Use of Augmented Reality Media in Learning

Augmented Reality media has been developed to improve critical thinking skills in elementary school students. The developed media has been reviewed and validated by several experts. Several validations were carried out, including media validation, design validation, material validation, and learning device validation. The results of the Augmented Reality (AR) media validation are as follows:

a) Media Expert Validation Result

Table 1. Media Expert Validation Result

Assessment Aspect	Score		Total Average	%	Category
	1	2			
Media Operation	3.50	4.00	3.75	94%	Highly Valid
Media Display	3.66	3.66	3.66	91%	Highly Valid
Media Usage Benefits	4.00	4.00	4.00	100%	Highly Valid
Total Average			3.80	95%	Highly Valid

The results of validation by two media experts in Table 1 show an average score of 3.80 with a percentage of 95%, so that Augmented Reality media is declared to be highly valid and suitable for use.

b) Result of Design Expert Validation

Table 2. Result of Design Expert Validation

Assessment Aspect	Score		Total Average	%	Category
	1	2			
Program Display	3.80	3.80	3.80	95%	Highly Valid
Media Quality	4.00	3.75	3.88	97%	Highly Valid
Total Average			3.84	96%	Highly Valid

The results of validation by two design experts in Table 2 show an average score of 3.84 with a percentage of 96%, so that Augmented Reality media is declared to be highly valid and suitable for use in learning.

c) Results of Content Expert Validation

Table 3. Results of Content Expert Validation

Assessment Aspect	Score		Total Average	%	Category
	1	2			
Material	4.00	4.00	4.00	100%	Highly Valid
Presentation Techniques	3.83	3.83	3.83	96%	Highly Valid
Validity	3.50	4.00	3.75	94%	Highly Valid
Total Average			3.86	97%	Highly Valid

The results of validation by two subject matter experts in Table 3 show an average score of 3.86 with a percentage of 97%, indicating that Augmented Reality media is highly valid and very suitable for use in learning.

d) Result of Learning Device Expert Validation

Table 4. Result of Learning Device Expert Validaton

Assessment Aspect	Score		Total Average	%	Category
	1	2			
ATP	3.67	3.67	3.67	92%	Highly Valid
Media Quality	3.80	3.80	3.80	95%	Highly Valid
Learning Materials	3.86	3.86	3.86	97%	Highly Valid
Assessment Sheets	4.00	3.67	3.84	96%	Highly Valid
Question Grids	3.80	3.80	3.80	95%	Highly Valid
LKPD	3.80	3.80	3.80	95%	Highly Valid
Total Average			3.80	95%	Highly Valid

The results of validation by two subject matter experts showed an average score of 3.80 with a percentage of 95%, so the learning tools were categorized as highly valid and suitable for use by fourth-grade students.

Implementation

During the implementation phase, the Augmented Reality (AR) media that has been developed can be implemented for fourth-grade students. The practicality of the Augmented Reality media was measured through small-group trials and large-group trials.

1. Results of Small-Group Trials

In the small group trial, students filled out the response questionnaire independently, while their activities were observed by an observer. The results are listed in the following table:

a) Results of the Small Group Student Response Questionnaire

A total of 6 fourth-grade students from class B served as respondents and filled out the questionnaire at the end of the lesson. The results can be seen in Table 5.

Table 5. Results of Student Responses in Small Group Trials

Absentee No.	Total	Average
4	44	3.67
6	43	3.58
9	43	3.58
13	40	3.33
20	36	3.00
23	43	3.58
Total Average		3.46

Based on the results in Table 5, it can be concluded that the average student response score in the small group test was 3.46 out of a maximum of 4.00, indicating that the Augmented Reality (AR) media received a good rating.

b) Results of the Small Group Student Activity Questionnaire

Table 6. Results of Small Group Student Activities

Name	Total	Average
DNA	31	3.10
FMZF	33	3.33
Total Average	32	3.22

Based on Table 6, the average total score obtained was 3.22 out of a maximum score of 4.00. Referring to the assessment criteria used, this score falls into the good category.

2. Large Group Trial Results

After conducting a small group trial, a large group trial was conducted. The results are listed in the following table:

a) Large Group Student Response Questionnaire Results

A total of 12 students from class IV B were respondents and filled out the questionnaire at the end of the lesson. The results are presented in Table 7.

Table 7. Large Group Student Response Results

Absentee No.	Total	Average
1	44	3.67
3	44	3.67
4	41	3.42
6	42	3.50
9	43	3.58
10	42	3.50
13	41	3.42
15	44	3.67
16	44	3.67
18	42	3.50
20	43	3.58
23	42	3.50
Total Average		3.57

Based on Table 7, the average total score was 3.57 out of a maximum of 4.00, indicating that students' responses to Augmented Reality (AR) media were very good.

b) Results of the Large Group Student Activity Questionnaire

Table 8. Results of the Large Group Student Activity Questionnaire

Name	Total	Average
DNA	35	3.50
FMZF	36	3.60
Total Average	35.5	3.55

Based on Table 8, it can be concluded that the average total score of 3.55 out of 4.00 indicates that students' responses to Augmented Reality media are in the very good category.

Both tests show significant differences between trial 1 (small group) and trial 2 (large group).

E. Evaluation

The evaluation stage aims to measure the effectiveness of Augmented Reality (AR) media through the T-test and N-Gain Score.

1. T-test

The T-test is used to analyze the effect of the dependent variable on the independent variable in the study. The test was conducted using SPSS software with the Independent Sample T-Test method.

Table 9. T-test Results

Class	**Mean**	**Std.Deviasi**	**N**
Experiment	78.99	7.00	12
Control	66.41	6.78	12

Statistic Uji T	t	df	Sig.(20-tailed)	Mean Difference	95% CI Lower	95% CI Upper
Mark	-4.377	22	0.000	-12.583	-18.549	-6.617

Based on Table 9, the T-test results using the Independent Sample T-Test method show a significance value of 0.000 < 0.05, so that the average learning outcomes of the experimental class (78.99) and the control class (66.41) differ by an average of 12.583. This indicates a difference in the average between the experimental class and the control class.

2. N-Gain Score Test

The N-Gain Score Test is used to measure the effectiveness of treatment in research with a Control Group Pretest-Posttest design, by calculating the difference between pretest and posttest scores to assess the effectiveness of Augmented Reality (AR) media. The results of the N-Gain Score Test can be seen in Table 10.

Table 10. N-Gain Score Test Results

	Kelas Eksperimen	Kelas Kontrol
N	12	12
Average Pretest	56.25	54.59
Average Posstest	86.00	73.42
100-Pre	43.75	45.41
Average Difference	29.75	18.83
Average Maximum Potensial (100-Pretest)	43.75	45.41
Average N-Gain (%)	68.09	40.62
Category	Sufficiently Effective	Less Effective

Based on Table 10, the experimental class obtained an N-Gain Score of 68.09%, which falls into the fairly effective category, while the control class obtained a score of 40.62%, which falls into the less effective category. These results show that Augmented Reality (AR) media is more effective than conventional media.

Discussion

This research and development has produced a product in the form of Augmented Reality (AR) media for fourth-grade elementary school students. The research process was conducted using the ADDIE model, which consists of five stages: Analyze, Design, Development, Implementation, and Evaluation. The results of this research indicate that learning using Augmented Reality (AR) media designed through the Assemblr EDU platform has proven to have high validity, practicality, and effectiveness in supporting the improvement of critical thinking skills in fourth-grade elementary school students in science lessons.

The validity of Augmented Reality (AR) media was obtained through a series of tests by experts, namely media experts, design experts, material experts, and learning device experts. Media experts assigned a score of 3.80, categorized as highly valid; design experts assigned a score of 3.84, categorized as highly valid; content experts assigned a score of 3.86, categorized as highly valid; and learning tool experts assigned a score of 3.80, categorized as highly valid. Therefore, it can be concluded that the overall validation results of the Augmented Reality (AR) media fall into the highly valid category. This indicates that the developed Augmented Reality media meets quality standards in terms of visual presentation, clarity of content, media functionality, and alignment with the characteristics of elementary school students. In line with the research conducted (Iqliya & Kustijono, 2019), which states that Augmented Reality as a learning medium can provide a more meaningful learning experience because it presents objects in three-dimensional form, allowing students to understand concepts visually and contextually.

In terms of practicality, the developed media received good and very good ratings based on the results of small and large group trials. Student responses showed that they were interested and found it helpful in understanding the material when learning using Augmented Reality media, and they became more active during the learning process. The average student response score in the small group trial was 3.46, and increased to 3.57 in the large group trial. Additionally, student activity also increased, with a score of 3.22 in the small-group trial and 3.55 in the large-group trial. This indicates that Augmented Reality (AR) media is not only easy to use but also successfully facilitates active student engagement in the learning process. These findings support the results of a study (Kharisma et al., 2023) which proved that Augmented Reality (AR) media with the theme “7 Wonders of the World” is effective in improving students' conceptual understanding and activity through interactive visual-based learning experiences. This is similar to the research conducted by (Apriliani et al., 2021), which states that innovative and technology-based learning media promote the development of 21st-century skills, one of which is critical thinking.

In terms of effectiveness, Augmented Reality (AR) learning media in this study proved to be able to significantly improve students' critical thinking skills. This was demonstrated by the T-test results, which produced a significance value of 0.000, smaller than the significance level of 0.05, indicating a significant difference between the learning outcomes of students in the experimental class

and the control class. Additionally, the N-Gain Score test results showed that the experimental class achieved an N-Gain Score of 68.09%, falling into the moderately effective category, while the control class scored 40.62%, classified as less effective. These results indicate that Augmented Reality (AR) media contributes more significantly to the improvement of critical thinking skills. The critical thinking skills referred to in this context include the ability to identify problems, analyze information, draw conclusions, construct arguments, and design problem-solving strategies (Adisty et al., 2021). These results reinforce the view (Rahardian, 2022) that technology-based learning not only facilitates content understanding but also promotes the development of higher-order thinking skills, such as analysis and synthesis.

Compared to previous studies, this study offers several advantages that demonstrate scientific innovation. The study by (Najib, 2024), which also used the Assemblr EDU platform in IPAS learning at the MI/SD level, did show positive results in improving students' retention and critical thinking skills. However, that study did not explicitly measure effectiveness through multi-expert validation tests and experimental control tests, as done in this study. On the other hand, the study by (Iqliya & Kustijono, 2019) was limited to the context of concept understanding, not specific and measurable indicators of critical thinking. Therefore, this study addresses the gap from previous studies by incorporating a comprehensive validation process, practicality testing based on student responses and activities, and effectiveness measurement based on quantitative data from the Control Group Pretest-Posttest Design.

Another novelty in this study is the integration of Grade IV IPAS material into an Augmented Reality application using the ADDIE development model systematically, which includes the stages of needs analysis, media design, development of interactive 3D content, implementation in the classroom, and evaluation of learning effectiveness. This approach has not been widely applied in the development of Augmented Reality (AR) learning media for elementary school levels. Therefore, the theoretical contribution of this study lies in strengthening the argument that Augmented Reality (AR)-based learning media designed with a strong pedagogical and evaluative approach can serve as an innovative solution to enhance students' critical thinking skills. From a practical perspective, the findings of this study provide recommendations for educators and educational media developers to begin integrating interactive technologies such as Augmented Reality (AR) media into elementary school curricula to align learning processes with the demands of the 21st century and the direction of the Merdeka Curriculum policy, which emphasizes active, adaptive, and contextual learning.

4. Conclusion

This study successfully developed an Augmented Reality (AR)-based learning medium using the Assemblr EDU platform, which has been proven to be valid, practical, and effective in improving the critical thinking skills of fourth-grade elementary school students in science subjects. The impact of using this medium shows a significant increase in student activity and response in learning, as well as better learning outcomes compared to conventional learning. The benefits of developing this media provide an innovative alternative for teachers in creating more interactive, engaging, and contextual learning experiences aligned with 21st-century needs. The recommendations from this study include the importance of integrating Augmented Reality media into the learning process at elementary schools, the need for support from schools and policymakers in providing facilities and training, and suggestions for future developers and researchers to expand the scope of content and interactive features, as well as to examine the impact of this media on other skills such as creativity, collaboration, and digital literacy.

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