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Developing an Augmented Reality-Based Textbook on Heat and Transfer Materials to Improve Students Critical Thinking Skills

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Abstract: The Society 5.0 era necessitates that society address problems by harnessing information technology. Augmented Reality, one of the information technologies utilized in the education sector, presents virtual objects alongside real ones in a three-dimensional format, allowing for observation, interaction, and auditory engagement. Heat and transfer materials can be simulated and applied in the form of 3D objects and animations, facilitating direct student interaction and providing a captivating and distinctive learning experience. The objective of this research is to create an Augmented Reality-based textbook on heat and transfer material to enhance the critical thinking skills of junior high school students. This Research & Development used the ADDIE model including analyze, design, develop, implement and evaluate steps. Based on the results, augmented reality-based textbook is highly valid, practical, and effective in showcasing an improvement in the critical thinking skills of junior high school students, with the observed increase falling within the high category, specifically at 0.71.

Keywords: Augmented Reality; Critical Thinking Skills; Textbook

Introduction

The Society 5.0 era requires society to be able to solve problems by utilizing information technology (IT). One of the information technologies used in the education sector is Augmented Reality (AR). Augmented Reality (AR) technology has become one of the main focuses of research in Indonesia and is one of the advances in the application of information technology (IT) in the education sector (Aprilinda et al., 2020). The Merdeka curriculum is one of the curricula that will begin to be implemented in the 2023/2024 odd semester academic year. This curriculum was implemented during the Society 5.0 Era. The main concept of Merdeka curriculum is that students are free to search for as wide a range of learning resources as possible without having to wait for teaching and learning activities at school. The Merdeka curriculum aims to strengthen the profile of Pancasila students. The element in the Pancasila profile is critical reasoning. Students who are able to reason critically can process information objectively, build and analyze relationships between various information, evaluate and conclude (Bilkisda & Sudibyo, 2021) (Gustianingrum, et al. 2023).

The Pancasila student profile is an effort to improve the quality of education in Indonesia with the aim of prioritizing the formation of a student's character. Currently, the role of education and character is needed to provide a balance between technological development and human development (Annisa et al., 2023). Critical thinking is a student's ability to make decisions about a problem. Currently, students must have the ability to analyze, synthesize, generalize, evaluate, clarify information, conclude, and make decisions on a problem, these are components of critical thinking skills (Nuryanti et al., 2018).

Critical thinking skills can be applied in science learning. Science learning involves students being active

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in carrying out skills, such as: searching, finding and concluding. However, in reality, students' critical thinking skills are still not developed in science learning. Science learning is currently still carried out theoretically using printed books and image-assisted media. This causes students to become passive in learning. Therefore, it will be more practical and efficient if textbooks are integrated into Augmented Reality-based textbooks in application format, so that students can visualize learning material in its real form (Octavia, 2021).

Textbooks are produced from the use of Augmented Reality technology, which provides its own uniqueness. This technology combines two-dimensional and three-dimensional objects so that it can display objects in an attractive virtual form. It is hoped that the use of Augmented Reality technology in textbooks can improve the quality of the learning process. Students also get a more enjoyable learning experience because Augmented Reality technology allows them to project material in real time (Fakhrudin & Kuswidyanarko, 2020). Therefore, Augmented Reality technology in textbooks is expected to help improve students' critical thinking skills in a more interesting and applicable way (Hartanto, 2016; Rafik et al., 2020; Safira et al., 2022).

Natural Sciences is a vital scientific discipline in studying phenomena that occur in the universe. IPA has gone through a series of systematic steps to ensure the correctness of each concept produced. Unity in science learning includes attitudes, processes and products. These three aspects form a unified whole in science learning. Science learning objects can be abstract or concrete objects. Abstract objects require modeling to be explained clearly, while concrete objects can be observed through the senses. Therefore, to facilitate students' understanding, abstract material objects need to be clarified through several models so that they can be understood well by students. Thus, science learning will help students to understand and appreciate the existence of the universe and increase students' curiosity and analytical skills in observing natural phenomena (Fransisca, 2018; Ismiyanti, 2020; Khairani & Ain, 2021; Riyanto et al., 2019).

Augmented Reality is defined as a technology that combines the real world with a virtual world specially programmed by a computer. The working principle of Augmented Reality is interactive, real time and objects are displayed in 3D form. The advantage of Augmented Reality is that it can be implemented widely in various media, and can be used as an application on smartphones (Tanjung & Faiza, 2019; Widiyhati et al., 2015). Augmented reality can also combine objects in a 2-dimensional or 3-dimensional virtual world (Aydin et al., 2023; Omar et al., 2018; Wellens et al., 2019), which can create a combined room and can be projected into real time (Ramadhan et al., 2021). The development of Augmented Reality is currently being used in various fields, especially in the field of education. Therefore, science learning media currently utilizes sophisticated technology, namely the Augmented Reality system which can be accessed via Android by students.

The application of augmented reality in the field of education can support teaching staff by adding teaching aids that function to reconstruct real objects that cannot be seen with the naked eye. The Augmented Reality can also make the learning process not tied to lesson hours or classrooms, by using augmented reality media students can study learning material anywhere and anytime (Fikri & Ramadana, 2021; Melinda & Saputra, 2021; Nistrina, 2021). Textbooks are reference books containing material in certain branches of science that are used for learning activities. In general, textbooks are in the form of textbooks, package books, and study series guidebooks. Textbooks are prepared according to learning objectives or certain competencies, so that textbooks can adapt to student needs. Textbooks must also have a clear point of view, especially the learning methods that will be applied, the approach that will be adopted, the teaching techniques that will be used, and the principles that will be applied in the process of learning activities (Kurniawan & Masjudin, 2017).

Critical thinking skills are defined as abilities that encourage students to be able to think reflectively about a problem accompanied by credible references. Currently, students need critical thinking skills. Someone who has critical thinking skills will be able to solve problems well and make decisions rationally (Priyadi et al., 2018; Susilawati et al., 2020). Critical thinking can also help students develop analytical and logical skills, so they are able to make decisions based on facts and not just based on assumptions or subjective opinions. Students will also be faced with problems or situations that require problem-solving skills, so that students can learn how to process information, analyze data, and make the right decisions based on the facts obtained. Developing these complex thinking abilities, students are expected to be able to face complex life challenges and become individuals who are intelligent, critical, and able to make the right decisions in difficult situations. From the outlined problem formulation, the author is keen on researching the development of an Augmented Reality-Based Textbook aimed at enhancing critical thinking skills among middle school students.

Method

The research aimed to produce valid, practical and effective of interactive textbooks based on Augmented Reality. The resulting Augmented Reality-based

textbook can be applied to class VII junior high school students. This Research & Development used the ADDIE model including analyze, design, develop, implement and evaluate steps. ADDIE is an approach that focuses on an analysis of each component to interact and coordinate between phases (Rayanto, 2020). The flow of the ADDIE's model in this study is as follows:

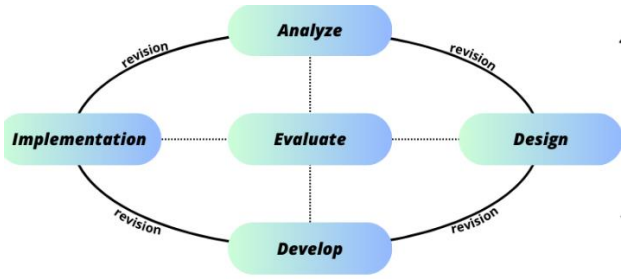

Figure 1. The ADDIE development model

Data collection was carried out in several stages, namely observation, interviews, validation questionnaires, pretest and posttest. The observation stage was carried out to determine the implementation of learning using augmented reality-based textbook development products. The interview was conducted to science teachers and students to obtain information regarding the obstacles experienced during the science learning process (Sahabuddin et al., 2021). The validation phase involved three validators such as two science teachers and a science education lecturer. Additionally, pretest and posttest were executed to objectively evaluate students' critical thinking skills subsequent to utilizing the product. Data analysis techniques in this research include validity, practicality and effectiveness analysis.

Analysis of textbook validation data

The validation data were obtained from the checklist results on the validation sheet provided by three validators, as per the criteria outlined in Table 1.

Table 1. Validity criteria for Augmented Reality-based textbook

Value achievement criteria (%)	Level of validity
86 - 100	Very valid
71 - 85	Valid
56 -70	Quite valid
41 - 55	Less valid
25 – 40	Not valid

Analysis of textbook practicality

The Augmented Reality-based textbook developed in this research is said to be practical seen from the results of learning implementation and student activities observed by observers by filling in implementation sheets. The practicality criteria for Augmented Reality-based textbook can be seen in Table 2.

Table 2. Practicality criteria for Augmented Reality-based textbook

Quality score	Eligibility criteria
$\bar{x} \geq 84$	Very practical
$68 < \bar{x} \leq 84$	Practical
$52 < \bar{x} \leq 68$	Quite practical
$36 < \bar{x} \leq 52$	Less practical
$25 < \bar{x} \leq 36$	Not practical

Analysis of textbook effectiveness

In analyzing the effectiveness test, researchers employ the N-Gain test to gauge the variance between the pre-test and post-test outcomes among a student cohort. Subsequently, upon conducting the N-Gain test, the findings will be categorized as outlined in Table 3 for conclusive assessment.

Table 3. N-Gain result categories

N-gain value (<*g*>)	Category
$g \geq 0.70$	Hight
$0.70 > g \geq 0.30$	Currently
$g < 0.30$	Low

Result and Discussion

Analyze

Analysis is carried out to collect data, namely in the form of needs analysis, analysis of the curriculum used, and student analysis. Needs analysis, namely determining the learning media needed by students to improve critical thinking skills, namely in the form of augmented reality-based textbook. The developing textbook is a medium that provides variety to the learning process, and integrates text, animation, 3D models and quizzes so that the information conveyed is more efficient. The curriculum currently used at SMP Negeri 7 Jember is the Merdeka curriculum. The preparations made by teachers before implementing this Merdeka curriculum include compiling learning outcomes (CP), flow of learning objectives (ATP), and chapters of learning material. The Merdeka curriculum has a positive impact, namely that students experience changes to become more active in the learning process and form good character, this is because students are given the opportunity to explore and express their interests in learning. In the Merdeka curriculum, the learning process is not only in the classroom, but also outside the classroom, namely strengthening the Pancasila profile (P5) through project-based learning. Researchers analyzed students through the characteristics of class VIIA students, namely that students tend to be passive, if they are given a question,

students answer simply and do not explain it using their own language. Additionally, students do not use the results (Nufus et al., 2021).

Design

The researchers planned to design by creating textbooks, teaching modules and pretest-posttest questions. Making textbooks refers to heat material and its transfer accompanied by Augmented Reality in the form of barcodes in textbooks. Making teaching modules refers to heat material and its transfer with a time allocation of 16 lesson hours or 8 meetings. The pretest-posttest questions are in the form of descriptions containing indicators of students' critical thinking skills. The pretest questions consist of 6 questions, while the posttest questions consist of 10 questions. The learning media that has been designed can be applied by students online on smartphones. The following are the design stages for developing Augmented Reality-based textbook:

Collection of materials

The collection of materials begins with learning materials, images, educational assembly designs, articles and interesting writing. These materials are collected in file form to facilitate the process of preparing Augmented Reality-based textbook materials (Dewi et al., 2022).

Preparing Augmented Reality-Based Textbook

Augmented Reality-based textbook material is prepared using Microsoft Word 2019 before being compiled into Microsoft Power Point. The appearance of Augmented Reality-based textbooks consists of a cover containing the material title "Heat and its Transfer" and there is a barcode that can be accessed by students online. The main menu display contains navigation buttons that can direct students to the subchapters they will study, such as: foreword, material learning (understanding heat and heat transfer), bibliography. Augmented Reality-based textbooks contain slides containing critical thinking activities through observing phenomena in Assemblr Edu which contain indicators of critical thinking skills.

Figure 2. QR code access

The Augmented Reality-based textbook design preparation is illustrated in the image below, showcasing an example display of the augmented reality-based textbook. To access the textbook, you can scan the augmented reality-based textbook barcode provided.

Figure 3. the Augmented Reality-based textbook design

Advantages of Augmented Reality Based Textbook

Augmented Reality-based textbook are designed to have advantages, including being accessible on smartphones, so they can be accessed anywhere and anytime. The features presented are also interesting, there is a feature to train students' critical thinking, namely in the form of observing phenomena that have been compiled in Augmented Reality. The Augmented Reality-based textbook application is equipped with navigation buttons that are directly connected to the book page you want to display. The attractive appearance of the pocket book can also foster students' interest in learning and make students interested in studying the material that has been presented.

Develop

Researchers validated Augmented Reality-based textbooks, teaching modules, pretest-posttest questions. Validation was carried out by 3 validators, consisting of one science education lecturer at the University of Jember and two science subject teachers at SMP Negeri 7 Jember. The validation results are then analyzed by calculating the average total score from the three validators and adjusting it to the validity level interval.

Table 4. Validation results of Augmented Reality based textbooks

Aspect	Average of each aspect (%)	Average of validity (%)
Format	94	92
Language	85	
Contents of the book	94	
Graphics	96	

Based on these results, the overall average for each aspect was obtained, namely 92% with a very valid category. The learning support tools that are validated are teaching modules. The following recapitulation of teaching module validation can be seen in Table 5.

Table 5. Teaching module validation results

Common components	Average validator score	Validity (%)
General information	4.5	90
Core competencies	4.4	88

The summary of the validation analysis of the teaching module can be declared very valid with a validity percentage of 90% for general information and a percentage of 88% for core competencies. Apart from the teaching module, validation is also carried out on the rubric for assessing pretest questions and posttest questions. Recapitulation of validation of pretest and posttest questions can be seen in Figure 3.

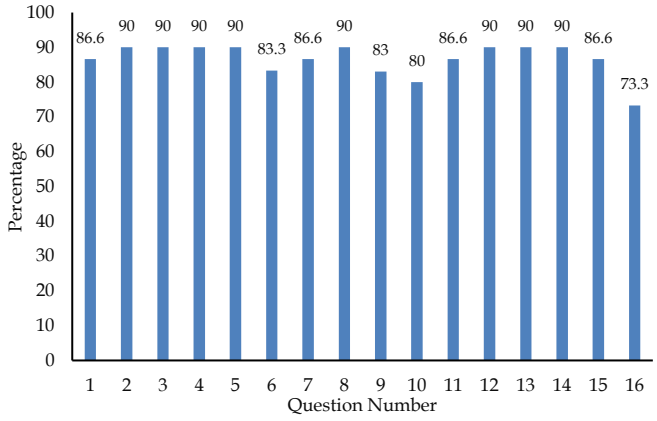

Figure 3. Results of validities of questions per number

Based on this analysis, it can be stated that the pretest and posttest assessment questions are suitable for training junior high school students' critical thinking skills.

Implementation

Augmented Reality-based textbook was tested on 36 students in class VIIA at SMP Negeri 7 Jember, during 6 meetings. The results of observation data on the implementation of learning to use Augmented Reality-based textbook were obtained from three observers during the learning process. A recapitulation of the analysis of learning implementation observation data can be seen in Table 6.

Table 6. Observation results of the implementation of Augmented Reality-based textbook

Activity	Meeting to- (%)					
	1	2	3	4	5	6
Ability to open activities	88.9	88.9	91.6	91.6	94	94
Mastery of the material	86	91.6	88.9	91.6	91.6	91.6
Implementation of activity steps	88,9	87.5	91.6	87.5	87.5	87.5
Use of learning media	93.7	91.6	93.7	83	87.5	87.5
Evaluation	91.6	83	87.5	83	87.5	91.6
Ability to close activities	91.6	94	91.6	91.6	86	88
Average	93.2	92.2	93	90	91	92

The recapitulation of implementation observation analysis shows the implementation of learning to use Augmented Reality-based textbook to train critical thinking skills with a practicality percentage of 90% with very practical criteria. The results of implementation observations prove that the learning process using Augmented Reality-based textbooks was declared successful (Ananda et al., 2015; Nasution et al., 2022; Nistrina, 2021; Pradana, 2020; Saputri, 2017; Usmaedi et al., 2020).

Evaluation

The evaluation stage is also needed to improve the product being developed so that the product can be improved based on validity, practicality and effectiveness. This stage is carried out with tests, namely pretest and posttest to train students' critical thinking skills. The test was given to 36 class VIIA students at SMP Negeri 7 Jember. The level of effectiveness of Augmented Reality-based textbook is calculated using the N-gain formula and can be seen in Table 7.

Table 7. Test results for training critical thinking skills

Component	Class VIIA		N-*gain* < *g* >
	Pretest	*Posttest*	
The number of students	36	36	
Lowest value	40	65	0.71
The highest score	70	100	
Average value	60.4	88.6	0.71

These results show that after using Augmented Reality-based textbook, the heat and displacement material is in the high category. Analyze the pretest and

posttest results for each indicator of critical thinking skills using the N-gain formula. The indicators of critical thinking skills analyzed are interpretation, analysis, evaluation, interference, explanation and self-regulation. A recapitulation of N-gain from critical thinking skills indicators can be seen in Table 8.

Table 8. N-gain results for indicators of critical thinking skills

Indicator	Question number	Average		N-gain <g>
		Pretest	Posttest	
Interpretation	1, 7, 8	55.3	91	0.79
Analysis	2, 9, 10	70.8	89.6	0.64
Evaluation	3, 11	35.5	94	0.91
Interfence	4, 12, 13	57.2	85.4	0.66
Explanation	5, 14	35.5	86	0.78
Self-Regulation	6, 15, 16	61	86.8	0.66

The recapitulation of the analysis of achievement of each indicator of critical thinking skills in table 4.6 shows that the students' pretest and posttest averages are not the same. Apart from that, the results of the data analysis show that Augmented Reality-based textbook are able to train junior high school students' critical thinking skills (Hendriyani et al., 2019; Irfansyah, 2017; Prasetiyo et al., 2018; Setyawan et al., 2019; Sugianto, 2018). This Augmented Reality-based textbook can be applied in science learning because science material, especially heat and its transfer, has a close relationship with natural phenomena in the surrounding environment (Suardi, 2018; Yupinus et al., 2020).

This Augmented Reality-based textbook has a positive impact on students by making students more active in learning activities, because in the Augmented Reality-based textbook there is a feature that displays a link that is directly connected to Assembler Edu. The features presented provide students with learning activities that can train students' critical thinking skills. The use of Augmented Reality-based textbook can attract high student interest and enthusiasm because this learning media is being implemented for the first time, and student and teacher interaction becomes more active because learning is student-center (Hayati et al., 2022).

Conclusion

Based on the outcomes of the developmental research, the Augmented Reality-based textbook focusing on heat and transfer material has been classified as highly valid, scoring 92% in validity. Hence, this developmental textbook proves suitable for educational implementation in middle schools. The practicality rating for the heat and transfer material product is exceptionally high, reaching 90%. This demonstrates the high practicality of using Augmented Reality-based textbook in class VIIA at SMP Negeri 7 Jember. The effectiveness of this developed textbook stands confirmed, evidenced by an average N-gain result of 0.71, placing it within the high-performance category.

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The authors declare no conflict of interest.

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