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Design and Application of Augmented Reality in Science Education to Develop Students' Critical Thinking Skills

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ABSTRACT: The goal of this project is to create instructional materials based on augmented reality (AR) that will enhance students' critical thinking abilities. There were 25 pupils enrolled in the public junior high school where the study was done. The ADDIE approach is being used in this development research study. The resulting product is AR-based media equipped with learning devices consisting of a Learning Implementation Plan, Student Worksheets, test instruments. Data collection was carried out using validation sheets, learning implementation sheets, student activity sheets, critical thinking tests and student response questionnaires. The percentage of each score attained was calculated in order to analyse the data. The findings indicated that the student worksheet's validity scored 85.3 in the very valid category, the learning implementation plan's validity scored 87.3 in the same area, and the learning outcome test's average validity score was 90 very valid. With an average of 93.6%, learning implementation indicated very good outcomes; student activities in learning showed very good results with an average of 94.3%; and 88% of student responses fell into the very good category. The critical thinking test's findings indicated that the critical thinking indicators of interpretation, analysis, and explanation had the biggest increases, and the conclusion indicator saw the lowest. The study's conclusion is that teachers can use the augmented reality-based learning tool to teach the Life Organization System's content since it is valid, practical, and effective.

KEYWORDS: Augmented reality, Learning device, Learning activities, Practicality.

INTRODUCTION

Digital technology is now used in education in the twenty-first century (Aslamiah et al., 2021; Dita et al., 2023) in order to improve the process of teaching and learning (Garzón, 2021; Syahriani & Hasruddin, 2024). Learning resources that integrate technology use must go together in side with the use of this technology. According to the 2013 curriculum, teachers can create learning implementation plans, student worksheets, media, and tests of critical thinking. Learning tools need to be arranged in such a way as a plan to achieve the expected competencies of students. Learning can be said to be of quality if the process is centered on students, not on teachers (Jayawardana & Gita, 2020; Nwankwo et al., 2024).

The development of critical thinking abilities and habituation are not given enough attention in today's scientific curriculum (Nasir et al., 2020). 50.49% of Indonesian high school pupils did not possess critical thinking abilities, according to test results (Sari et al., 2019). But the aim of science education is to provide kids advanced thinking abilities (Romero Ariza et al., 2024). In reality, students just retain knowledge passively and refer to it during examinations (Wasser, 2021). A portion of this can be attributed to the learning tools' poor planning. The learning process might be unpleasant if educational resources are created without taking into account the demands of students nowadays. As a result, learning objectives are ultimately unsuccessful because students lose motivation and learning outcomes are subpar (Nasir et al., 2023). Students must be provided with relevant information and learning resources in order to assist the development of their critical thinking abilities (Novitasari et al., 2024; Puig et al., 2021; Sartika et al., 2023). The quality of learning is also impacted by the usage of educational resources that are not designed for the needs of the students today (Christian-Ike et al., 2024; Murti et al., 2024; Pambudi et al., 2022).

According to Kadry and Ghazal (2019), digitally based learning tools with visual drawings can serve as a substitute to boost students' interest in learning. Augmented reality (AR) is one component of technology that can be used in the classroom as a teaching tool. AR can improve learning experiences that are hard to get from real-world encounters (Thurner et al., 2021). AR includes a range of technologies that overlay text, images, and videos created by computers to real-world experiences (Yuen et al., 2011). Researchers

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Sahin and Yilmaz (2020) discovered that scientific curriculum heavy on abstract ideas lowers student engagement and performance. With augmented reality (AR) technology, the real and virtual worlds are combined to enhance the user experience and offer more information in the form of photos, audio, and video captured by cameras on computers or mobile devices (Sommerauer & Müller, 2014). With AR, abstract ideas, intricate spatial relationships, and occurrences can be visualized in ways that are not possible to experience in the physical world. Students become more interested in learning as a result (Wu et al., 2013). To ensure that students achieve at their best, digital technology use must be in line with the infrastructure that is already in place (Chaturvedi et al., 2021).

Based on the results of field observations at one of the public junior high schools, it shows that learning outcomes in the material on the Organizational System of Life are still below the standard of completion. Teachers in learning the organizational system of life still use media in the form of power point presentations, learning videos, and making cell models using simple materials and tools such as styrofoam and plasticine. Many educational resources just make material harder to remember, slow down the learning process, and impair students' ability to think critically (Afify, 2019). They are unable to assist in making the subject more understandable. This is because teachers in learning have not accustomed students to thinking critically. Students have not been directed to solve problems that require critical thinking, so that the test results show numbers below the minimum completion. In order for students to meet their learning objectives, this situation therefore motivates researchers to be able to create AR-based learning tools, which are anticipated to increase students' critical thinking abilities.

The learning process utilizing the created learning tools is the main subject of this study. Utilizing augmented reality media, learning resources such as lesson plans, student workbooks, and learning outcome tests are created. The validator's evaluation provides information about the learning tools' validity. The application of this learning aid in the educational process shows its practicality. The teacher's execution of the teaching process, the students' activities, and the students' reactions to what they have learned are the main subjects of observation. 1) the implementation of the learning process refers to the extent to which the learning tools can be applied by the teacher effectively and efficiently. 2) student activities that have been planned in the learning tools can be fully implemented, students are involved in them, and learning objectives can be achieved. 3) student responses are obtained by giving a questionnaire to see how they can accept, respond, and be involved in them. After completing the pretest and posttest, students' learning outcomes show how effective the learning resources were. It is anticipated that students' critical thinking abilities will increase with the use of augmented reality-based learning resources.

The main goal of this project is to create learning materials based on augmented reality that will help students become more adept at critical thinking. One technology that makes studying more engaging and dynamic while also fostering students' critical thinking abilities is augmented reality. Many earlier research have provided a thorough explanation of the application of augmented reality in education. The use of augmented reality in learning has been widely explained in several previous studies. However, in different school conditions and different subject matter, it will certainly provide different results. Therefore, this study is important to be carried out to see whether the developed learning devices have an impact on improving students' critical thinking skills (Saputri et al., 2020).

METHOD

This research is a development research or RnD using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. The resulting product is Validation is carried out by the validator by giving a score on each aspect of the assessment. To determine the practicality, the observer observes the activities of teachers and students including initial, core, and closing activities. The observer gives a score on each aspect assessed using the existing rubric. The degree of practicality of the learning tool created is next ascertained by analyzing and reviewing the outcomes. Analyzing learning outcome tests yields information about how effective the learning device is. Students are given pretest questions then undergo the learning process and fill out the posttest at the end of learning. This study used 25 seventh grade students at a Public Junior High School in Gorontalo Province. The school is located in East Suwawa District, Bone Bolango Regency.

This study used a validation sheet to see the validity of the device. The validator validated the lesson plan, student worksheets, and critical thinking tests. Observation of the implementation of the learning process, student activity observation sheets, and student response questionnaires. The learning implementation observation sheet was measured using three aspects with 22 observation sub-aspects. Syntax is used in learning through a variety of means, such as problem identification, the collection of data, processing, verification, and generalization. When observing student actions during learning, the student activity observation sheet served as a guide. Observers watched while students engaged in three forty-minute learning sessions over the course of four meetings. The

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activities observed were, 1) answering apperception questions from the teacher, 2) watching learning videos, 3) identifying problems, 4) collecting data using augmented reality, 5) processing data by answering questions in the worksheet, and 6) formulating conclusions. The critical thinking test was created using critical thinking indicators by Fascione consisting of interpretation, analysis, conclusions, evaluation, explanation, and self-regulation.

The validation data of the learning device provided by the three validators were analyzed descriptively quantitatively, where the average validation score was adjusted to the criteria of 100 < very valid ≤ 81; 61 < valid ≤ 80; 41 < less valid ≤ 60; 21 < less valid ≤ 40; and 0 < less valid ≤ 20 (Fatayah et al., 2022). Analysis of the learning implementation sheet and student activities was carried out by calculating the score on the learning implementation observation sheet that had been filled in by the observer (Lainata et al., 2021). Observations of learning implementation were carried out for 4 meetings. Data on learning implementation and student response questionnaires in learning activities were also analyzed descriptively quantitatively, namely calculating the percentage of answers for each question asked. Meanwhile, for pre-test and post-test data, learning outcomes were calculated using the normalized gain formula and the results were adjusted to the n-gain criteria in Table 1.

Table 1. Normalized Gain Categorization Criteria

No	Gain	Category
1.	(g) ≥ 0,7	High
2.	0,3 ≤ (g) < 0,7	Currently
3.	< g > < 0,3	Low

RESULTS

Validation is carried out to assess whether a product is suitable or not for use by expert validators and practitioners. Expert validators consist of two people and one practitioner validator who is a certified Natural Science teacher. The results of the validation of the learning device are presented in Table 2.

Table 2. Learning device validation results

Learning device components	Validator value			Rate-rate	Criteria
	V1	V2	V3		
Lesson plan	84	85	93	87,3	Very valid
Student worksheet	80	86	90	85,3	Very valid
Learning Results Test	88	84	94	90	Very valid
Media *augmented reality*	76	80	86	81	Very valid

Analysis of the implementation of teacher activities is very important in determining the level of practicality of the learning devices created. The observed teacher activities include preliminary, core and closing activities that are adjusted to the objectives of the study itself. There were two observers of this learning activity, who observed for four meetings, in each limited trial and extensive trial. The results of the observer's observations are seen in Figure 1.

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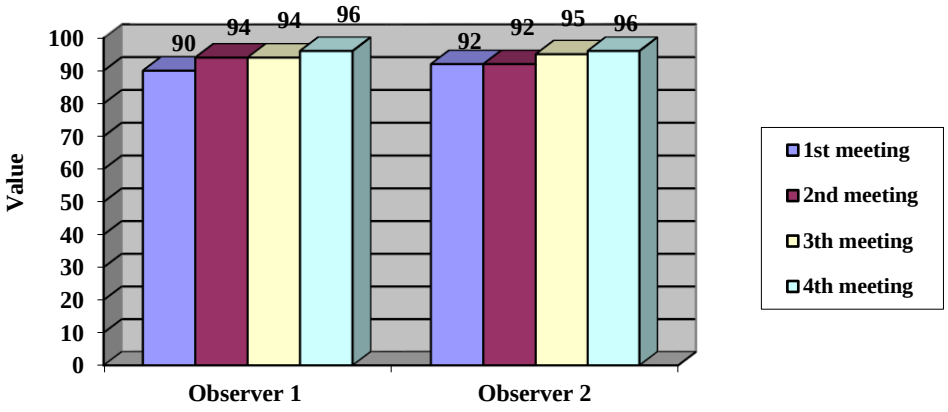

Figure 1. Results of assessing the implementation of teacher activities

Through Figure 1, it is known that the results of the assessment of the implementation of teacher activities from meeting 1 to meeting 4 are in the very good category. Observer 1 and observer 2 gave almost the same value and overall were in the very good category. There was an increase in the implementation of teacher activities from meeting 1 to meeting 4. This shows that teacher activities in learning using AR are very good.

Analysis of student activities in the learning process can also show the practicality of the learning tools created. There are two observers to observe student activities in this learning. In four meetings, observers made observations by giving scores on each aspect of the assessment.

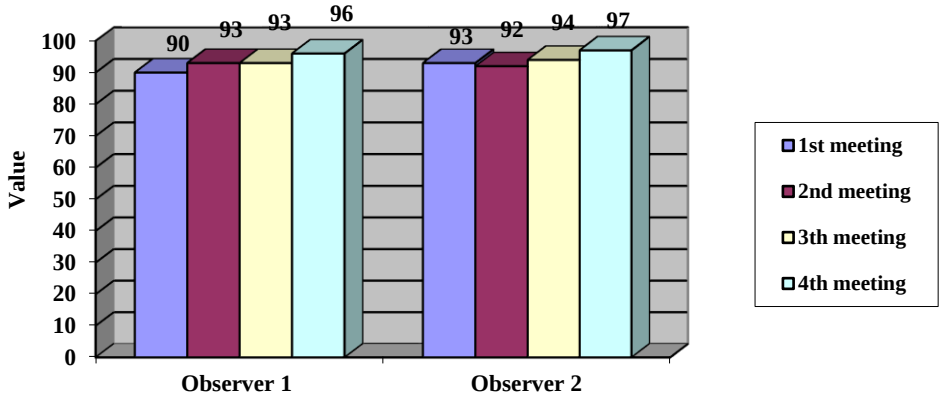

Figure 2. Results of student activity assessment

Figure 2 shows the average results of student activity assessments showing that student activity is in the very good category. Observer 2's assessment shows an increase in student activity from meeting 1 to 4. While observer 2's assessment experienced a decrease in student activity at meeting 2, then increased at meetings 3 and 4. These results indicate that the learning device is very practical to be applied in learning in Class VII.

The second practicality test was conducted through a student response questionnaire filled out after the learning activity. The student response questionnaire was given with the aim of obtaining data on student response results during the learning process using augmented reality. The results of the student response questionnaire obtained an average score of 86% in the very good category, which means that the student's response to learning using augmented reality was very good.

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Table 3. Percentage of Student Responses to Learning

Student Response	Percentage (%)
Strongly agree	30
Agree	70
Disagree	-
Don't agree	-
Strongly Disagree	-

Based on Table 3, 100% are in positive responses, with the category of strongly agree 30% and agree 70%. Based on the results obtained, it shows that many students are interested in the learning that is developed. This shows that students like the media and learning models used (Rahmawati & Taylor, 2019).

The effectiveness of learning devices can be seen from student learning outcomes. The results of the pre-test and post-test data analysis of student learning outcomes are presented in Table 4.

Table 4. Pre-test and post-test results for each meeting

Information	Average value		N-Gain	Category
	Pre-test	Pos-test		
Meeting 1	60	81	0,53	Currently
Meeting 2	46	80	0,62	Currently
Meeting 3	49	85	0,71	High
Meeting 4	55	80	0,55	Currently

Based on table 4, the pre-test results show that students' critical thinking skills are still below the minimum completion criteria standard. After AR-based learning was implemented, students' post-test scores showed that students' critical thinking skills had reached the Minimum Completion Criteria. This is also reinforced by the n-gain values produced at each meeting being in the medium and high categories. This increase is inseparable from the teacher's efforts in compiling and developing learning tools using AR technology.

The critical thinking indicators used in this study are critical thinking indicators according to Fascione, namely interpretation, analysis, conclusion, evaluation, explanation, and self-regulation. The results obtained from the learning outcome test based on these indicators are shown in Figure 4.

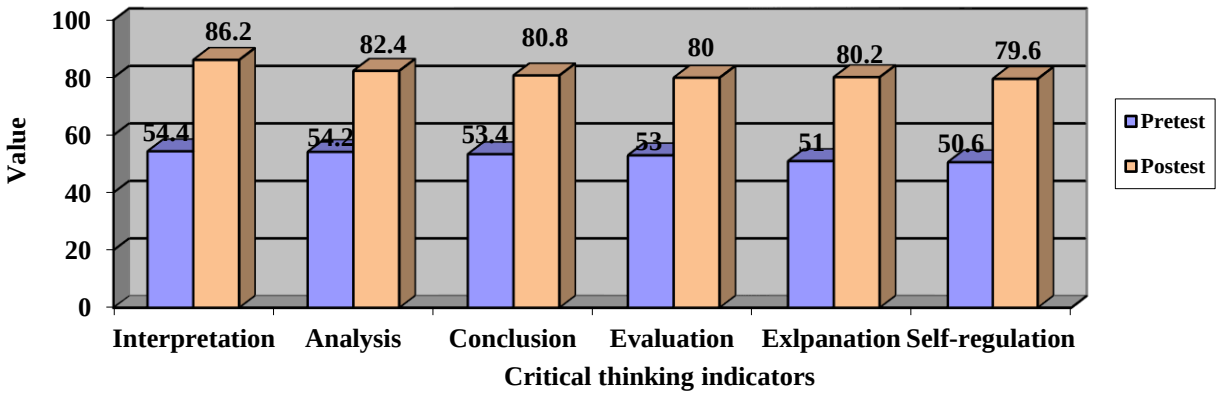

Figure 4. Average results of critical thinking indicators

Figure 4 shows that the outcomes of the critical thinking indicator were different before and after the use of augmented reality-based learning tools. The lowest indicator value in the pretest was on questions in the form of self-regulation, and the highest was on the interpretation question indicator, which was 54.4. After learning and being given a posttest, the critical thinking indicator increased.

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DISCUSSION

Learning tools are something that must be provided by teachers before learning. The learning tools that are developed should meet the requirements of being valid, practical, and effective. Validation carried out by experts is the basis for the validity of learning tools. AR media that has been validated can be used for trials in the classroom (Huda et al., 2021). The implementation of learning, student activities, and student response questionnaires are tools used to measure the practicality of learning tools. Meanwhile, measuring student learning outcomes using pre-test and post-test questions can be used to determine the effectiveness of learning tools (Windari et al., 2022). Valid requirements if they are in accordance with the subject of science and all components in the tool are interrelated. The practicality of learning tools can be seen from the implementation of student-centered learning. The practicality of the media can be categorized as good if it can be accepted and used easily by users. Teachers in providing learning to achieve learning objectives must be able to implement what has been stated in the learning tools, and pay attention to material and pedagogical aspects (Shariffudin et al., 2012).

The teacher's ability to carry out the learning process appears by the implementation of learning in each syntactic, as evidenced by the implementation value falling into the very high category. The implementation's outcomes demonstrate that the teacher can successfully complete the steps involved in teaching and learning activities. AR-based learning devices are able to provide student interest in increasing learning enthusiasm. This is shown when students are enthusiastic about participating in learning and providing responses in the form of answering questions. The use of 3D objects in teaching materials can facilitate student understanding and strengthen memory of what they have learned. This is in line with research by (Kirikkaya & Başgül, 2019) that AR has a positive influence on students because students find new technology, find the technology interesting, and consider it a miracle, because AR technology and objects appear on paper in three dimensions. Integrating AR technology into learning activities can help improve student learning achievement and increase positive attitudes towards the material. Students will practice a lot in the process of thinking and understanding the material and problems presented by this media with the help of AR (Fidan & Tuncel, 2019).

Teachers in developing learning tools must be able to stimulate students' critical thinking skills as part of 21st century skills. Students have not been able to achieve their learning goals because there are no tools that can accommodate these skills, so students are not trained to think critically. The current fact is that students are not given the opportunity to develop knowledge in solving problems and thinking critically about a problem or phenomenon. This is because the learning system used is generally still centered on the teacher, so that students only become recipient objects. Analysis of learning outcome tests in the study showed that the pre-test scores were still below the minimum completion criteria. After being taught using AR, students' scores then rose above the minimum completion criteria. This is consistent with Syawaludin et al. (2019) research, which found that students' critical thinking abilities improved following their use of AR-based interactive learning multimedia compared to pre-use. Students' incapacity to comprehend concepts and the impracticality of the learning process are overcome via the usage of AR (Al Weshah et al., 2021).

The interpretation indication has increased the most from the pre-test to the post-test when compared to the other indicators, according to an analysis of the critical thinking test results for each indicator. This is because learning materials containing virtual visuals make it easier for students to comprehend and keep the information. This is consistent with the findings of Mubarok et al.'s research from 2020, which shows that the creation of AR-based media can efficiently teach cognitive abilities related to interpretation, analysis, and explanation—all aspects of critical thinking. The explanation indicator also experienced a significant increase, according to the results of the critical thinking indicator study. Students are accustomed to questions in the form of explanations which is the cause of this increase. This finding is in line with research by Agnafia (2019) which found that the explanation indicator or giving an explanation obtained good critical thinking ability results, because this indicator is commonly carried out by students so that the score results are in the good category. The concluding and evaluating indicators have increased. This happens because students do not understand the questions well and have not been able to link one understanding with another. The class VII who were the subjects of the study were children who were still adjusting to the change in mindset from concrete to abstract. So it is necessary to first bring them into real conditions before entering into an explanation related to abstract concepts. In the next meeting, students have begun to understand how they should think in solving a problem in the Student Worksheet by utilizing AR. The use of multimedia in science learning in Chen's (Chen, 2020) research is in the form of AR media and digital games. These media have been proven to make it easier for students to understand the concept of natural science and increase learning motivation. During the transition from elementary school to secondary school, students still need concrete examples in solving learning problems. According to the outcomes of Damopolii's (Damopolii et al., 2022) study, 76% of students were able to

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relate AR media content to things they had seen, done, or thought about in their daily lives. As a result, using augmented reality (AR) can help students perceive abstract concepts as more real. According to (Ikhsan et al., 2020), a 3D display that shows objects as they actually are encourages students to ask questions, stimulates their curiosity, and strengthens their CT abilities. AR shares reflections with users about the merging of the real world with the virtual world seen from the same place. Augmented reality, which combines real and virtual objects, makes it possible to visualize abstract ideas and intricate spatial relationships as well as to experience phenomena in ways that are not possible in the real world. This improves understanding, deepens the learning process, and increases student motivation, engagement, and participation (Alqarni, 2021).

Following their use of the augmented reality learning equipment, the student' response was excellent. According to the study's findings, all indicators fall into the 30% and 70% agreement categories, indicating a positive response. The results obtained indicate a high level of student interest in the developed learning. This demonstrates that students enjoy the media and instructional strategies employed. Fidan and Tuncel (2019) explained that integrating AR technology into learning activities can help improve student learning achievement and increase positive attitudes towards the material in the subject. Students who previously had no experience at all using this media felt happy to learn, which was shown through the responses given after learning. These results seem to support the argument made by Omurtak and zeybek (2022), and Çetin and Türkan (2022) that using augmented reality (AR) apps creates a fun learning environment and increases student participation in the classroom.

CONCLUSION

The results of the study on creating instructional materials based on augmented reality have been able to satisfy the criteria for validity, effectiveness, and usability. The learning outcome test has an average value of 90 in the very valid category, the student worksheet has an average value of 85.3 in the very valid category, the augmented reality media has an average value of 81 in the very valid category, and the learning implementation plan has an average value of 87.3 in the very valid category, according to the validator's assessment. With an average value of 93.6, the instructional materials' practicality falls into the very good category for learning implementation, while the average value of 94.3 falls into the very good category for student activities. Students' responses to their education range into the "very good" category. With an average N-gain value from four meetings of 0.60 in the moderate category, the students' learning of critical thinking abilities has been completed to the required extent.

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