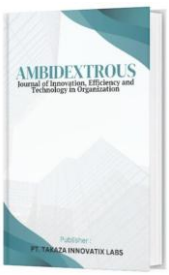
Ambidextrous: Journal of Innovation, Efficiency and Technology in Organizations

https://journal.takaza.id/index.php/ambidextrous

Vol. 5 , no. 01 , 2026 , pp. 117-129
E-ISSN: 3031-7002

E-mail:ambidex@takaza.id



Design and Construction of Interactive Learning Media Based on Augmented Reality for 3D Object Visualization Using the Marker-Based Tracking Method

Tasya Mauliza[1], Zainal Azis[2]
Program Studi Teknologi Informasi Fakultas Ilmu Komputer Dan Teknologi Informasi
Universitas Muhammadiyah Sumatera Utara
Corresponding Author e-mail : tasyamauliza59@gmail.com

Article History:
Received : 12-10-2026
Revised : 06-11-2026
Accepted : 07-11-2026

Keywords: Android Application, Augmented Reality, Interactive Learning Media, Marker-Based Tracking, Medicinal Plants

Abstract : *Digital technology provides opportunities to utilize Augmented Reality (AR) as an interactive learning medium for presenting educational materials through three-dimensional visualization. This study aimed to design and develop an AR-based learning application for visualizing six medicinal plants using the Marker-Based Tracking method. The study employed a Research and Development (R&D) approach, with application development following the Multimedia Development Life Cycle (MDLC), which consists of six stages: concept, design, material collecting, assembly, testing, and distribution. The application was developed for Android devices using Unity 6 LTS and Vuforia Engine, with 3D models created in Blender. Functional testing was conducted by the researchers using Black Box Testing, while compatibility testing was performed on three Android devices. The initial functional testing showed that five core features, namely application launch, marker detection, 3D object visualization, audio narration, and menu navigation, operated according to the expected specifications. However, additional features, including object rotation and zoom, button sound effects, marker saving, and application stability, still require systematic testing. Compatibility testing indicated that the application could run on the tested devices, although performance varied depending on device specifications and lighting conditions. Direct usability evaluation involving seventh-grade students at SMP Muhammadiyah 07 Medan has not yet been conducted, and the population and sample sizes have not been established. Therefore, the findings demonstrate the initial functional feasibility of the application rather than its effectiveness in improving learning outcomes. Further testing involving students and broader device compatibility assessments is required to evaluate usability and its potential contribution to learning.*

How to Cite : Tasya Mauliza, Zainal Azis. (2026). *Design and Construction of Interactive Learning Media Based on Augmented Reality for 3D Object Visualization Using the Marker-Based Tracking Method*. 5(01). Pp. 117-129. https://doi.org/10.61536/ambidextrous.v5i01.949

https://doi.org/10.61536/ambidextrous.v5i01.949

This is an open-access article under theCC-BY-SA License.

Introduction

The development of digital technology has driven changes in the use of learning media in education. Learning media is no longer limited to textbooks and printed materials, but also includes learning videos, interactive simulations, educational games, and Augmented Reality (AR), which can enrich students' learning experiences (Hasan et al., 2021; Wijaya & Darmawan, 2021). This development aligns with the importance of learning media in supporting students' understanding of the material presented by teachers (Arsyad, 2017). Augmented Reality is a technology that combines virtual elements with the real environment through the assistance of computer technology so that digital objects can be displayed and observed directly (Billinghurst et al., 2015). This technology has the potential to be utilized in learning because it can present objects in a more interactive three-dimensional (3D) form. The development of AR-based learning media has also been carried out by Djafar & Novian (2021) through a study entitled "Implementation of Augmented Reality Technology in the Development of Computer Hardware Learning Media." The study employed a 4D model of development research and development, with data collected through observation, interviews, documentation studies, and questionnaires, analyzed quantitatively and descriptively. The results demonstrate that AR can be utilized as a learning tool.

Although digital technology has opened up opportunities for the development of more interactive learning media, its application in learning still needs to be adapted to the characteristics of the material being studied by students. Learning that still relies on conventional methods, such as textbooks and printed media, can face obstacles when students learn concepts that require more detailed object visualization. One topic that requires such visualization support is medicinal plants, particularly in recognizing morphology and understanding their uses. The limited availability of engaging learning media can reduce students' interest in learning and curiosity, especially when the material is presented only in the form of text or two-dimensional images (Purwoko, 2023). However, technological developments allow learning materials to be presented through more interactive media tailored to students' needs. AR has several advantages, including ease of use, relative affordability, widespread applicability, and the lack of complex hardware (Mursyidah & Saputra, 2022). Furthermore, AR technology is considered effective, applicable to various media forms, easy to operate, and more interactive than other learning media (Widyasari & Ismawati, 2020). Therefore, the use of AR in learning medicinal plants has the potential to be an alternative to help students observe objects visually and understand the material in a more interesting way.

These problems are the basis for the need to develop AR-based learning media that specifically presents medicinal plant material for seventh-grade students in the Cultivation aspect of the Craft subject at Muhammadiyah 07 Middle School Medan. This development uses the Marker-Based Tracking method, which is a method that utilizes visual markers to recognize and display virtual objects through the device's camera. This method was chosen because it allows 3D objects to be displayed based on marker scan results, making it suitable for supporting interactive learning using plant picture cards. This study also considers the use of Android devices so that the application can be operated on devices that support the specified specifications. In the development process, Unity 3D was used as a game engine and Vuforia as an AR development tool, while Blender was used for creating and modifying 3D objects and Canva to support visual design. The development of this multimedia application refers to the Multimedia Development Life Cycle (MDLC) model which consists of six stages, namely concept, design, material collecting, assembly, testing, and distribution (Luther, 1994; Munir, 2017). Through these stages, the application was developed by paying attention to design, material requirements, object creation, and functionality testing. This study also limits the visualization objects to six types of medicinal plants, namely ginger, turmeric, aloe vera, betel, galangal, and Javanese ginger, with 360-degree object rotation features, zoom in/out, simple animation, as well as brief information regarding scientific names, main properties, and processing methods.

Based on these problems, this study aims to design and develop an AR-based interactive learning media that displays 3D visualizations of six types of medicinal plants, implements basic interaction features and educational information, and builds an Android-based application using the Marker-Based Tracking method using Unity 3D and the Vuforia SDK. Furthermore, this study aims to test the application's functionality using the Black Box Testing method to ensure each feature runs according to the specified specifications. The urgency of this research lies in the need for learning media that can

https://doi.org/10.61536/ambidextrous.v5i01.949
This open-access article is distributed under a Creative Commons Attribution (CC-BY-SA) 4.0 license

help teachers deliver medicinal plant material more interactively while providing opportunities for students to observe 3D objects without having to rely entirely on physical plant samples. The novelty of this research lies in the development of an AR application with the Marker-Based Tracking method specifically directed at learning the morphology and utilization of medicinal plants for seventh-grade students, by integrating visualizations of six types of plants, basic interactions, and educational information in one Android application. Thus, this research is expected to provide alternative learning media that are appropriate to the context of medicinal plant material and support the implementation of learning based on the learning outcomes of the Independent Curriculum (Kemendikbudristek, 2022).

Method

This study uses the Research and Development (R&D) method, a research method aimed at producing a specific product and testing its effectiveness (Sugiyono, 2022). The product developed is an interactive learning media based on Augmented Reality (AR) for visualizing three-dimensional (3D) objects of medicinal plants for seventh-grade students of SMP Muhammadiyah 07 Medan. The application development uses the Multimedia Development Life Cycle (MDLC) model consisting of six stages: concept, design, material collecting, assembly, testing, and distribution (Luther, 1994; Munir, 2017). The application applies the Marker-Based Tracking method using Unity 3D and Vuforia SDK, with 3D objects created using Blender and markers designed using Canva.

The research instrument was a Black Box Testing scenario used to evaluate the application's functionality. Testing included application launch, marker detection, 3D object visualization, rotation and zoom features, narration audio playback, menu navigation, and application stability. Data were analyzed descriptively by comparing the test results with the expected output. The success rate was calculated based on the number of successful features divided by the total number of tested features, then multiplied by 100%. The analysis results were presented in tabular form and categorized based on the success rate, ranging from very poor to excellent.

The research subjects were junior high school students who were users of an AR learning media application for medicinal plants. Students were involved in testing to determine ease of use and the suitability of the application's functions to their learning needs. However, the population and sample size were not specified in the provided research materials, so adjustments were needed to accommodate the research implementation.

The research procedure is carried out through the six MDLC stages as follows.

1. **Concept (Concept).**Identifying medicinal plant learning problems, determining development objectives, analyzing user needs, and determining the scope of application.
2. **Design (Design).**Designing system workflows, application interfaces, menu structures, markers, and user interactions with 3D objects.
3. **Material Collecting (Material Collection).**Collecting learning materials and application assets, including information on six types of medicinal plants, 3D models, markers, and audio narration.
4. **Assembly (Manufacturing).**They created a 3D model using Blender, designed markers using Canva, integrated the Vuforia SDK with Unity 3D, and built features for object visualization, plant information, rotation, zoom, and audio narration. The application was then built in APK format for Android devices.
5. **Testing.**Testing application functionality using Black Box Testing to ensure marker detection, 3D object display, information presentation, audio playback, navigation, and application stability run according to specifications.
6. **Distribution.**Distributing applications in APK format that can be installed on Android devices with a minimum operating system of Android 10.0 (API Level 29), as well as providing medicinal plant markers in the form of printed cards to support the learning process.

Results and Discussion

System Implementation Results

1. Implementation Environment

During the development process, it was discovered that the latest version of the Vuforia Engine used (version 11.3.4) requires a minimum operating system of Android 10.0 (API Level 29) along with a 64-

https://doi.org/10.61536/ambidextrous.v5i01.949
This open-access article is distributed under a Creative Commons Attribution (CC-BY-SA) 4.0 license

bit architecture (ARM64) and an IL2CPP scripting backend, so the specifications listed in Chapters I and III were adjusted to comply with these requirements. Furthermore, it was discovered that the Vulkan Graphics API caused the camera display on the test device to become completely dark, so the Graphics API was locked to OpenGL ES 3.0 to ensure the Augmented Reality camera display ran properly. Full details of the final implementation environment are presented in Table 1.

Table 1. Implementation Environment Specifications

No	Component	Specification
1	Hardware Development	ASUS Vivobook Go E1404FA Laptop, AMD Ryzen 5 7520U, 16GB RAM
2	Test Device	Android smartphone with rear camera
3	Game Engine	Unity 6 LTS (Built-in Render Pipeline)
4	AR SDK	Vuforia Engine 11.3.4
5	3D Modeling Application	Blender 4.2 LTS
6	Programming language	C#
7	Backend Scripting	IL2CPP
8	Architecture Target	ARM64
9	Graphics API	OpenGL ES 3.0
10	Minimum Operating System	Android 10.0 (API Level 29)
11	Tracking Method	Marker-Based Tracking (Image Target)

2. DesignInterface

User interface design is the stage carried out to design the application's appearance so that it is easy to use (user-friendly) and can provide an engaging learning experience for users. The application interface is designed with the characteristics of junior high school students in mind, so that each menu has a simple, informative, and easy-to-understand display. Furthermore, the interface design is also structured so that users can easily access all application features without experiencing difficulties in the learning process. The interface design in this application consists of several main pages, namely:

A. Splash Screen Page



Figure 1. Splash Screen Page

The splash screen is the first screen to appear when an application is launched on an Android device. This screen displays the application logo, title, and institutional identity before the system automatically switches to the main menu. The splash screen aims to provide an initial impression to users and ensure all application components have loaded properly before use.

B. Main Menu Page



Figure 2. Main Menu Page

https://doi.org/10.61536/ambidextrous.v5i01.949
This open-access article is distributed under a Creative Commons Attribution (CC-BY-SA) 4.0 license

The main menu page is the application's navigation center, providing access to all available features. This page contains several menu buttons, including:

a. Scan Marker
b. Medicinal plants
c. Guide
d. About
e. Download Marker
f. Go out

Through this page, users can select the menu according to their needs so that the process of using the application becomes easier and more focused.

C. Scan Marker Page



Figure 3. Scan Marker Page

The marker scan page serves as the primary medium for implementing Augmented Reality technology. When the user selects this menu, the smartphone camera activates and is ready to detect medicinal plant markers using the Marker-Based Tracking method. If the marker is successfully recognized by the system, the application will display a three-dimensional object of the medicinal plant in real time along with related information.

D. 3D Object Visualization Page



Figure 4. 3D Object Visualization Page

This page displays a three-dimensional object of a medicinal plant after the marker has been successfully recognized by the system. Users can observe the plant's shape more clearly through a 3D visualization of the object that appears above the marker. In addition to displaying the object, this page also provides interactive features such as rotation, zoom in, zoom out, and audio narration buttons that explain information about the medicinal plant.

https://doi.org/10.61536/ambidextrous.v5i01.949
This open-access article is distributed under a Creative Commons Attribution (CC-BY-SA) 4.0 license

E. Medicinal Plant Information Page



Figure 5. Medicinal Plant Information Page

This medicinal plant information page contains learning materials about the plants being studied. The information displayed includes:

a. Plant Name
b. Scientific Name
c. Classification
d. Benefit
e. Contents
f. How to Use

This page is designed so that students not only see three-dimensional objects, but also gain complete knowledge about the benefits of medicinal plants.

F. User Guide Page



Figure 6. Usage Guide Page

The user guide page contains instructions for using the app, from opening the app, scanning markers, to using the available features. The guide is designed to be simple and easy for students to

https://doi.org/10.61536/ambidextrous.v5i01.949
This open-access article is distributed under a Creative Commons Attribution (CC-BY-SA) 4.0 license

understand. This menu aims to assist first-time users, ensuring a smooth learning process.

G. About App Page



Figure 7. About Application Page

The About page displays information about the application being developed, its purpose, the identity of the author, supervisor, study program, faculty, and university. This page serves as a source of information about the background of the application's development and provides the developer's official identity.

H. Marker Download Page



Figure 8. Marker Download Page

The marker download page provides the markers needed for the Augmented Reality visualization process. Users can download the markers and then print them as a scanning medium using their smartphone camera. The printed markers will be used as the primary markers for displaying three-dimensional medicinal plant objects in the app.

https://doi.org/10.61536/ambidextrous.v5i01.949
This open-access article is distributed under a Creative Commons Attribution (CC-BY-SA) 4.0 license

3. Implementation of 3D Markers and Objects

The markers in the final implementation use real photographs of the six medicinal plants, rather than vector illustrations as originally designed in Chapter III. This change was made so that students could immediately recognize the images on the markers as representations of the actual plants. To maintain the tracking success rate by Vuforia, the photos were combined with supporting elements in the form of a double frame, four corner markers with different shapes to prevent rotational symmetry, and a high-resolution geometric pattern field around the photo area. This combination resulted in an average visual feature density above 4.5% across all markers, which is within the recommended range for stable Marker-Based Tracking. Examples of two markers from the final implementation are shown in Figure 8.

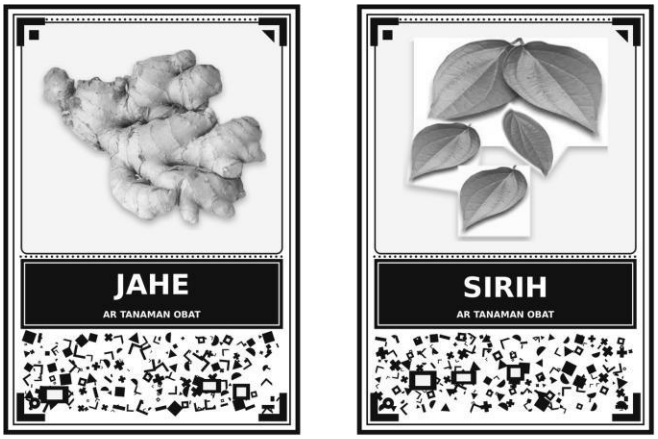


Figure 9. Example of Implementation Result Marker

The three-dimensional objects for the six plants were procedurally constructed using Blender with polygon counts ranging from 2,500 to 4,000 triangles per model, well below the maximum budget of 8,000 triangles set during the design phase. Each model was normalized to a height of 0.18 meters, which is 1.8 times the marker's print width of 0.10 meters, so that the objects appear in reasonable proportion to the marker size without requiring additional scaling in Unity. The surface textures of the leaves, rhizomes, and stems were procedurally generated to give a natural feel without significantly increasing the application file size.

4. implementation of Augmented Reality (Scan Marker)

At this stage, the Augmented Reality feature is implemented by testing the marker scanning process using a smartphone camera. Testing is carried out to ensure that the created Image Target can be recognized by the system and is capable of displaying the corresponding three-dimensional medicinal plant object. The process begins when the user points the smartphone camera at a provided marker. The system then matches the captured image with a marker previously entered into the Vuforia database. If the marker is successfully recognized, the system will determine its position and direction as a reference for displaying the 3D object.

The implementation results show that the Scan Marker feature can function according to its design. Each marker can be used to display different medicinal plant objects according to predefined relationships in Unity. In addition to 3D models, the application also displays supporting information about the plants, such as their name, scientific name, benefits, and other predefined information.

This feature allows users to observe medicinal plants in three dimensions directly on their smartphone screen. Users can also utilize available interactive features, such as rotating and zooming in and out, allowing them to observe plant information from various angles.

https://doi.org/10.61536/ambidextrous.v5i01.949
This open-access article is distributed under a Creative Commons Attribution (CC-BY-SA) 4.0 license

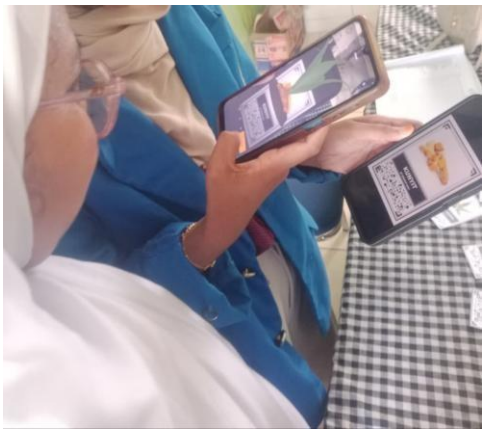


Figure 10. Implementation of Turmeric Plant Markers

Figure 10 shows the results of scanning a turmeric plant marker using an Augmented Reality application. After the marker is successfully recognized by the smartphone camera, the system displays a three-dimensional object of the turmeric plant on the device's screen. This result indicates that the marker has been connected to the corresponding 3D object and can be displayed through the marker tracking process. With this visualization, users can observe the shape of the turmeric plant more interactively through the developed application.



Figure 11. Implementation of Galangal Plant Markers

Figure 11 shows the process of using the Augmented Reality application when the user scans a galangal plant marker. Once the marker is successfully recognized by the smartphone camera, the application displays a three-dimensional object of the galangal plant on the device screen. This visualization allows users to observe the plant's shape more clearly and interactively. With the 3D object displayed directly, users can more easily recognize the characteristics of the galangal plant and obtain learning information available in the application.



Figure 12. Implementation of Ginger Plant Markers

Figure 12 shows the app's display when a ginger plant marker is scanned using a smartphone camera. Once the marker is successfully recognized, the app displays a three-dimensional object of the ginger plant along with supporting information about it. This visualization allows users to more clearly

https://doi.org/10.61536/ambidextrous.v5i01.949
This open-access article is distributed under a Creative Commons Attribution (CC-BY-SA) 4.0 license

observe the ginger plant's shape through a three-dimensional display, allowing for a more interactive process of recognizing and understanding the characteristics and benefits of ginger.

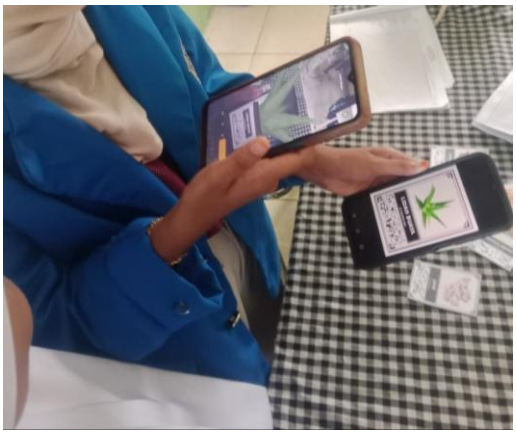


Figure 13. Implementation of Aloe Vera Plant Markers

Figure 13 shows the process of using the Augmented Reality application when the aloe vera plant marker is pointed at the smartphone camera. Once the marker is successfully recognized by the system, the application displays a three-dimensional object of the aloe vera plant on the device screen. This display allows users to see the plant's shape more clearly and attractively through 3D visualization. This feature allows users to more easily recognize the characteristics of the aloe vera plant and understand the information provided in the application in a more interactive manner.

5. Content Database Implementation

All textual data for the six plants, including their scientific names, families, benefits, contents, and usage methods, is stored in a ScriptableObject data structure called PlantData, organized through a single master file, PlantDatabase. This data-driven approach allows for future additions or revisions to plant material without the need for changes to the scene structure or program code; simply by editing the data in the Unity Inspector.

System Test Results

1. Black Box Test Results by Researchers

Table 2. Results of Black Box Testing by Researchers

No	Tested Features	Expected results	Status
1	Application Opening & Main Menu	The application opens and displays the main menu.	Succeed
2	Detection of Medicinal Plant Markers	Markers are recognized by the system	Succeed
3	3D Object View of Medicinal Plants	3D objects appear clearly above the marker	Succeed
4	Plant Narration Audio	Audio explanation is clearly audible	Succeed
5	Navigation Between Menus	All menus are easily accessible	Succeed
6	Rotate & Zoom 3D Objects	Objects rotate and change size following touch	Further testing is needed
7	Button Sound Effects (SFX)	Sound effect is heard when the button is pressed	Further testing is needed
8	Save Marker to Gallery	Marker images are saved on the device	Further testing is needed
9	Application Stability	The application runs stably without crashing during long-term use.	Further testing is needed
10	ConvenienceStudent Use	Students can use it without any significant confusion.	Not yet implemented

Of the ten planned test scenarios, five scenarios related to the application's core functions, namely application opening, marker detection, 3D object display, audio narration, and menu navigation,

https://doi.org/10.61536/ambidextrous.v5i01.949
This open-access article is distributed under a Creative Commons Attribution (CC-BY-SA) 4.0 license

have been tested directly by researchers on Android devices and all were declared successful according to the expected results. Scenarios related to advanced interactions (rotation, zoom, button sound effects, and marker saving) have been implemented in the program code but have not been tested systematically and repeatedly, while testing the ease of use by junior high school students as research subjects could not be carried out at the stage of preparing this report. The success percentage graph for the tested scenarios is shown in Figure 4.9.

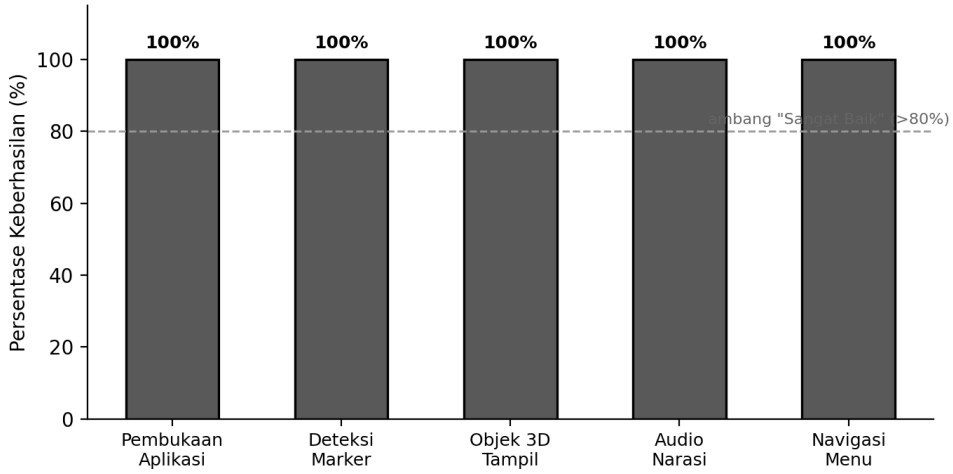


Figure 14. Graph of Initial Testing Success Percentage

It should be emphasized that the percentages in Figure 14 only illustrate the progress of initial testing of the five core features, not the overall success rate of the application. The final success rate calculation using the formulas and categories in Table 2 will be performed after all scenarios in Table 3 have been tested, including testing with research subjects.

2. Device Compatibility Testing

Table 3. Test Device Compatibility

No	Device Brand / Model	Android Version	RAM	Test Results
1	Xiaomi Redmi Note 11	Android 11	4 GB	Success. The application was successfully installed. Transitions in and out of UI panels are smooth. The camera functions normally, and markers instantly appear in 3D within seconds.
2	Samsung Galaxy A54	Android 13	8 GB	It worked. The performance was very smooth. The click sound (Sfx Tap) and the effect when the marker was found (Sfx Found) sounded clear. The 3D objects were stable even though camera position shifts.
3	Oppo A3s	Android 8.1	3 GB	Success with Notes. The app runs, but there's a slight drop in frame rate (mild lag) when the AR camera is active. The markers need brighter lighting for the Vuforia system to work. detect it.

Discussion

The implementation results show that the application has answered most of the problem formulations proposed in Chapter I. Interactive learning media based on Augmented Reality was successfully designed and implemented using the Marker-Based Tracking method with Unity 3D and Vuforia Engine, capable of displaying three-dimensional objects of the six medicinal plants along with educational information and audio narration. Initial testing of the core features showed results that were

https://doi.org/10.61536/ambidextrous.v5i01.949
This open-access article is distributed under a Creative Commons Attribution (CC-BY-SA) 4.0 license

in accordance with the designed specifications.

During the implementation process, several technical challenges were encountered that required adjustments to the initial design. The first challenge was related to the Image Target mode in the Vuforia Engine. The initial design assumed the use of an online database via the Vuforia Target Manager, but in the implementation, the version of Vuforia used provided a From Image mode that allows marker images to be linked directly to the project file without going through the online database. The second challenge was related to the AudioListener component not being automatically available in the built scene, so all audio, both sound effects and narration, could not be heard until the component was explicitly added. The third challenge was related to the process of exporting 3D models from Blender to Unity, where the surface textures of objects were not embedded into the FBX file, requiring re-linking of materials manually or through a helper script. These three challenges were successfully overcome and did not affect the final application result, but they are important notes regarding the difference between the conceptual design and the technical reality during implementation.

The findings of this study also strengthen the results of previous studies that stated that the Marker-Based Tracking method is relatively easy to implement and has a good level of detection accuracy on Android devices with general specifications (Ramiza Amir, 2023; Nais Edi Purwoko, 2023). The use of original plant photos as markers, combined with high-density geometric patterns around them, has been proven to be well detected by the Vuforia Engine while making it easier for users to visually recognize plant objects, thus being a consideration that can be used in similar studies in the future.

Conclusion

This research successfully designed and implemented interactive learning media based on Augmented Reality (AR) using the Marker-Based Tracking method with Unity 6 LTS and Vuforia Engine. The developed application is able to display three-dimensional object visualizations of six types of medicinal plants, namely ginger, turmeric, aloe vera, betel, galangal, and Javanese ginger, along with educational information and audio narration via Android devices. Initial testing results showed that five core features, including application opening, marker detection, 3D object display, audio narration, and menu navigation, have functioned according to the expected results. Compatibility testing on several devices also showed that the application can be run, although its performance is affected by device specifications and lighting conditions. Thus, this application has the potential to be an alternative learning media that helps teachers deliver medicinal plant material more visually and interactively and provides opportunities for students to observe 3D objects without having to rely entirely on physical plants. Practically, the application can be used as a supporting media for learning Practical Work aspects of Cultivation for grade VII students at SMP Muhammadiyah 07 Medan.

This study has limitations: student usability testing has not been conducted, several interactive features have not been tested systematically and repeatedly, and compatibility testing still covers a limited number of devices. Furthermore, marker tracking may experience performance degradation in inadequate lighting conditions or when there is excessive light reflection. The material coverage is also limited to six types of medicinal plants, thus not representing all material relevant to the Independent Curriculum. Therefore, further research is recommended to involve students as respondents to evaluate the app's ease of use, user acceptance, and its usefulness for understanding the material. Further testing should also include more Android devices, various lighting conditions, and all interactive features to obtain more comprehensive evaluation results. Future developments could expand the range of medicinal plants and educational materials to make the app more relevant to learning needs. This step is expected to improve the app's reliability and strengthen its application as an interactive learning medium.

Bibliography

Arsyad, A. (2017). *Media pembelajaran* (Edisi revisi). PT RajaGrafindo Persada.

Billinghurst, M., Clark, A., & Lee, G. (2015). A survey of augmented reality. *Foundations and Trends in Human–Computer Interaction, 8*(2–3), 73–272.

Djafar, A., & Novian, R. (2021). Implementasi teknologi augmented reality dalam pengembangan media pembelajaran perangkat keras komputer. *Jurnal Pendidikan Teknologi Informasi, 5*(2), 45–54.

https://doi.org/10.61536/ambidextrous.v5i01.949
This open-access article is distributed under a Creative Commons Attribution (CC-BY-SA) 4.0 license

Hasan, M., Milawati, Darodjat, Harahap, T. K., Tahrim, T., Anwari, A. M., Rahmat, A., Masdiana, & Indra, I. M. (2021). *Media pembelajaran*. Tahta Media Group.

Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi. (2022). *Capaian pembelajaran Kurikulum Merdeka*. Kemendikbudristek.

Luther, A. C. (1994). *Authoring interactive multimedia*. Academic Press.

Munir. (2017). *Multimedia: Konsep dan aplikasi dalam pendidikan*. Alfabeta.

Purwoko, N. E., & B. P. (2023). Aplikasi pembelajaran bangun ruang menggunakan augmented reality marker based tracking. *Jurnal Ilmiah MEDIA SISFO, 11*.

Sugiyono. (2022). *Metode penelitian kuantitatif, kualitatif dan R&D* (Edisi ke-2). Alfabeta.

Wijaya, A., & Darmawan, D. (2021). Pengembangan media pembelajaran berbasis augmented reality menggunakan Unity 3D. *Jurnal Teknologi Informasi dan Pendidikan, 14*(2), 115–123.

Amir, R., & A. M. (2023). Pengembangan media pembelajaran augmented reality dengan memanfaatkan marker based tracking pada materi sistem komputer. *JVST, 8*.

https://doi.org/10.61536/ambidextrous.v5i01.949
This open-access article is distributed under a Creative Commons Attribution (CC-BY-SA) 4.0 license