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Multimarker Augmented Reality in Human Digestive System Application Using the MDLC Method

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ABSTRACT

Learning media has a crucial role in supporting the learning process, especially in subjects related to natural sciences. Using conventional media such as blackboards, pictures in books, and less varied teaching methods can make students feel bored, less active, and lose concentration. Therefore, this research aims to implement augmented reality technology in science subjects to create exciting and memorable learning experiences for students and encourage student involvement in the learning process. This research uses the Multimedia Development Life Cycle (MDLC) method, which applies the latest technology, Multimarker, to display more than one three-dimensional (3D) object. The research results show that learning media using Augmented Reality Technology on the human digestive system obtained a "Good" predicate and can be used in the learning process at Tuguran State Elementary School.

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1. INTRODUCTION

The human digestive system is a series of organs and processes that combine to transform food into nutrients the human body can absorb. Its primary purpose is to convert food into tiny particles, break down nutrients, and transport them throughout the body. The human digestive system consists of several parts, namely the mouth, esophagus, pancreas, liver, gallbladder, small intestine, large intestine, and anus[1].

The current technological advancements indirectly influence Indonesian society, particularly in information and communication technology progress, especially in education. Today's technology and communication development encourage individuals to be more creative and innovative in managing knowledge. This can transform human thinking patterns to be more efficient and keep up with technological advancements in every era[2]. The use of technology in education has the potential to enhance the quality and effectiveness of learning. However, it is essential to consider factors such as students' characteristics, the surrounding environment, and the learning media used to implement technology as a learning tool[3].

The utilization of learning media is a crucial element in learning resources[4]. Technological developments provide easy access and simplify the process of creating learning media. By utilizing audio-visual media, the learning process can become more efficient, exciting, and easy to understand[5]. In the context of the learning system, media can attract students' attention, indicating that learning media can increase students' focus and excitement through the interactions presented[6]

Several factors that influence students' interest in learning involve using inappropriate media in the learning process. Based on the observation results conducted at Tuguran Elementary School, it is evident that the fifth-grade Science teacher still relies on traditional teaching media such as blackboards and illustrative images found in textbooks. Additionally, the teaching methods used need more variety in delivering learning materials. This situation causes students to feel bored, less engaged, and have difficulty concentrating during the learning process. The interaction between teachers and students and among students should proceed more smoothly, leading to students paying less attention to the teacher[7]. Therefore, there is a need for improvement in the teaching approach to make it more engaging and interactive. One solution that can be implemented is to leverage Augmented Reality (AR) technology.

Augmented Reality is a method that integrates two-dimensional (2D) and three-dimensional (3D) virtual objects into a real-world scope and then projects these virtual objects in real-time[8]. Augmented Reality technology in education can facilitate the communication of lessons from teacher to student due to the visualization expected to enhance students' cognitive abilities by providing a real-time 3D representation of the human anatomy[9]. Using abstract content in visual representations allows students to explore learning topics more thoroughly[10].

The research entitled "Prehistoric Animal Learning Media Design Using Augmented Reality" aims to create an innovative and exciting learning media concept that can effectively introduce prehistoric animals to school students. The method used is marker-based, and the results of this research passed the functional system trial [11].

The following research is entitled "Augmented Reality: The Influence of Student Achievement, Satisfaction and Interest in Science Education" using the Research and Development (R&D) method. This research analyzes students' perspectives and the impact of Augmented Reality in science education. This research concludes that learning using Augmented Reality technology gets higher grades than traditional teaching methods[12].

The research "Using Augmented Reality (AR) in Learning Introduction to Electronic Components Based on Android" aims to design an application that provides information about electronic component symbols, including names, functions, and images, from their physical form. The method used in this research is the Multimedia Development Life Cycle (MDLC) with a marker-based approach. The test results show that this application is successful in system functionality and received a "Good" category rating. Even though it faces several problems related to camera quality and lighting, the test results show that this application is attractive and has the potential for further development. Therefore, implementing Augmented Reality at SMK Nusantara 1 Kotabumi is considered the right step to support the concept of learning methods[13].

Then, the research "Fluid Material Learning Media with Android-Based Augmented Reality Technology for High School Students" aims to develop and create learning media products using Android-based Augmented Reality technology for fluid material. The method applied is the Borg & Gall development model. The research results show that the learning media with augmented reality on the fluid material developed is considered suitable for use as a learning media[14].

Finally, the research "Design and Development of Augmented Reality-Based Multimedia in Citizenship Education in Garuda Pancasila Subjects in Elementary Schools" aims to design and test the feasibility of augmented reality-based learning multimedia in Elementary Schools. The method used is analysis, design, development, implementation, and evaluation (ADDIE). The research results show that the Augmented Reality application is suitable for learning and received a positive response from students and teachers[15].

In developing this application, implementing augmented reality technology in learning media and using Multimarker represent the latest innovative steps that set it apart. The main advantage of this technology lies in its ability to simultaneously display multiple 3D objects, offering significant potential to improve students' understanding of the subject matter. By enabling the simultaneous display of more than one 3D object, Multimarker technology creates a learning environment that is more interactive and profound. This is expected to create a more engaging and memorable learning experience for students, fostering their active involvement throughout the learning process.

2. RESEARCH METHOD

This research employs the Multimedia Development Life Cycle (MDLC), conducted through six stages: concept, design, material collecting, assembly, testing, and distribution

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[16]. Specifically, the marker method used in the Augmented Reality (AR) application utilizes a Multimarker. The use of markers is chosen because their reading process is relatively fast in displaying 3D objects and is highly suitable for educational modeling [17].

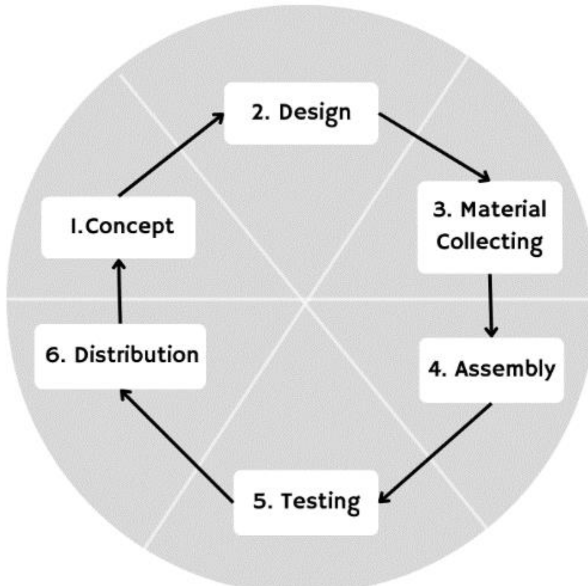

Figure 1. The stages of Multimedia Development Life Cycle (MDLC).

2.1. Concept

The concept stage is the initial phase to determine the goals of application development and identify the audience or users of the application. This application aims to create a more engaging and memorable learning experience for students, fostering their active involvement in the learning process.

2.2. Design

The design stage determines the program architecture, style, appearance, and material requirements. It requires a system design to provide a detailed and clear picture of the design and implementation of the system.

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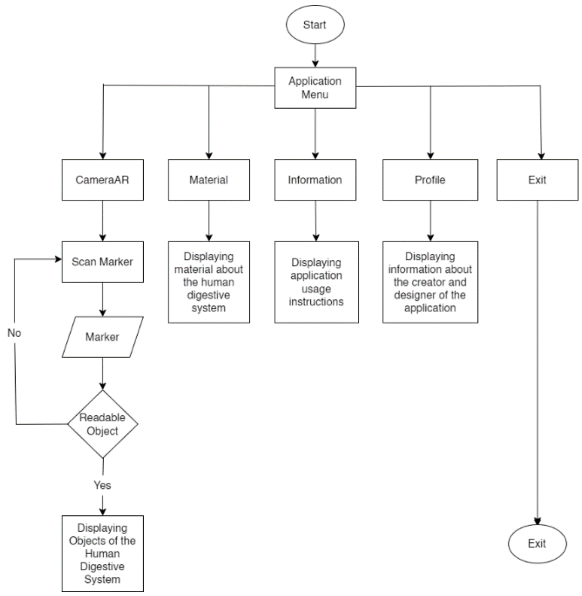

Figure 2. The Flow of Augmented Reality Application for the Human Digestive System.

2.3. Material Collecting

Material collecting gathers assets relevant to the work's needs, such as images, illustrations, animations, audio, video, and other materials. These can be sourced from books, literature studies, the internet, or other learning resources.

2.4. Assembly

Assembly is the process of processing all previously collected materials based on the design, storyboard, and navigation structure prepared in the design stage. The research materials and tools include hardware (laptops and smartphones) and software for creating the human digestive system application. The hardware and software specifications used in the application's production and development are listed below.

2.4.1. Hardware Requirements

This research uses hardware like an MSI GF63 Thin 11SC laptop and a Samsung Galaxy A51 smartphone. The MSI GF63 Thin 11SC laptop is the primary research tool, while the Samsung Galaxy A51 smartphone is a supporting device. Following are the hardware specifications of both:

Table 1. laptop Specifications

Hardware	Description
Brand and Model	MSI GF63 Thin 11 SC
Operating System	Windows 11
Processor	Intel Core i5-11400H

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RAM	8GB
Storage	SSD 512GB
Graphic Card	Nvidia GeForce GTX 1650

Table 2. Smartphone Specifications

Software	Description
Brand and Model	Samsung Galaxy A51
Operating System	Android 13
Screen Resolution	Full HD, 1080x2400 pixels
RAM	8 GB
Battery Capacity	4000 mAh
Internal Storage	128 GB

2.4.2. Software Requirements

The software applied in this research aims to support the application development process. This software has a significant role in facilitating the creation of Human Digestive System applications using Augmented Reality technology. The following is a list of software used in the application creation stage, along with a description:

Table 3. Software Specifications

Software	Description
Vuforia SDK	Library used to store markers and serves as indicators to display 3D objects
Unity3D	Software used to create the Augmented Reality Human Digestive System application
Blender	Software used to create 3D objects for the Human Digestive System
Figma	Software used to design the user interface of the Human Digestive System application
Draw.io	Software used to create flowcharts
QR Code Generator	Software used to generate QR codes

2.5. Testing

Testing is the process of trial and error to determine whether the application or marker can function optimally and meet expectations, as well as to identify potential errors or operational issues in the application. In this stage, the author and supervisor conduct device testing, Black Box testing, Tracking Marker testing, and Content or Material Validation testing.

2.6. Distribution

Distribution is the process of publishing the application to SD Negeri Tuguran so that the students at the school can use it. This stage also serves as an evaluation of the application. If there is feedback or evaluation, the research will return to the concept stage for further refinement.

3. RESULTS AND DISCUSSION

3.1. The Results of Augmented Reality Implementation

3.1.1 Main Menu Display

There are several features on the main menu display when first opening the application. On this page, there are menu options such as CameraAR to access the Augmented Reality camera page, Materi displaying the material page about the human digestive system, Informasi showing the user guide page, Profil displays information about the application developer, and Exit as an option to exit the application.

Future 3. Main Menu Page

3.1.2 CameraAR Display

On this page, the human digestive organs are displayed using the multimarker method, allowing a complete visualization of all digestive organs.

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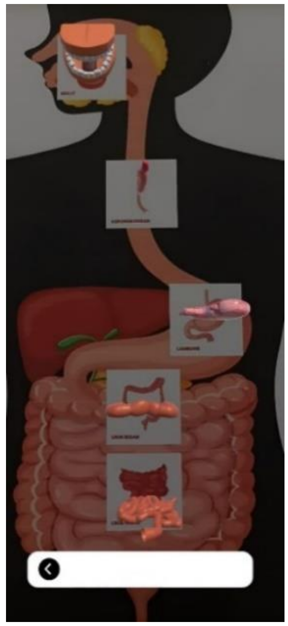

Future 4. CameraAR Display

3.1.3 Material Display

This page presents various materials, offering comprehensive information about the organs comprising the human digestive system. These essential components include the mouth, esophagus, stomach, small intestine, large intestine, and anus.

Future 5. Material Display

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3.1.4 Information Display

This page has instructions on how to use the Augmented Reality application camera. This guide provides detailed information and steps for users to utilize the camera in Augmented Reality effectively.

Future 6. Information Display

3.1.5 Profile Display

On this page is the developer's profile of the human digestive system application, including details and background information about the development team. This information provides an overview of their experience, expertise, and contributions to creating informative content about the human digestive system.

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Future 7. Profile Display

3.2. System Testing

System testing on the human digestive system application aims to ensure that the application can function according to the specified requirements and expectations. Some main functions of system testing in the application involve testing on different devices, black box testing, marker testing, and content or material validation.

3.2.1 Testing on Different Devices

The application is evaluated by testing its functionality on various devices to ensure optimal performance [18]. Each device exhibits distinctions in screen dimensions, processing capabilities, operating systems, and several other variables that can influence the efficiency of applications and the overall user experience. Regarding the initial device, the Samsung Galaxy A12, detailed specifications are provided in Table 4:

Table 4. Specifications of Samsung Galaxy A12

Hardware	Description
Operating System	Android 12
Screen Resolution	6.5", 720x1600 pixels
Processor	Mediatek Hello P35 Octa-core
RAM	4 GB
Internal Storage	128 GB

In this testing, the second device used is the Samsung Galaxy A33. The hardware specifications, such as the OS, Screen Resolution, Processor, RAM, and Internal Storage, are as follows in Table 5:

Table 5. Specifications of Samsung Galaxy A33

Hardware	Description
Operating System	Android 13
Screen Resolution	6.5", 1080x2400 pixels
Processor	Exynose 9611 Octa-core
RAM	8 GB
Internal Storage	258 GB

In this testing, the third device used is the Redmi Note 10 5G. The hardware specifications, such as the OS, Screen Resolution, Processor, RAM, and Internal Storage, are as follows in Table 6:

Table 6. Specifications of Redmi Note 10 5G

Hardware	**Description**
Operating System	Android 11
Screen Resolution	6.5", 1080x2400 pixels
Processor	MediaTek Dimensity 700 Dual 5G
RAM	8 GB
Internal Storage	128 GB

In this testing, the fourth device used is the Oppo A54. The hardware specifications, such as the OS, Screen Resolution, Processor, RAM, and Internal Storage, are as follows in Table 7:

Table 7. Specifications of Oppo A54

Hardware	**Description**
Operating System	Android 11
Screen Resolution	6.5", 720x1600 pixels
Processor	Delapan-inti (octa-core)
RAM	4 GB
Internal Storage	64 GB

In this testing, the fifth device used is the Realme C15. The hardware specifications, such as the OS, Screen Resolution, Processor, RAM, and Internal Storage, are as follows in Table 8:

Table 8. Specifications of Realme C15

Hardware	**Description**
Operating System	Android 11
Screen Resolution	6.5", 720x1600 pixels
Processor	Delapan-inti (octa-core)
RAM	4 GB
Internal Storage	64 GB

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Application testing is conducted on each device to assess the application's functionality on each of them. The device testing results are displayed in a table, including those above.

Table 9. Results of Testing Different Devices

Feature Tested	Samsung Galaxy A51	Samsung Galaxy A33	Redmi Note 10 5G	Realme C15	Oppo A54
Main Menu	Successful	Successful	Successful	Successful	Successful
CameraAR	Successful	Successful	Successful	Successful	Successful
Marker	Successful	Successful	Successful	Successful	Successful
Material	Successful	Successful	Successful	Successful	Successful
Information	Successful	Successful	Successful	Successful	Successful

The table displays the results of testing different features on various devices, including Samsung Galaxy A51, Samsung Galaxy A33, Redmi Note 10 5G, Realme C15, and Oppo A54. All features were successfully tested on each device.

3.2.2 Testing on Different Devices

Black box testing is conducted according to the prepared testing scenarios.

Table 10. Results of Black Box Testing Using Different Devices

Component	Testing Procedure	Expected Result	Conclusion
Scene MainMenu	Click CameraAR Button	Transition to the camera and display 3D object	Successful
	Click Material Button	Display material page	
	Click Information Button	Display Information page	
	Click Profile Button	Display Profile page	
Scene CameraAR	Click Camera Button	Display 3D object based on marker	Successful
	Click Back Button	Return to the main menu	
Scene Material	Click Material Button	Display material about digestive system organs	Successful
	Click Back Button	Return to the main menu	
Scene Information	Click Information Button	Display information guide on using the app	Successful
	Click Back Button	Return to the main menu	
Scene Profile	Click Profile Button	Display profile page	Successful
	Click Back Button	Return to the main menu	

3.2.3 Marker Testing

Marker testing is conducted to evaluate how light intensity, distance, and the angle of inclination of the device affect the effectiveness of the Multimarker in identifying markers and displaying 3D objects. This testing also aims to determine the minimum and maximum requirements for light intensity, distance, and angle to ensure that the Multimarker method can effectively detect markers and render 3D objects [19].

3.2.3.1. Light Intensity Testing

Light intensity testing is conducted at different time periods, namely during the day and at night. The results of the light intensity testing are presented in Table 11.

Tabel 11. Light Intensity Testing

Conditions	Results Obtained	Testing Results
Daytime	3D object can be detected when the marker has been identified	Successful
Nighttime (Bright Light)	3D object can be detected when the marker has been identified	Successful
Nighttime (Dim Light)	3D object can be detected when the marker has been identified	Successful
Nighttime (Dark)	3D object cannot be detected when the marker has been identified	Failed

3.2.3.2. Occlusion Testing

Occlusion testing aims to assess the extent to which a system or device can detect and handle objects or markers that are obstructed or overlapped by other objects[20]. The results of occlusion testing can be found in Table 12.

Tabel 12. Occlusion Testing

Conditions	Results Obtained	Testing Results
Marker covered 25% on the marker's surface	3D object can be detected when the marker has been identified	Successful
Marker covered 50% on the marker's surface	3D object can be detected when the marker has been identified	Successful
Marker covered 75% on the marker's surface	3D object can be detected when the marker has been identified	Successful

3.2.3.3. Distance Testing

Distance testing involves measuring the height of the marker from the smartphone camera using a ruler. The results of the distance testing can be seen in Table 13.

Table 13. Distance Testing Results

Conditions	Results Obtained	Testing Results
Distance 10 cm from the marker	The camera can still detect the marker, so the 3D object continues to appear	Successful
Distance 25 cm from the marker	The camera can still detect the marker, so the 3D object continues to appear	Successful

Distance 40 cm from the marker	The camera can still detect the marker, so the 3D object continues to appear	Successful
Distance 55 cm from the marker	The camera can still detect the marker, so the 3D object continues to appear	Successful

3.2.4 Validation Testing of Material or Content

Validation testing for the human digestive system application involves examining and evaluation the information or material presented in the application. The results of material validation testing can be seen in Table 14:

Table 14. Material Validation Results

Indicators	Digestive Organs	Assessment Scale			
		1 "Very bad"	2 "Bad"	3 "Good"	4 "Very Good"
Depth of Material	Mouth			✓	
	Esophagus			✓	
	Stomach			✓	
	Small Intestine			✓	
	Large Intestine and Anus			✓	
Appropriateness of 3D Objects	Mouth			✓	
	Esophagus			✓	
	Stomach			✓	
	Small Intestine			✓	
	Large Intestine and Anus			✓	

Based on material testing results, material depth, and the appropriateness of 3D objects in the application, a rating of "good" is given on a scale of 3. This indicates that the material has adequate quality and the application can be effectively used in learning. Multimarker technology provides significant added value, enhancing the overall learning experience. Thus, this application proves to positively contribute to the learning process by providing an excellent experience to its users. This evaluation strengthens the belief that this application can be an effective tool to support further learning.

4. CONCLUSION

Based on the research, this application has successfully integrated various software such as Blender, Figma, and Unity while implementing the latest method, Multimarker. The application operates smoothly and efficiently on different Android devices. Marker testing involves lighting stages, distance, and occlusion; unfortunately, the 3D objects do not appear successfully in low-light marker testing conditions. Nevertheless, the application has been awarded a "Good" rating in the context of Augmented Reality learning media for the human digestive system. In this context, educational content and 3D objects of the digestive system can be displayed effectively on markers, and button functions across all pages operate as expected. This aligns with the application's intended purpose, aiming to provide a satisfying and informative learning experience.

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