



Development of Augmented Reality-Based Educational Games as Learning Media for Temperature and Heat Material for Elementary School Students

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Abstract. This study aims to develop an educational game as a learning medium for temperature and heat material for Elementary School (SD) students based on Augmented Reality. The method used is Research and Development (R&D) with the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). In the analysis stage, observations and interviews were conducted with teachers at SD Negeri 06 Rantau Panjang to identify learning needs. This educational game is designed to help students understand the concept of temperature and heat through direct interaction and more interesting learning experiences. The implementation results showed a significant increase in student understanding. The average pretest score of students was 60, while the average posttest score after using the educational game increased to 83.8. This increase was measured using N-Gain, which produced a score of 0.63, which is included in the moderate increase category. In addition, feedback from students and teachers showed that this educational game was effective in attracting students' interest in learning and facilitating the learning process.

Keywords: Educational Games, Augmented Reality, Immersive Learning

1 Introduction

Education in the digital era allows students to obtain information faster and easier [1]. The ever-evolving educational technology has produced various tools and media that help students achieve their goals. Learning media also follows the development of existing technology, including print technology, audio visual, computers, and a combination of print and computer technology. Currently, learning media combines print and computer technology to realize Augmented Reality (AR) [2].

In the learning process, especially at the elementary school level, understanding scientific concepts such as temperature and heat is often a challenge for students. In the context of science learning, especially physics, learning is desired to form a complete understanding of student concepts [3], while student understanding is often limited because conventional teaching methods are still abstract and less interactive [4].

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The use of AR-based learning media has the potential to answer these challenges, because AR can provide a richer and deeper learning experience through direct interaction with virtual objects [5]. Several studies have shown that educational games, especially interactive multimedia, including AR, can increase students' learning motivation and help them understand concepts that are difficult to understand conventionally [6], [7], [8], [9].

However, the results of field observations, especially at SD Negeri 06 Rantau Panjang, show that the use of interactive media in the learning process is still very limited. This is due to the lack of teachers, understanding technology and limited resources. Based on this background, this study aims to design and develop an AR-based educational game as an interactive learning media for temperature and heat materials. It is hoped that this innovation can not only improve students' understanding of these scientific concepts, but also make it easier for teachers to deliver materials more interestingly and effectively.

2 Related Work

The use of Augmented Reality (AR) as a learning medium has experienced rapid development in recent years. AR technology allows students to combine the real world with virtual elements, such as 3D models, videos, and animations, providing a more interactive and immersive learning experience [7]. The use of AR in education can help visualize abstract concepts that are difficult to understand only through conventional learning methods [10], especially in science subjects that require in-depth understanding such as temperature and heat.

Several previous studies have shown that game-based interactive multimedia can improve students' understanding of abstract and difficult-to-understand subject matter, such as concepts in natural science (IPA). For example, research by Nata and Putra [11] shows that interactive multimedia learning media is very effective in improving student learning outcomes, with a focus on the DDD-E development model that allows students great control in its operation.

Other research by Purnomo [12] and Diharjo [13] also shows the effectiveness of educational games in increasing students' interest in learning and abilities. The educational games developed in this study are designed to present learning materials in a fun and interesting form for elementary school children. In addition, educational games can also sharpen students' mindsets and improve their ability to understand learning materials through interactive gaming experiences. This is in line with the research of Nurcholis et al. [14], who developed an educational game to recognize Japanese letters which has been proven to improve students' language skills through interactive game-based methods. The research proposed in this project is a further development of previous studies with a focus on the use of augmented reality-based educational games for science learning, especially on temperature and heat materials. The innovation of this research lies in the use of learning media that is in accordance with the characteristics of elementary school students at SD Negeri 06 Rantau Panjang, which is expected to be able to significantly improve their learning outcomes.

3 Method

This research was conducted at SD Negeri 06 Rantau Panjang and aims to develop an Augmented Reality (AR)-based educational game as an interactive learning media for fifth grade students. The material used is the concept of temperature and heat, which is often difficult for students to understand abstractly. This learning is focused on visualizing concepts in three dimensions using AR technology, so that students can more easily understand the material concretely [15].

The method used in this study is the Research and Development (R&D) development method with the ADDIE model as in Figure 1, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation [16].

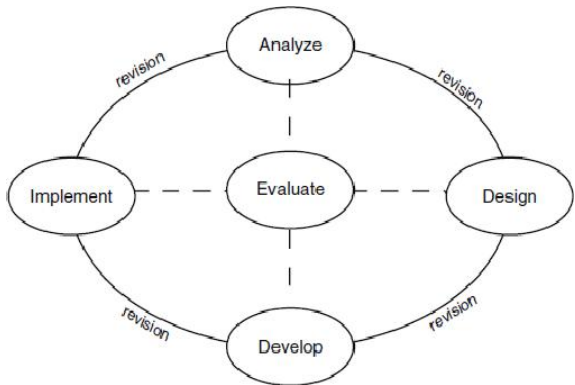


Fig. 1. ADDIE Stages [16].

Data collection in this study was carried out through three main instruments, namely observation, questionnaires, and pretests and posttests. Observations were carried out to see the learning conditions in the classroom before the use of AR media, with the aim of identifying the challenges faced by students in understanding the material on temperature and heat. Questionnaires were given to students and teachers to collect their perceptions regarding the design, ease of use, and effectiveness of AR-based learning media. The pretest was conducted to measure students' initial knowledge before using the educational game, while the post test was used to assess the increase in understanding after using the game. The data obtained were analyzed quantitatively and qualitatively. Quantitative data came from the results of the pretest and posttest which were analyzed using the N-Gain technique to calculate the increase in student understanding. This method is a way to measure how much increase in understanding occurs due to learning interventions. The N-Gain test formula according to Melter (in Septiani et. Al. 2021) [17] used is calculated using Equation (1).

$$N - Gain = \frac{PostTest\ Score - PreTest\ Score}{Maximum\ Score - PreTest\ Score}$$

Then, Table 1 present the criteria of normalized gain score.

Table 1. Normalized Gain Score Criteria

Gain score	Interpretation
$g > 0.7$	High
$0.3 < g \leq 0.7$	Medium
$g \leq 0.3$	Low

4 Results and Discussion

Based on the previously designed design, a learning media named “Aku Suka” has been produced. This learning media is an AR-based educational game designed for science material on Temperature and Heat for fifth grade elementary school students. In the development process, this study used the ADDIE method. The stages in the ADDIE method allow for structured development with stages, namely Analysis, Design, Development, Implementation, and Evaluation [16]. The following are the results of the ADDIE stages.

4.1 Analysis Stage

Requirements Analysis stages through direct observation at SDN 06 Rantau Panjang is the first step in this development. The results of this analysis are the basis for creating interactive learning media based on Augmented Reality (AR) that focuses on temperature and heat in Natural Science (IPA) material. Observations made in class V showed that the learning media used were very limited, traditional methods, such as lectures, were still the learning media. Although currently, the "independent learning" curriculum requires teachers to be able to use technology in learning.

Researchers developed learning media that focused on temperature and heat material by considering the needs found through observation and supported by literature studies. This medium is designed to provide an interactive and interesting learning experience.

4.2 Design Stage

The design stage produces concept designs, flowcharts, storyboards, and game assets. The design results at this stage can be seen in Table 2 (Game Concept), Figure 2 (Game Flowchart) and Figure 3 (Storyboard Design) and Figure 4 (Asset Design).

Table 2. Game Concept

Concept	Concept Description
Title	Aku Suka (Heat and Temperature)
Target Audience	Grade V Students of SD Negeri 06 Rantau Panjang
Direction	Single Player, Educational, Relaxing, Soft Color
Graphics	2D vector images in *.png format created as assets
Audio	Sound effects and background music used for the game

Game Mechanics

Quiz & Action Game (Falling Objects Games)

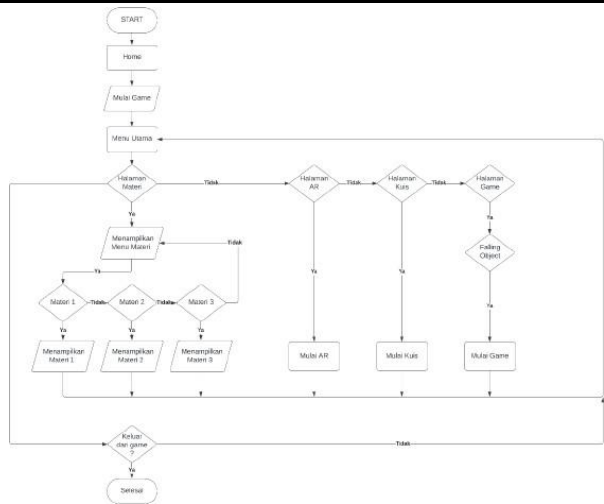
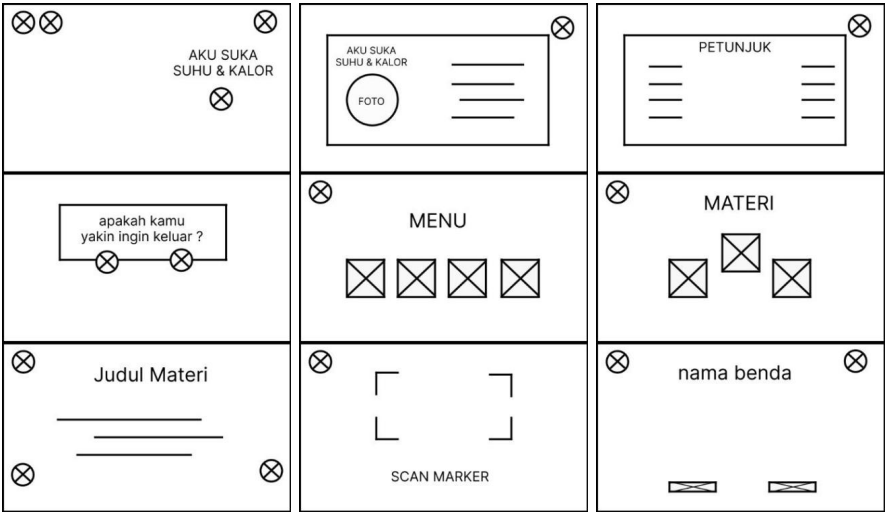


Fig. 2. Game Flowchart



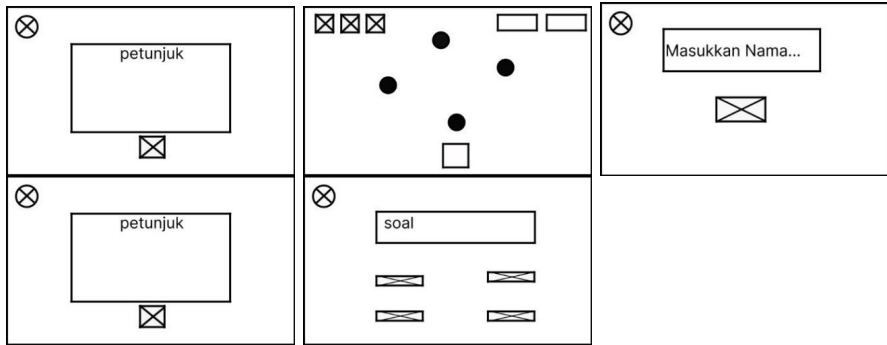


Fig. 3. Desain storyboard

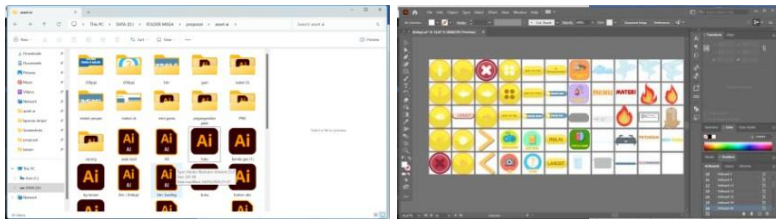


Fig. 4. Asset Design

4.3 Development Stage

At this development stage is the implementation of the design that has been made previously according to the storyboard. In accordance with the explanation at the development stage with the collection of materials for game assets, then combined and developed using Unity. The image shows the display results of the application that has been developed.

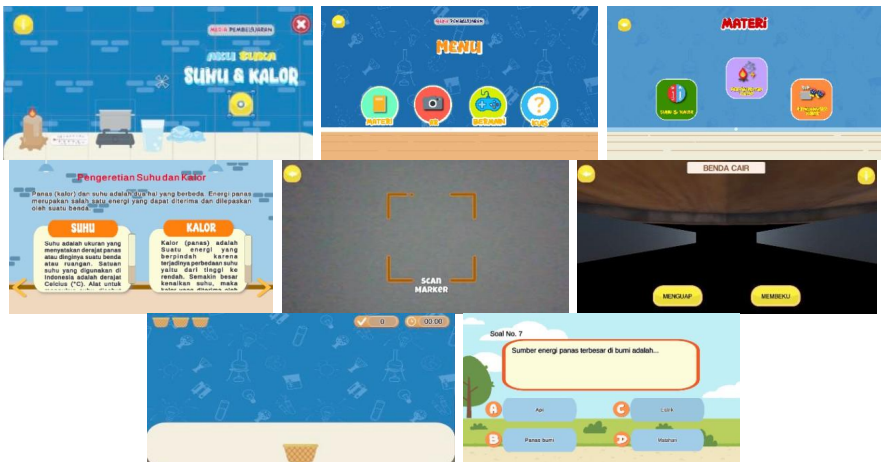


Fig. 5. View of the developed application.

4.4 Implementation Stages

Implementation was carried out by testing the educational game on 20 fifth grade students at SD Negeri 06 Rantau Panjang. Before students used the game, a pretest was conducted to measure their initial understanding of the concept of temperature and heat. After students used the educational game, a post test was conducted to measure the increase in students' understanding. Figure 6 is a graph of the results of the pretest and posttest.

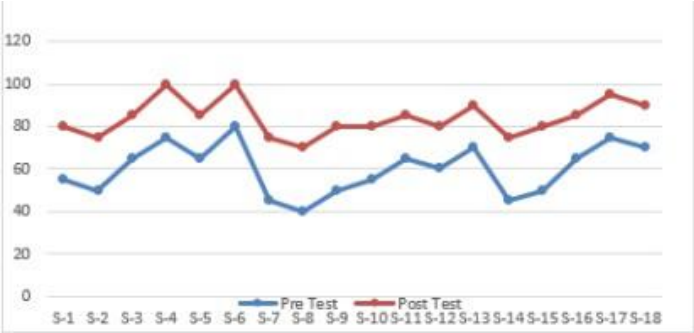


Fig. 6. PreTest and PostTest Results

The graph in Figure 6 shows a significant increase in student understanding, where the average pretest score is 60 and the average posttest score is 83.8. Next, calculate the N-Gain to determine the increase in students' understanding ability. The calculation data for the pre-test and post-test results with the N-Gain formula can be seen in Table 3.

Table 3. N-Gain Score Calculation Results Pre Test and Post Test

Kode Siswa	Pre Test	Post Test	Post - Pre	Skor Ideal (100 - Pre)	N-Gain skor
S-1	55	80	25	45	0,56
S-2	50	75	25	50	0,50
S-3	65	85	20	35	0,57
S-4	75	100	25	25	1
S-5	65	85	20	35	0,57
S-6	80	100	20	20	1
S-7	45	75	30	55	0,55
S-8	40	70	30	60	0,50
S-9	50	80	30	50	0,60
S-10	55	80	25	45	0,56
S-11	65	85	20	35	0,57
S-12	60	80	20	40	0,50

S-13	70	90	20	30	0,67
S-14	45	75	30	55	0,55
S-15	50	80	30	50	0,60
S-16	65	85	20	35	0,57
S-17	75	95	20	25	0,80
S-18	70	90	20	30	0,67
Rata-rata	60	83,88			0,63

Based on the N-Gain calculation results, the average improvement in student comprehension falls into the moderate category, with an N-Gain score of 0.63

4.5 Evaluation Stages

Evaluation was conducted based on the results of the pretest and posttest of students using educational games based on Augmented Reality (AR) on temperature and heat material. Evaluation was also conducted by involving subject teachers to evaluate the content of the educational games created and involving experienced media experts to assess the technical and visual aspects of the game.

The results of the questionnaire also showed that 85% of students felt more motivated to learn using AR educational games, and 90% of teachers gave positive responses to the ease of delivering material with the help of games. Meanwhile, media experts assessed the appearance, ease of use, and usability of the game with a validity value of 84% and the criteria "Very Valid". Although there are suggestions for improvement in the UI and audio-visual aspects. The overall results show that this educational game is effective and worthy of use as an interactive learning medium.

4.6 Conclusion

This study successfully developed educational game-based learning media with Augmented Reality (AR) technology for temperature and heat material in class V of SD Negeri 06 Rantau Panjang. The use of the ADDIE development model has proven effective in ensuring the quality of learning media. The trial results showed a significant increase in student understanding, with an average N-Gain score of 0.63, indicating a moderate category increase. This media also received positive assessments from material experts and media experts, with a validity reaching 90%, indicating the feasibility and effectiveness of its use in supporting the interactive learning process. Students felt more motivated, and teachers felt it was easy to deliver material that was previously difficult to understand with conventional methods.

Although the results of this study showed success, there are several aspects that still need to be improved. Application optimization is needed so that this AR-based educational game can run well on devices with lower specifications, considering the hardware limitations of some students. In addition, additional training is needed for teachers to utilize AR technology more optimally in learning. In the future, the development of

more interactive audio-visual features is also expected to further improve the quality of students' learning experiences.

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