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Development of Augmented Reality (AR) Media to Improve Learning Outcomes on Earth Structure for Eighth Grade Students

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ABSTRACT

Purpose of the study: This study aims to develop Augmented Reality (AR)-based learning media on the topic of Earth structure and its development to improve the learning outcomes of eighth-grade students.

Methodology: The research employed a Research and Development (R&D) method using the 4D development model (Define, Design, Develop, Disseminate). The media was validated by media, content, and language experts. Practicality testing involved 25 students from MTsN 9 Ngawi and one science teacher. Effectiveness was tested through an independent sample t-test between the experimental and control groups.

Main Findings: The AR media developed was deemed highly feasible with validation scores: 86% (media), 92% (content), and 95% (language). Practicality received scores of 96% from the teacher and 84% from students. The t-test showed a significant difference ($p < 0.001$) between the learning outcomes of the experimental and control groups.

Novelty/Originality of this study: This study confirms that AR technology effectively improves students' understanding of Earth structure concepts through interactive visualizations. It also boosts learning motivation and can be used independently both inside and outside the classroom. However, successful implementation requires adequate infrastructure and teacher training.

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1. INTRODUCTION

Education is a fundamental aspect in building quality human resources. In the era of globalization, education not only functions as a means of transferring knowledge, but also as a tool to shape the character, skills, and critical thinking abilities of students so that they are able to face the challenges of the times. Along with the rapid development of technology, the education sector has also undergone a significant transformation to adapt to the demands of the 21st century. One of the main challenges in learning natural sciences is the presentation of complex and abstract material, especially on the concept of the structure of the earth and its development [1]. Natural Science is concerned with systematic ways to study nature, and science is the process of discovering and obtaining a body of knowledge in the form of facts, concepts, and principles. Science learning is scientific learning that involves interactions between learning components to achieve goals [2]. In this context, learning outcomes become a measure of students' success in understanding and applying science concepts in everyday life. According to Oemar Hamalik, Learning outcomes can be interpreted as changes in behavior that occur after someone learns, both in terms of attitudes and habits [3]. The improvement of student learning

outcomes during the learning process indicates that the learning objectives have been achieved. However, if the learning outcomes are still low, then an evaluation of the methods used is needed in order to identify factors that hinder the effectiveness of learning.

One of the main obstacles is the use of conventional learning media which is still focused on books and lecture methods [4]. Based on the results of initial observations at MTsN 9 Ngawi, it shows that the majority of students have difficulty in understanding the structure of the earth due to the limited interactive visualization media. As a result, student learning outcomes have not reached the expected competencies. Previous studies have shown that Augmented Reality (AR) has great potential to improve conceptual understanding through the presentation of materials in the form of three-dimensional (3D) visualizations, animations, and in-depth digital interactions [5]-[8]. However, the use of AR in learning at the junior high school level is still limited and has not been optimally integrated into the earth structure material according to the national curriculum [9].

This gap shows the need for the development of AR-based learning media that is specifically designed to convey the material of the earth's structure visually and contextually. The use of AR is believed to not only be able to improve students' understanding of abstract concepts, but also strengthen learning motivation through more interesting and participatory learning experiences [7], [10], [11]. This technology can be used to model the structure of the earth in three dimensions, so that students can understand the relationship between components more clearly and deeply [12], [13].

Based on previous studies, the use of AR has been proven effective in significantly increasing student motivation and learning outcomes in various disciplines, including science subjects [14]-[16]. However, the main challenges in implementing this technology in the school environment include infrastructure readiness, teacher training, and the availability of content that is in accordance with the curriculum [17]. Therefore, further research is needed to evaluate the effectiveness and practicality of AR-based learning media in improving student learning outcomes.

This study aims to develop and evaluate AR-based learning media on the material of earth structure and its development. The Research and Development (R&D) method with the 4D development model (Define, Design, Develop, Disseminate) is used as the main approach in this study [18]. Validation is carried out by media, material and language experts to ensure the quality and feasibility of the product being developed [19], [20]. In addition, the trial was conducted on grade VIII students of MTsN 9 Ngawi to evaluate the effectiveness and practicality of AR media in the learning process. Therefore, this study focuses on the development of Augmented Reality (AR)-based learning media for the material of earth structure and its development to improve the learning outcomes of grade VIII students. By integrating AR technology into the learning process, it is expected to create innovative and effective learning media in bridging the gap in students' understanding of abstract concepts in science.

2. RESEARCH METHOD

This study uses a Research and Development (R&D) approach with the 4D development model (Define, Design, Develop, Disseminate) developed by Thiagarajan et al. [18]. This model is designed to develop Augmented Reality (AR) based learning media to improve students' understanding of the concept of earth structure and its development.

The 4D model consists of four main stages as follows: Define. This stage aims to identify needs and problems in learning through needs analysis, student analysis, task analysis, and concept analysis. Data collection is carried out through literature studies and interviews with teachers [21]. Design. At this stage, a prototype design of AR learning media was carried out using Unity 3D [5]. The design process includes format selection, layout design, and initial validation of visual and navigation aspects. Develop. The development stage includes expert validation, namely assessment by media, material and language experts [19], [20]. After validation, development testing was carried out, namely a trial on 25 students of class VIII MTsN 9 Ngawi and a science teacher to measure the effectiveness and practicality of the media developed [21], [22]. Disseminate. Dissemination is carried out on a limited basis in one school to evaluate how students and teachers receive and use the media, as well as measure its effectiveness in learning. The results of the trial can provide input for improvement or adjustment before the learning media is implemented in more schools or larger educational environments [18].

Data were collected through interviews, questionnaires, and documentation. Validation questionnaires were used to measure the feasibility of the media, while student and teacher response questionnaires were used to assess the practicality of the media. In addition, learning outcome tests in the form of posttests were applied to measure the effectiveness of the media in improving students' understanding of the material.

Data analysis is carried out in three main aspects at the development stage: Feasibility, Practicality, and Effectiveness. Media Feasibility Test. Contains expert validation, namely, media, material, and language expert validation. Validation is carried out based on a tiered scale with the following equation [23].

$$P = \frac{\text{Totale score}}{\text{Maximal score}} \times 100\% \ldots (1)$$

The percentage results obtained are then classified into criteria based on the following table 1.

Table 1. Eligibility Criteria

Persentage (%)	Criteria
81 – 100	Very worthy
68 – 80	Worthy
32 – 67	Quite decent
16 – 37	Not worthy
0 – 15	Not feasible

Media Practicality Test. Media practicality is analyzed based on the results of teacher and student response questionnaires, with the following equation [23]:

$$P = \frac{\text{Totale score}}{\text{Maximal score}} \times 100\% \ldots (2)$$

The results of the presentation are classified according to practicality criteria based on the following table [24].

Table 2. Practicality Criteria

Persentage (%)	Criteria
86 – 100	Very Practical
76 – 85	Practical
60 – 75	Quite Practical
55 – 59	Less practical
54	Not very practical

Media Effectiveness Test. The effectiveness test was conducted using an independent sample t-test, after normality and homogeneity tests. Before conducting the t-test, each question item was first tested through instrument testing, namely: validity test which aims to ensure the suitability of the test content with learning objectives, reliability test aims to measure the stability of the results provided by the test instrument, difficulty level test to identify the level of difficulty of each question item in the test, and the master's discriminatory power test to see the extent to which each question item is able to distinguish students with high and low understanding [25].

3. RESULTS AND DISCUSSION

The results of this study aim to evaluate the process of developing Augmented Reality-based learning media through a series of tests, namely feasibility tests, practicality tests and effectiveness tests to ensure the quality and impact on student learning outcomes.

3.1. Media Eligibility Results

The validation process carried out by media experts, material experts and language experts to assess the suitability of Augmented Reality (AR) learning media can be seen in Figure 1.

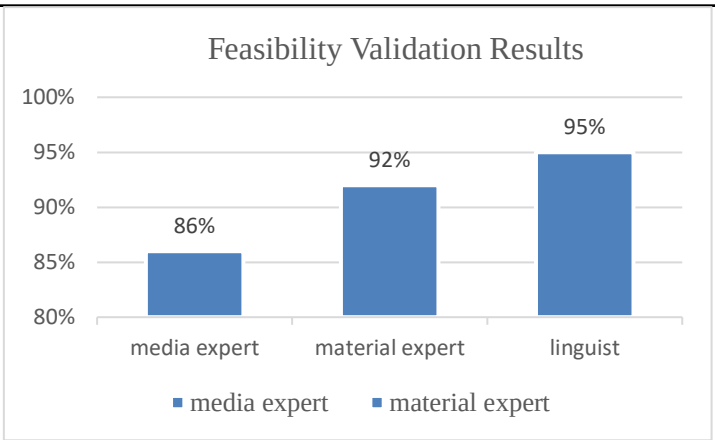

Figure 1. Feasibility Validation Results Diagram

Based on the validation results by three experts, the Augmented Reality (AR)-based learning media developed is categorized as very feasible for use in the learning process. Validation by media experts showed a percentage of 86%, reflecting that the visual appearance, user interface, and technical aspects of the media have met the eligibility criteria, although there are still opportunities for improvement in terms of navigation design and aesthetics. Furthermore, validation by material experts obtained a score of 92%, indicating that the content presented is in accordance with the curriculum, and is able to represent the concept of the earth's structure accurately and comprehensively [9], [26], [11]. Validation by linguists achieved the highest score of 95%, indicating that the use of language in the media has met the principles of readability and suitability to the cognitive level of grade VIII students. Overall, the results of this validation confirm that the AR learning media developed has met the eligibility standards in terms of content, language, and visual appearance, so that it is declared ready to be implemented in science learning at the junior high school level [16], [26].

3.2. Media Practicality Results

The practicality of Augmented Reality media is measured through teacher and student response questionnaires regarding ease of use and its effectiveness in the learning process. The results of the teacher response questionnaire showed a practicality value of 96%, while the results of the student response questionnaire got a value of 84%, which shows that this media is easy to use and helps understand concepts interactively. Student responses show that the visual and animation features in AR media increase student motivation and involvement in learning[10]. The results of the data practicality test are seen in figures 2 and 3.

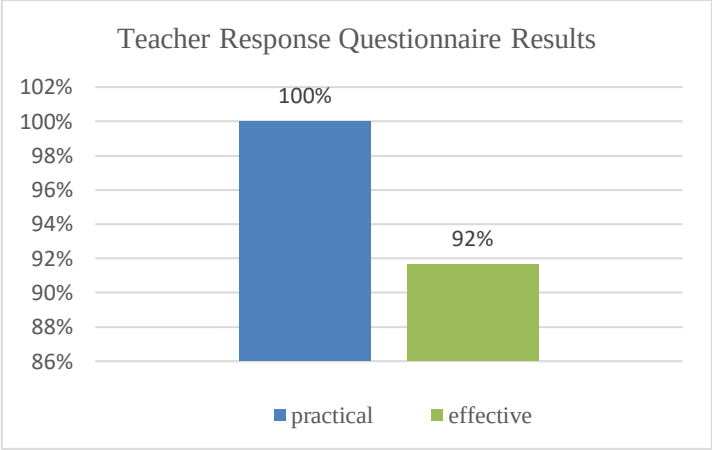

Figure 2. Teacher Response Questionnaire Results Diagram

Based on the results of the questionnaire given to teachers, Augmented Reality (AR)-based learning media showed a very high level of practicality and effectiveness. The practicality aspect obtained a maximum score of 100%, which indicates that this media is very easy to use in the learning process, both in terms of technical operations and integration with existing learning devices. Meanwhile, the effectiveness aspect obtained a score of 92%, which indicates that the media is able to support the achievement of learning objectives optimally. This high score with an average of both aspects of 96% shows that teachers consider AR media not only easy to operate and apply in class, but also has a positive impact in facilitating students' understanding of

the material on the structure of the earth. Thus, this media has the potential to be a strategic alternative in the application of innovative and efficient learning technology in the educational environment [27].

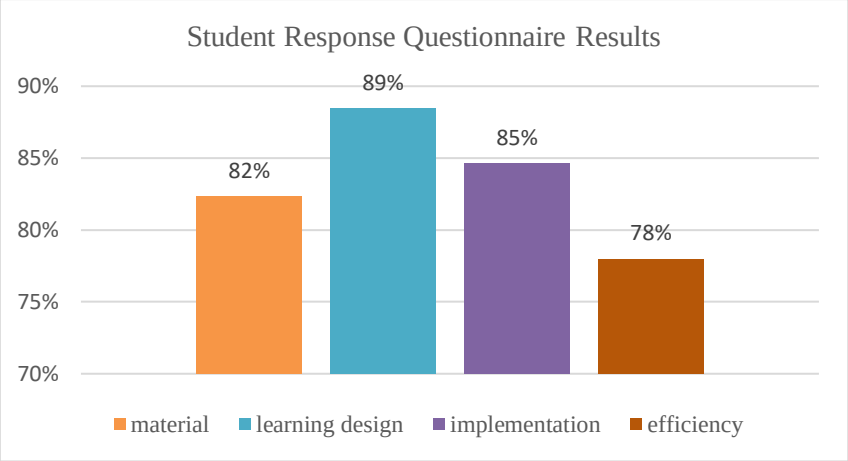

Figure 3. Student Response Questionnaire Results Diagram

The results of the student response questionnaire showed four main aspects that were evaluated, namely material, learning design, implementation, and efficiency. The learning design aspect received the highest response with a percentage of 89%, indicating that students were very satisfied with the design and presentation of the learning that had been carried out. The implementation aspect with a percentage of 85%. This shows that the implementation of learning has been effective. Furthermore, the material aspect received a percentage of 82%, indicating that students considered the material presented to be quite clear, relevant, and easy to understand. As for the efficiency aspect, which received 78%, indicating that there is still room for improvement in terms of time management, media use, and delivery strategies. Each aspect received a high score, indicating that Augmented Reality media is included in the practical and very good category [28]. The high score also reflects the effectiveness of the media in supporting student learning, especially in increasing their understanding and involvement in the learning process.

3.3 Media Effectiveness Results

The effectiveness of Augmented Reality media in improving student learning outcomes was tested through prerequisite tests, namely, normality tests and homogeneity tests, then tested through independent sample t-tests by comparing the posttest results between the experimental and control groups in tables 3, 4 and 5.

Table 3. Normality Test

	Class	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Learning Outcome	Experiment	.154	25	.128	.967	25	.571
	Control	.135	25	.200*	.956	25	.333

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

The normality test used the Shapiro-Wilk method, because the sample size consisted of 25 students [29]. The results of the normality test analysis obtained a posttest sig of the experimental class of 0.57 > 0.05 and a posttest sig value of the control class of 0.33 > 0.05. Thus, it can be concluded that the posttest data from both classes are normally distributed, and meet the prerequisites for the homogeneity test analysis.

Table 4. Homogeneity Test

		Levene Statistic	df1	df2	Sig.
Learning Outcome	Based on Mean	1.595	1	48	.213
	Based on Median	1.181	1	48	.283
	Based on Median and with adjusted df	1.181	1	47.767	.283
	Based on trimmed mean	1.590	1	48	.213

The homogeneity test of the significant level used is α = 0.05. Based on the established criteria, if the significant value (sig) is more than 0.05, then the data is considered homogeneous. Conversely, if the significant value (sig) is less than 0.05, then the data is not homogeneous [30]. Based on the analysis results in the table, the significant value for the experimental and control classes was 0.21>0.05, so it can be concluded that the data meets the homogeneity requirements. The results of the normality and homogeneity tests show that the data are normally distributed and have homogeneous variance, so that the t-test analysis can be carried out with high validity.

Table 5. Independent Sample T Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					
						Significance		Mean Difference	Std. Error Difference
		F	Sig.	t	df	One-Sided p	Two-Sided p		
Learning Outcome	Equal variances assumed	1.595	.213	22.636	48	<,001	<,001	57.160	2.525
	Equal variances not assumed			22.636	46.884	<,001	<,001	57.160	2.525

The criteria used in the t-test are, if the p-value < 0.05, then there is a significant difference between the two groups. Meanwhile, if the p-value > 0.05, then there is no significant difference [31]. The t-test results showed p < 0.001, meaning that there was a significant difference in learning outcomes between the experimental and control classes. The average posttest score of the experimental class was 57.16 points higher than the control. This confirms that the use of AR media can significantly improve learning outcomes.

The findings of this study indicate that Augmented Reality-based learning media has a positive impact on student learning outcomes. The main advantage of AR media lies in the visualization of 3D models, interactive animations, and illustrations that facilitate conceptual abstraction, so that students understand the material more easily compared to conventional methods [32]. Compared with previous research, this study contributes to developing AR-based learning media that is integrated with the curriculum and can be accessed via Android devices, thereby increasing the flexibility of independent learning for students [9], [15], [33].

Although this media is effective, there are still challenges in implementing it in schools, such as limited infrastructure and teacher readiness in operating AR technology. Therefore, training for teachers and broader content development need to be done to increase the impact of using this technology in education [7].

4. CONCLUSION

Based on the results of the research and data analysis, it can be concluded that the development of Augmented Reality (AR)-based learning media on the material on earth structure and its development has met the standards of feasibility, practicality, and effectiveness in improving student learning outcomes. The validation results by media experts, material experts, and language experts show that AR media is very feasible to be used in learning, with high validation scores for visual aspects, readability, and suitability to the curriculum. In addition, practicality tests through teacher and student response questionnaires indicate that this media is easy to use and effective in supporting learning, with high practicality scores. Furthermore, the effectiveness test using the t-test showed a significant difference between the experimental and control groups, which confirmed that the use of AR media was able to improve students' understanding more deeply than conventional methods. With interactive visualization and 3D model features, this media allows students to understand abstract concepts more clearly. However, although AR media has proven to be effective, there are challenges in implementing it in schools, such as limited infrastructure and teacher readiness in operating AR technology. Therefore, further research is needed to develop usage guidelines and training for teachers to support the optimal implementation of this technology in learning. This research provides a real contribution to the integration of Augmented Reality technology for education, and has the potential to be a reference for the development of other interactive learning media in improving the quality of science education.

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