



Android-Based Markerless Augmented Reality as a Learning Media for Human Internal Organs

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Abstract. Human internal organs cannot be observed directly in routine classroom learning, while SMP Negeri 2 Langke Rembong has only two physical teaching aids for a large number of students. This study developed an Android-based markerless Augmented Reality (AR) application as an interactive learning medium for introducing nine human internal organs to ninth-grade students. The application integrates three-dimensional organ visualization, object rotation, organ information, a quiz, and an application guide in a single mobile learning environment. The system was developed through data collection, requirements analysis, interface and system design, implementation, and evaluation. Functional verification was performed using black-box testing for the main application features, while user experience was evaluated with ten ninth-grade students. The black-box tests showed that the tested features operated according to the specified functional requirements, and the user experience evaluation produced an average score of 91.80%, categorized as very good. These findings support the application's feasibility as an interactive supplementary learning medium. However, the study did not conduct a controlled pre-test/post-test evaluation; therefore, claims regarding learning-gain effectiveness require further investigation with larger and more diverse samples.

Keywords: Augmented Reality, Learning Media, Markerless Method

1 Introduction

The development of information and communication technology has had a significant impact on the learning process. The use of digital media in education enables the delivery of learning materials in a more interactive, visual, and easily understandable way for students. One technology that can be used as a learning medium is Augmented Reality (AR), which combines virtual objects, such as images or three-dimensional models, with the real environment using a camera (Hutahaean et al., 2022).

Given the learning conditions at SMP Negeri 2 Langke Rembong, the introduction of the human body's internal organs still largely relies on textbooks and laboratory teaching aids (Wang et al., 2024). However, the number of available teaching aids remains limited, with only two models provided, so the learning process has not yet run optimally. This limitation may make it difficult for students to understand the material, especially since the internal organs of the human body cannot be observed directly.

Therefore, an alternative learning medium is needed to help students understand the material more engagingly and interactively. The use of Android-based Augmented Reality technology with a markerless approach may be a solution, as it allows students to view three-dimensional models of human internal organs without requiring special markers. This application is expected to support the learning process in biology, increase students' interest in the subject, and facilitate independent learning through Android devices.

This study is limited to the introduction of nine internal human organs using markerless Augmented Reality technology. The material discussed is focused on instructional content for ninth-grade students at SMP Negeri 2 Langke Rembong (Murdhani et al., 2023). The organs presented in the application include the brain, heart, liver, lungs, stomach, kidneys, pancreas, intestines, and urinary bladder.

Previous studies have demonstrated the potential of AR for anatomy learning in medical education, high-school contexts, and mobile learning environments (Almesta et al., 2025; Bakar et al., 2021; Iparraguirre-Villanueva et al., 2024; Murdhani et al., 2023; Wang et al., 2024). However, the cited studies do not specifically address the local constraint faced at SMP Negeri 2 Langke Rembong, where a limited number of physical anatomy models must be shared by many junior high school students. Accordingly, the contribution of this study is not a new AR tracking algorithm, but a context-specific educational system integration: an Android-based markerless AR application tailored to ninth-grade biology that combines nine 3D internal-organ models, rotatable visualization, organ information, an embedded quiz, and an application guide in one portable learning medium. This integrated design is intended to reduce dependence on scarce laboratory teaching aids and support individual or small-group exploration through students' mobile devices.

Based on these problems, this study aims to develop an Android-based Augmented Reality application to introduce the human body's internal organs using a markerless method. The application is expected to help teachers explain the shape, location, and function of human internal organs more visually and interactively. In addition, it is expected to provide students with clearer information by presenting three-dimensional models of the human body's internal organs, thereby making their anatomy easier to understand.

2 Methodology

This study was conducted at SMP Negeri 2 Langke Rembong to develop an Android-based Augmented Reality application as an interactive learning medium for introducing the human body's internal organs. The research method employed included data collection, system requirements analysis, application design, and application implementation and testing.

2.1 Data Collection

During the data collection stage, documentation was conducted on several objects used in the biology learning process at SMP Negeri 2 Langke Rembong. The data collected

included teaching aids for human internal organs available in the biology laboratory, as well as documentation of the learning materials used to introduce them. These data served as the basis for developing three-dimensional objects for the Augmented Reality application.

2.2 System Overview

The developed application is a markerless Augmented Reality app that runs on Android devices. The system was designed as an interactive learning medium that enables students to visually study the human body's internal organs through 3D models (Prayitno et al., 2025).

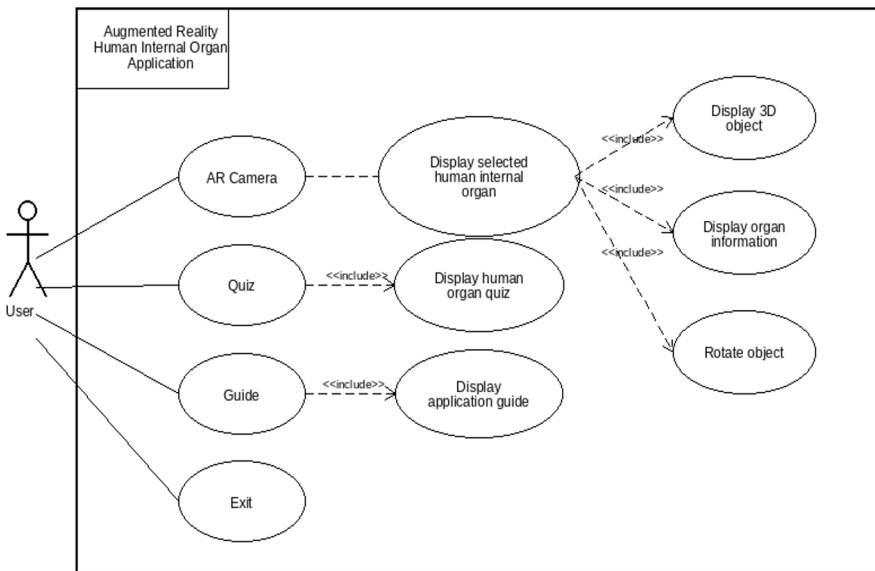


Figure 1. Use Case Diagram

The application usage process begins with the user downloading and installing the application on a smartphone device. After launching the application, the user selects the “AR Camera” menu to access the Augmented Reality feature. Next, the user chooses one of the human internal organs to study. The system then automatically activates the camera and displays a three-dimensional object of the selected organ. The displayed object can be rotated, allowing the user to observe the organ in greater detail. In addition, the application provides information on the function and description of the selected organ (Bakar et al., 2021). The application's use case diagram is shown in Figure 1.

The use of Augmented Reality technology in this application is expected to provide students with a more interactive and engaging learning experience. With this application, students do not always need to be in the biology laboratory to study the

human body's internal organs, as the learning materials can be accessed flexibly on a smartphone (Iparraguirre-Villanueva et al., 2024)

2.3 Functional Requirements Analysis

Functional requirements are the main features that a system must provide. The functional requirements of the Augmented Reality application for introducing the internal organs of the human body are as follows:

- a) The application can be installed on Android smartphones and used by both teachers and students.
- b) The application can display three-dimensional models of the human body's internal organs.
- c) The application can present information for each selected organ.
- d) The displayed three-dimensional objects can be rotated to facilitate observation.
- e) The application provides usage guidelines for users.
- f) The application provides information about the application developer.

2.4 Development Tools

The application was implemented using the Unity development environment and deployed on Android smartphones. Unity was used to integrate the user interface, three-dimensional human-organ assets, camera-based markerless AR interaction, object-rotation controls, organ-information panels, quiz components, and navigation between application pages. The Android device camera provides the real-world view used by the AR feature, while the application overlays the selected 3D organ model on the detected environment. The study focuses on application-level implementation and educational media functionality; no new computer-vision or tracking algorithm was proposed.

2.5 Evaluation Procedure

Two forms of evaluation were conducted. First, black-box testing was used to verify whether each user-accessible feature produced the expected output without examining the application's internal source-code structure. The test cases covered application launch, main-menu navigation, AR camera activation, organ selection and 3D visualization, object rotation, organ information, quiz execution and score display, guide access, return navigation, and application exit.

Second, user experience testing was conducted with ten ninth-grade students from SMP Negeri 2 Langke Rembong from July 27 to July 29, 2024. After using the application under developer guidance, the students completed the existing questionnaire. This user study evaluates perceived attractiveness, ease of use, clarity, and usefulness; it should not be interpreted as evidence of learning-gain effectiveness because no pre-test/post-test or control-group design was conducted.

3 Results and Discussion

3.1 Result

Main User Interface. The splash screen is the initial display that appears when the application launches. At this stage, the application displays its logo as the primary identifier before the user reaches the system's main page. The splash screen of the Augmented Reality application introducing the human internal organs is shown in Figure 2(a). The dashboard page, or main menu, is displayed after the loading process is complete. This page contains several main menus for the user: Start, Guide, and Exit. The main menu features a simple, easy-to-understand interface, making it easier for users to access the application's features. The appearance of the application's main menu is shown in Figure 2(b).

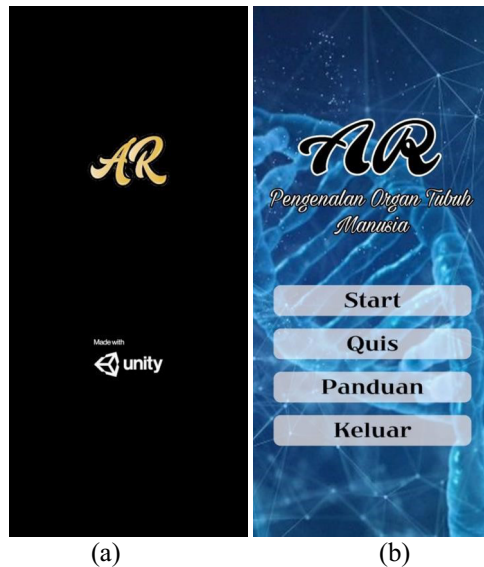


Figure 2. User Interface Splash Screen and Dashboard

AR Camera Menu User Interface. The AR Camera menu is the main feature of the application and displays three-dimensional models of human internal organs using markerless Augmented Reality technology. On this page, users can select the organ they want to study, after which the system automatically activates the device camera to detect the surrounding environment and display the 3D object (Almesta et al., 2025). Once the object is successfully displayed, the user can view information about the selected organ and rotate it to observe it from various angles. The AR Camera menu interface is shown in Figure 3.

Organ Information User Interface. The organ information page displays an explanation of the selected organ. This page provides information about the organ's

name and function in the human body, helping users gain a more comprehensive understanding of the material (Namri et al., 2023).

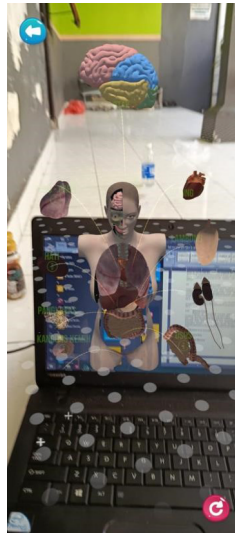


Figure 3. User Interface AR Camera

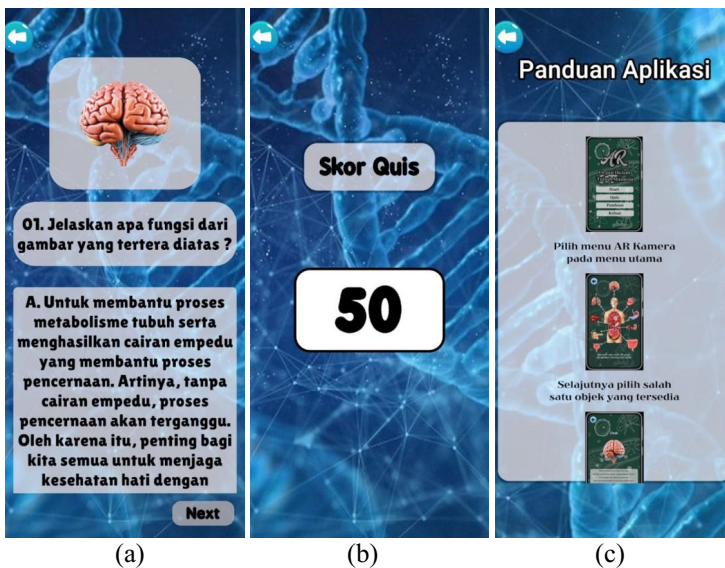


Figure 4. Quiz and Application Guide User Interface (in Indonesian Language)

Quiz and Guide User Interface. The Quiz page serves as a learning assessment tool for users after studying the material on the human organs. Users are asked to answer

several questions in the application until the Quiz is complete. After the user completes the Quiz, the application displays a score page showing the user's result (Sembayev et al., 2021).

In addition, the application includes a guide page to help users understand how to use it. This page outlines the steps for using the application's features, helping users operate the application more easily. The Quiz, score, and guide pages are shown in Figure 4.

3.2 Discussion

Functional evaluation was performed using black-box testing to verify the behavior of the application from the user's perspective. The revised test set maps directly to the functional requirements and visible application features, including installation and launch, main-menu navigation, AR camera activation, display of selected 3D organs, object rotation, organ information, quiz and score presentation, guide access, back navigation, and application exit. This approach is appropriate for confirming whether the implemented functions respond as specified, although it does not measure internal code quality or educational learning gains (Ariansyah et al., 2022).

Table 1. Black-Box Testing

#	Test Class	Test Scenario	Expected Results	Test Results
1	Application Launch	Open the installed application.	The splash screen is displayed and the application proceeds to the main menu.	Valid
2	Main Menu	Access the main menu after the splash screen.	Start/AR, Quiz, Guide, and Exit options are displayed and selectable.	Valid
3	AR Camera	Select the AR Camera/Start menu.	The device camera is activated and the AR learning interface is displayed.	Valid
4	Organ Selection	Select one of the available internal organs.	The selected 3D internal-organ model is displayed in the AR scene.	Valid
5	Object Rotation	Use the rotation control on the displayed organ.	The 3D organ rotates according to the user interaction.	Valid
6	Organ Information	Open the information function for the selected organ.	The application displays the organ name, description, and/or function information.	Valid
7	Quiz	Select and answer quiz questions.	Quiz questions are displayed and the user can proceed through the quiz.	Valid
8	Quiz Score	Complete the quiz.	The application displays the final quiz score.	Valid
9	Guide	Select the Guide menu.	The application displays instructions for using the application.	Valid
10	Back Navigation	Press the back button from AR/information/guide pages.	The application returns to the appropriate previous menu without closing unexpectedly.	Valid
11	Exit	Select the Exit menu.	The application closes as intended.	Valid

The results in Table 1 show that all tested functions produced the expected outputs. This finding indicates that the integrated application workflow is operational across the main learning interactions: students can open the application, access the markerless AR camera, select and inspect a 3D organ, rotate the object, read organ information, complete the quiz, view a score, consult the guide, and return to the main menu. Functional validity is important because interruptions in navigation or visualization would reduce the usefulness of AR as a classroom learning medium.

In addition to functional testing, user experience testing was conducted to examine users' experiences with the application. The testing was conducted from July 27, 2024, to July 29, 2024, with 10 ninth-grade students from SMP Negeri 2 Langke Rembong as respondents. At this stage, the respondents were asked to try the application under the developer's guidance and then complete a questionnaire about their experience (Singh & Ahmad, 2024). A recapitulation of the responses can be seen in Table 2.

Table 2. Presentation of User Experience Testing Data

No	Question	Answer					Total
		SS	S	RR	TS	STS	
1	The design of this application is very attractive	3	5	2	0	0	10
2	The design of this application is very attractive	2	5	3	0	0	10
3	This application provides a new experience for students and teachers	4	4	2	0	0	10
4	This application makes it easier for students to obtain information and helps them learn about the internal organs of the human body more clearly	4	2	3	1	0	10
5	This AR application is easy to scan and can display 3D objects properly	5	3	2	0	0	10
6	The rotation, information, and audio buttons in this application function properly	5	1	4	0	0	10
7	The information presented is clear and easy to understand	4	4	2	1	0	10
8	The guide on how to use the application is easy to understand	5	3	2	0	0	10
9	This application is very helpful for students in learning about the internal organs of the human body	4	3	3	0	0	10
10	This application has a modern appeal	4	4	2	0	0	10

The user experience testing produced a reported average score of 91.80%, placing the application in the very good category. The responses indicate that students generally perceived the application as attractive, modern, easy to use, and helpful for accessing organ information. Positive responses are plausible because the application combines spatial 3D visualization with direct interaction, allowing students to inspect organ models from different angles rather than relying only on static textbook images or two shared physical teaching aids. This interpretation is consistent with prior AR studies reporting benefits in visualization, engagement, and interactive learning experiences

(Bakar et al., 2021; Iparraguirre-Villanueva et al., 2024; Lin & Yu, 2023; Singh & Ahmad, 2024; Wang et al., 2024).

Table 3. User Experience Testing Calculation Results

No	Question										Answer	Percentage
	1	2	3	4	5	6	7	8	9	10		
1	4	4	5	4	5	5	4	5	5	5	46	92%
2	5	4	5	4	5	5	4	5	4	5	46	92%
3	4	5	4	4	5	5	4	5	5	5	46	92%
4	5	5	5	4	5	5	5	5	5	5	49	98%
5	5	5	5	5	5	5	5	5	5	5	50	100%
6	3	4	5	2	5	5	2	5	4	5	40	80%
7	4	4	4	4	4	4	4	4	4	4	40	80%
8	5	4	5	5	4	5	5	5	5	5	48	96%
9	5	5	4	5	5	4	5	5	5	5	48	96%
10	4	4	5	5	4	4	5	5	5	5	46	92%
Average												91.80%
Criterion												VERY GOOD

Compared with previous AR-based anatomy learning studies, the present work contributes a junior-high-school implementation centered on a practical classroom resource constraint. Previous mobile and markerless AR anatomy applications have shown that augmented visualization can support anatomy exploration (Almesta et al., 2025; Bakar et al., 2021; Iparraguirre-Villanueva et al., 2024; Kurniawan et al., 2018), while the current application packages nine internal organs, organ descriptions, object rotation, a quiz, and an application guide into a single Android-based markerless learning medium. The educational implication is that students can repeatedly explore organ representations without waiting for access to limited physical models, and teachers can use the application as a supplementary visualization tool during biology instruction rather than as a replacement for teacher explanation or laboratory learning. Nevertheless, the evaluation has two important limitations. First, the user experience study involved only ten students from one school, so the results describe a small local sample and cannot be generalized to broader student populations. Second, black-box testing and satisfaction questionnaires demonstrate functionality and perceived usability, but they do not establish educational effectiveness. No controlled pre-test/post-test comparison or conventional-learning control group was included in the available study data. Future research should therefore recruit larger samples from multiple classes or schools and evaluate learning outcomes using pre-test/post-test scores, effect-size analysis, and, where feasible, comparison with conventional learning media.

4 Conclusion

Based on the study's results, the Android-based Augmented Reality application for introducing the human body's internal organs using a markerless method was

successfully designed and developed as an interactive learning medium for students at SMP Negeri 2 Langke Rembong. The application development process consisted of several stages: data collection through observations and interviews with biology teachers; system and user interface design; and the implementation of the Augmented Reality-based application.

The developed application includes several main features, including a main menu, an Augmented Reality camera feature for displaying three-dimensional models of human internal organs, an organ information feature, a quiz feature, and an application user guide. Through these features, students can learn about the human body's internal organs more interactively and engagingly than with conventional learning media.

The black-box testing results showed that the tested application features functioned properly in accordance with the functional requirements. User experience testing with ten students yielded an average score of 91.80%, categorized as very good, indicating positive perceptions of usability and learning-media experience. These findings support functional feasibility and user acceptance; however, they should not be interpreted as proof of improved learning outcomes because the study did not include a pre-test/post-test or control-group evaluation.

Future studies should improve the application by enriching the information associated with each 3D object, adding other organ systems such as the nervous, muscular, and immune systems, and introducing additional interactive learning activities (Uruthiralingam & Rea, 2020). Methodologically, subsequent evaluation should involve a larger and more diverse sample across multiple classes or schools and should measure educational effectiveness through pre-test/post-test comparisons and, where possible, comparison with conventional learning methods.

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