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Developing Augmented Reality-Based Interactive Learning Media to Improve Critical Thinking Skills of Elementary School Students

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Abstract: This study aims to develop augmented reality according to interactive learning media to improve the skills of critical thinking of students at elementary school. This research used research and also development by using a 4D model including Define, Design, Develop, and also Disseminate. The data collection technique used questionnaires, observations and tests used for validity tests, practicality tests and effectiveness tests in research. The findings of the study showed that the augmented reality based interactive media of learning developed was included in having an average validity score of 90.01% in the highly valid category. The practicality test based on the findings of student responses and observation of implementation had an average score of 84.03% categorized as highly practical. The effectiveness test of ability of critical thinking analysis resulted in a score of an N-gain of 0.51 in the medium category, which can significantly improve the thinking ability of elementary school students in subjects of science. In short, the use of augmented reality-based interactive learning media in elementary school learning can improve critical thinking skills.

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Introduction

The Kurikulum Merdeka aims to achieve maximum educational results (Anggraini et al., 2022). However, the implementation of the Kurikulum Merdeka in the field still has problems. These problems are related to learning in the 5.0 era, namely knowledge, skills, attitudes and mastery of technology (Aaron, 2021). In the outcomes of learning of students in the aspect of knowledge, there are several aspects, one of which is skills of critical thinking. They are beocoming one of the demands in learning in the 5.0 era (Jude, 2024). Therefore, this critical thinking skill is needed in learning in the 5.0 era to face life in the future.

Critical thinking demands learning in the 5.0 era (Yudha, 2024). Therefore, this critical thinking skill is needed in learning in the 5.0 era to face life in the future. Critical Thinking Skills are the main ability in dealing with a problem (Imamudin et al., 2024). Exploring the ability and skills in searching, processing, and assessing various information critically can be trained through students' critical thinking skills (Asamad et al., 2024). A student who has the ability to think critically can make decisions independently and analyze existing problems, so critical thinking skills are needed in students.

Augmented reality (AR) can be known as technology which tends to help combining a 3D object to become such a real environment through webcam or android phone cameras (Saadiyah & Anjarwati, 2022). AR is used as a learning medium that provides information clearly, real-time, interestingly, interactively, and educatively (Carolina, 2022). AR can project it in real time as an interactive learning medium implemented on Android and iOS-

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based smartphones (Saputra et al., 2022). The appearance of AR is done virtually visualizing 3D objects like the real thing by inserting on a card that contains an image pattern (Rahman et al., 2017).

The advantage of this method of AR is its attractive visual, it helps displaying such as 3D objects to be seemed to look like in a real life (Rozi & Anwar, 2024). However, the implementation of the concepts is way brought to help increasing students' reasoning and also imagination (Sakti & Sejati, 2024). This is a certain interest in the use of AR-based media of learning, especially if used to science in elementary school, students' reasoning power and imagination power increase.

According to the outcomes of a survey conducted through the distribution of questionnaires, it is known from 18 elementary school teachers in East Java, as many as 72.2% only use learning resources derived from LKS, 66.7% from textbooks and 66.1% using digital media. The data indicated that the use of digital media of learning is still not optimal. In fact, 88.9% of teachers admitted that learning at school requires digital learning media. It has been used by teachers has only been able to support 38.9% of students with high skills of critical thinking, and 61.1% of students whose critical thinking skills are relatively low. The reason for the low level is because it only depends on problem-solving learning (Asamad et al., 2024). Critical thinking skills in elementary school students can be trained from grade IV/V (Firdausi et al., 2021).

Development of AR-based learning media (Prasetyo et al., 2024) produced an AR application as an Android-based Learning Media for Human Body Anatomy. Based on user feedback, the use of the attractiveness and ease test resulted in an attractiveness score of 3.26 with a very interesting category. Other researchers by Sari *et al*., (2022) produced Augmented Reality Learning Media on flat side space building materials was declared very valid with a value of 0.97, practical with a value of 89%, effective with a value of 0.72 so that the media can be said to be effective with the "High" category. Moreover, Trianda Rexa & Anistyasari, (2018) developed Augmented Rality-based learning media using the Ethnomathematical Approach of the material Building a flat-sided space with a validity value of 0.83 with very valid results, and the average outcomes of the questionnaire on the practicality of augmented reality-based learning media with an ethnomathematical approach were 82% with very practical criteria.

Digital-based learning media helps supporting critical thinking and also learning outcomes is Augmented Reality. AR-based media of learning can be known as technology that has two or three-dimensional objects in virtual into a real life appearence (Jannah & Oktaviani, 2022). In addition, there is a three-dimensional video along with the material listed in the media. This is in related to the character of students where they will be more interested if there is media that is in cyberspace but as if it is real. Interesting learning media has been proven to make students more active in learning process (Kartini, Ketut Sepdyana Lukman, 2024). Based on these problems, there is a research gap in research on the development of this learning media to help improving skills of critical thinking in science subjects of level of elementary school. Therefore, this study aims to test the validity, practicality and also effectiveness of AR-based learning media in improving skills of critical thinking in grade V elementary school students.

Research Method

This study applied type of Research and also Development through a 4D model (Thiagarajan *et al*., 1974). This development research was carried out in several schools in

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Jember Regency, namely at SD Assuniyah Kencong, SDN Paleran 01, SDN Bangsalsari 05. It was done at the odd semester of the 2024/2025 academic year. The subject of this study was grade 5 elementary school students.

The data analysis included the practicality,validity, and also effectiveness of AR-based interactive learning media for students at the elementary school. Validity analysis was obtained from the average of the adapted validity scores (Akbar, 2015)

Table 1. Product validity criteria

Percentage (%)	Category
82 ≤ and < 100	Highly Valid
63 ≤ and < 81	Valid
44 ≤ and < 62	Less Valid
25 ≤ and < 43	Invalid

Furthermore, the analysis of the practicality of learning media is according to the analysis of data on implementation and student response. The analysis of practicality was obtained from the average of the implementation data scores and the responses of the students who were adapted (Akbar, 2016).

Table 2. Criteria for implementation and student response

Percentage value range	Criterion
82 ≤ P < 100	Highly Practical
63 ≤ P < 81	Practical
44 ≤ P < 62	Less Practical
25 ≤ P < 43	Impractical

The analysis of media effectiveness was obtained from the results of the pretest analysis and posstest of skills of critical thinking, using the criteria set by the (Hake, 1999).

Table 3. Criteria for the *N-gain category*

Score interval	Category
G < 0.3	Low
0.3 ≤ g < 0.7	Keep
G ≥ 0.7	Tall

Results and Discussion

AR-based interactive learning media is a product developed that helps students with reasoning and imagination to learn (Sakti & Sejati, 2024). This learning media in the form of electronic applications, namely cellphones, which presents 3D images that look like they exist in real environments, 2D, video, and text. This is in accordance with the Carolina, (2022) who said that learning media is said to be interactive if it is able to combine more than two media, both video, audio, images, text and so on. In addition, AR-based interactive learning media includes learning outcomes (CP), learning objectives (TP) and questions to help measuring students' critical thinking skills.

According to findings, the analysis of teacher needs showed that the use of digital learning media was still not maximized. In fact, 88.9% of teachers admitted that learning at school required digital learning media. It has been used by teachers and has only been able to support 38.9% of students with high critical thinking skills, and 61.1% of those whose critical thinking skills are relatively low. This is the basis for researchers to develop media in the form of AR-based learning media to help improve skills of critical thinking in elementary school students. Media access can be done at school or at home using the guidelines listed.

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This research stage used a 4D model (Thiagarajan *et al*., 1974). The definition stage is to analyze the problem. The initial analysis of the problem consists of an analysis of the needs of teachers and students. The results showed that 66.7% of teachers (n=18) need digital learning media for learning, while students showed that 97.6% of students (n=41) need easy-to-use learning media, containing 2D or 3D images.

Design Stage posess the stage of preparing the test and selecting the format on the media. At the test preparation stage, skills of critical thinking indicators from Facione (2015) were used, namely interpretation, evaluation, analysis,inference, explanatory, and also self-regulation. The number of critical thinking skills questions is 20 questions. The stage of selecting a media format uses flutter, API (Application Programming Interface), and Canva.

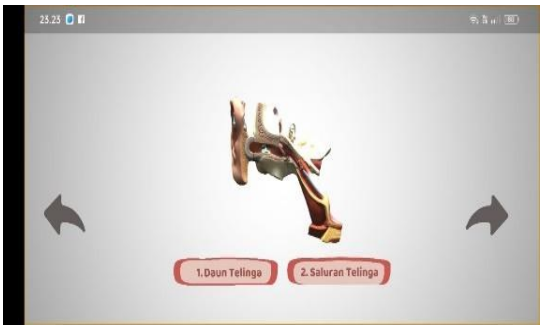

Figure 1. AR-based learning media on the first look : Figure 2. AR-based learning media on the display of materials

In this stage of development, media validation was brought by 1 expert validation and also 2 practitioner validation. The assessment was done by expert validators takes aspects of content feasibility, linguistic feasibility, presentation feasibility, graphics, and development aspects. The validation results showed the following scores: expert validation of 94.6% while the validation results of user 1 were 89.3% and user 2 validation was 86.6%. The average media validation of 90.1% is categorized as highly valid. The data is showed at the table 3.

Table 4. Validation results

Validation Indicators	Validator Assessment Results (%)			Average Score
	Member 1	User 1	User 2	
Fill	22	23	21	22
Serving	24	22	22	22,6
Language	10	9	8	9
Graphics	15	13	14	14
Total score	71	67	65	67,6
Yield (%)	94,6 %	89,3%	86,6%	90,1%
Validity categories	Highly Valid	Highly Valid	Highly Valid	Highly Valid

The Disseminate stage is the dissemination stage to test the effectiveness and also practicality of the research. The results of the test on practicality were obtained from the results of observation of implementation and student response. The average result of the implementation score was 85.6% in the very practical category, and the average student response was 88% in the very practical category.

Table 4. Implementation results

Statements from 1-10	Meeting (%)			Meeting (%)			Meeting (%)		
	SDSA Kencong			SDB05			SDKL02		
	1	2	3	1	2	3	1	2	3
Total score	4,16	4,07	4,47	4,51	4,43	4,36	3,8	4,29	4,33
Practicality Score	83,2	81,4	89,4	90,2	88.,6	87,2	76	85,8	87

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Statements from 1-10	Meeting (%) SDSA Kencong			Meeting (%) SDB05			Meeting (%) SDKL02		
	1	2	3	1	2	3	1	2	3
Average practicality score	85			89			83		
Practicality straightness score	85,6								
Category	Very Practical								

Table. 5. Results of student responses

No.	Statement	Score		
		SDA K	**SD B05**	**SDKL2**
1.	Learning media can be used	77	68	96
2.	Instructions for use	88	83	108
3.	Learning materials	86	83	100
4.	Interesting picture	83	83	105
5.	Features in media	87	86	105
6.	Directions for work	85	80	109
7.	Practice questions	87	93	106
8.	Fun learning	94	89	116
9.	Media AR	92	84	113
10.	Passion for learning	86	87	113
Average number of scores		**86,5**	**83,6**	**107,1**
Practicality Score		**86,5**	**83,6**	**82,3**
Average overall score			**84,13**	
Category			**Very Practical**	

The outcomes showed that the average *N-gain* score on all indicators of critical thinking ability is in the high category at SD Assuniyyah, the medium category at SDN Bangsalsari 05, and the low category at SDN Kemuningsari Lor 2. *N-gain data* is presented in table 6.

No.	Indicators	Average Score								
		SDS Assuniyyah			**SDN Bangsalsari 05**			**SDN Moringa 02**		
		Pre	**Post**	**N-gain**	**Pre**	**Post**	**N-gain**	**Pre**	**Post**	**N-gain**
1.	Interpretation	2,8	4,3	0,68	2,8	4,4	0,72	3,1	4,1	0,50
2.	Analysis	3,8	4,6	0,66	3,5	4,4	0,60	3,3	3,7	0,23
3.	Evaluation	3,3	4,1	0,47	2,0	3,7	0,56	2,1	2,3	0,10
4.	Inference	1,9	4,2	0,74	3,1	4,6	0,56	3,2	3,8	0,30
5.	Explanation	2,8	4,7	0,86	3,2	4,6	0,77	3,0	3,4	0,20
6.	Self-regulation	3,5	4,3	0,53	4,1	4,3	0,22	3,3	3,6	0,40
Average		3,02	4,37	0,71	0,71	4,33	0,57	0,57	3,48	0,27

Discussions

The validity is brought to produce a viable product through a test from experts and then the results can be continued to test the product in the field (Sarip et al., 2022). According to the results, this AR-based learning media was declared valid in terms of content, language, presentation, and also graphics. The development of AR-based interactive learning media has been taken in the category of very valid with a percentage of 90.1%. The researcher made revisions to improve the quality of the AR-based learning media developed. The first revision

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that was carried out was to help improve the placement of outcomes and also learning objectives contained in the cover of the material. The second part of the application size used is too large so it experiences lag when used. The researcher revised by reducing the size of the 700MB application to 510MB. The third part of the application still lacks material on how to maintain ear health. Based on the outcomes of the validation, AR-based learning media is claimed to be very valid and also able to be implemented in the process of learning.

Practicality, learning media can be said to become more practical if teachers and also students are willing to apply learning tools that are easy to use in the field (material is understood) and related to the researcher's design plan (Zulhelmi et al., 2017). The test outcomes on practicality were done from the results of observation of implementation and student response. The research at the dissemination stage was carried out in 3 schools, namely SDS Assuniyyah, SDN Bangsalsari 05 and SDN Kemuningsari Lor 02. The average learning implementation at SD Assuniyyah Kencong is 85% of the category was very practical, in SD Bangsalsari 05 89% of the category was very practical, in SD Kemuningsari lor 02 83% of the category was very practical. In addition, the response questionnaire At the dissemination stage, the three elementary schools showed a score of average of 84.03 with a very practical category. According to the results of this practicality, AR-based learning media is said to be very practical to be applied in learning (Meliyani *et al*., 2022).

Effectiveness of the importance of educators in designing effective learning strategies and utilizing interactive media of learning to help improve the learning quality of schools (Maghfiroh et al., 2024). The effectiveness of this AR-based learning media in this study was determined through the average score *N-gain* skills of critical thinking showed a higher rate in each indicator of critical thinking ability. The results of the test on effectiveness were obtained from the results of observation of implementation and student response. The research at the dissemination stage was carried out in 3 schools, namely SDS Assuniyyah, SDN Bangsalsari 05 and SDN Kemuningsari Lor 02. Score *N-gain* The highest occurred in the explanatory indicator and the lowest in the evaluation indicator. Score *N-gain* Each indicator of critical thinking ability in all dissemination schools has increased, only in different categories, namely high, medium and low. Average results *N-gain* the critical thinking ability of each school, namely at SD Assuniyyah, is shown on average *N-gain* which reached 0.70 with the high category, the second at SDN Bangsalsari 05 reached 0.57 with the medium category, and the third at SDN Kemuningsari Lor 02 reached 0.27 with the low category. The difference in N-gain values is due to several obstacles, namely at SDN Kemuningsari lor 2 there are limitations in media of learning in the form of cellphones which Media Application Specifications is not appropriate so that the application of media is not optimal. Looking at the results, the average value of average of N-gain is 0.51 with the medium category. It itself shows that maximum media use will affect students' skills of critical thinking (Rahman et al., 2017). The application of AR-based learning media can significantly improve students' skills of critical thinking in the classroom (Faiza *et al*., 2022).

Conclusion

The AR-based interactive learning media developed is included in the category of highly valid, very effective and also practical. According to the findings of the validation test, the average score of media validation of 90.1% was declared valid with a slight revision from expert validators and users because it had met the aspects of content, presentation, language and graphics so that it was relevant for use in science learning in elementary schools. The practicality test has met the criteria with an average learning implementation of 85.6% in the

category of very practical and a student response score of 84.13% in the very practical category. The test effectiveness based on the pretest and posttest showed effective learning, because it met the criteria of being able to improve the average critical thinking ability of N-gain scores in the high, medium, and also low categories. It is able be taken conclusion that the use of AR-based learning media can improve skills of critical thinking effectively.

Recommendation

The recommendation of this research for teachers is that this AR-based interactive learning media is able to be applied as an optional media on science subject in grade 5 elementary school. In addition, it is expected to prepare media in the form of cellphones that are in related with the specifications of the application of learning media to be used so that there are no obstacles during the learning process.

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