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Design of Android-Based Augmented Reality Media for Teaching Computer Network Models

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ABSTRACT

The development of digital technology has a major impact on the education sector, especially since the Covid-19 pandemic changed the learning system to online. One technology that has great potential in supporting the learning process is Augmented Reality (AR). This technology allows the integration of two or three-dimensional virtual objects into the real environment interactively. This study aims to design and build Android-based learning media with marker-based AR technology for the introduction of computer network models for class XI at SMA Negeri 4 Padang. Based on the results of observations and interviews with informatics teachers, it is known that learning is still dominated by theory without direct visualization of computer network devices due to limited practical tools. The learning media developed uses AR technology with markers as markers to display 3D objects, utilizing the Vuforia platform, 3D models are created using Blender, interface design using Figma, and system integration is carried out with Unity. The visualized material includes network topology (bus, star, ring, mesh) and the Open System Interconnection (OSI) Layer model. With this media, students can understand the concept of computer networks more interactively and deeply, and increase their involvement in the learning process.

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1. INTRODUCTION

The rapid advancement of digital technology has significantly transformed the educational landscape. This shift became more prominent during the COVID-19 pandemic, which forced face-to-face learning activities to transition into online formats using digital platforms such as Zoom, Google Meet, and various educational applications. As a result, both teachers and students have increasingly adopted digital media as learning tools due to their efficiency and flexibility [1], [2].

Augmented Reality (AR), among other innovations, has become a potent teaching tool. Through real-time interaction and the integration of virtual 2D or 3D objects into the physical world, augmented reality (AR) helps students better visualize abstract or difficult concepts [3], [4]. When physical learning resources are scarce, AR-based learning tools are especially useful for improving comprehension through spatial visualization [5]. According to earlier studies, augmented reality (AR) can help students learn independently by enabling them to engage with digital content without the need for physical equipment [6].

High school computer network education frequently consists of theoretical instruction presented through static resources like PowerPoint slides. According to observations and interviews done at SMA Negeri 4 Padang, the Informatics course was primarily taught through lectures and group discussions with little assistance from interactive or hands-on resources. Additionally, students found it hard to figure out the structure and operation of network models, such as topologies and the OSI model, because the school lacked the necessary hardware to support practical sessions.

This study suggests creating an Android-based augmented reality (AR) learning tool to teach computer network models, such as the seven-layer OSI model and different topologies (bus, star, ring, and mesh), in order to address these problems. Blender for 3D modeling, Vuforia SDK, and Unity 3D are used in the development of the application. Through virtual hands-on experiences, it allows students to view interactive 3D objects and scan image markers, improving their conceptual understanding.

The goal of this research is to develop an accessible, interactive, and visual learning tool that enhances both in-class instruction and independent study. This media fills the gap in the availability of physical hardware by utilizing augmented reality technology, which also aids students in better visualizing and understanding intricate computer network structures [7].

2. RESEARCH METHOD

The development of this AR-based learning media followed the Multimedia Development Life Cycle (MDLC) method, as proposed by Luther and later refined by Sutopo [8] - [10]. This model consists of six flexible and iterative stages: Concept, Design, Material Collecting, Assembly, Testing, and Distribution.

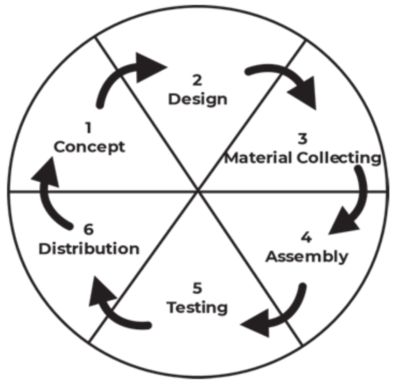

Figure 1. Multimedia Development Life Cycle (MDLC) Model adapted from Luther and Sutopo

As shown in Figure 1, the MDLC model provides a structured yet adaptable framework for multimedia system development. In this study, the Concept phase involved analyzing the existing learning environment and identifying the need for visual and interactive media in teaching computer network models. The Design phase focused on structuring the system using diagrams (e.g., flowcharts, UML) and UI/UX mockups designed in Figma. During the Material Collecting stage, the team prepared assets such as 3D models (created in Blender), AR markers, and learning texts.

In the Assembly phase, these components were integrated in Unity using the Vuforia SDK, producing a functional AR application. The system was then evaluated through Black-Box Testing, ensuring each feature functioned as intended. Finally, the Distribution phase involved deploying the application in APK format for student use on Android devices. This implementation demonstrates how MDLC supports the systematic development of AR-based educational tools tailored to classroom needs. [11] - [13]

3. RESULTS AND DISCUSSION

The results of the Augmented Reality learning media design process for computer network models at SMA Negeri 4 Padang are presented in this section. As outlined below, the development process applied the Multimedia Development Life Cycle (MDLC) method to structure and implement the system design effectively.

3.1. Concept

In this stage, the current conditions of teaching network models were analyzed. Based on field observations and interviews conducted at SMA Negeri 4 Padang, it was found that the learning process relied heavily on conventional methods such as printed materials and PowerPoint slides, which lacked interactivity and visual support. As a result, students found it difficult to grasp abstract concepts such as network topology and the OSI

Layer. This led to the formulation of a solution through the development of an AR-based learning application to enhance visualization and engagement.

The core problems identified included (1) limited visualization using 2D media, (2) lack of student engagement, and (3) time-consuming explanations without technological support. As a solution, this research proposed an augmented reality (AR)-based learning media that allows students to interact with 3D models of network devices and layered communication protocols.

Table 1 outlines the system requirements needed for the development and use of the Android-based augmented reality learning media. These requirements are categorized into four main components: hardware, software, content, and functional needs.

Table 1. System Requirements for AR-Based Learning Media

No	Requirement Type	Details
1	**Hardware Requirements**	- **Minimum device (student):** Android 8.0 (Oreo) or higher, 3 GB RAM, quad-core processor - Functional rear camera for AR marker detection - **Development device:** Intel Core i5 (10th Gen), 16 GB RAM, NVIDIA RTX 3050 GPU, 500 GB SSD
3	**Software Requirements**	- **Development tools:** Unity (AR integration), Vuforia SDK (marker tracking), Blender (3D modeling), Figma (UI/UX design), Visual Studio (C# coding & debugging) - **User device:** Android-based AR app (APK format)
4	**Content Requirements**	- **Learning content:** 3D illustrations of network topologies (bus, star, ring, mesh); interactive explanations of OSI Layer components; simple data flow simulations - **3D models:** Models of topologies and OSI Layers in AR-compatible formats (.fbx, .obj)
5	**Functional Requirements**	- Display 3D visualizations of network topologies and OSI Layer - Enable interactions such as zoom, rotate, and pop-up information - Provide intuitive navigation and menu structure suitable for student use

3.2. Design

This stage involved designing the learning media architecture and user experience. Flowcharts were created to illustrate the system workflow, and various UML diagrams were developed, including Use Case, Activity, Class, Sequence, State Machine, Component, Deployment, Communication, and Package diagrams [14], [15].

3.2.1. Flowchart Design

Flowchart can be interpreted as problem solving steps written in certain symbols. This flowchart will show the flow in the program logically. flowchart is needed not only as a communication tool but also as a guideline, and before the components can be better understood, the rules need to be communicated [16].

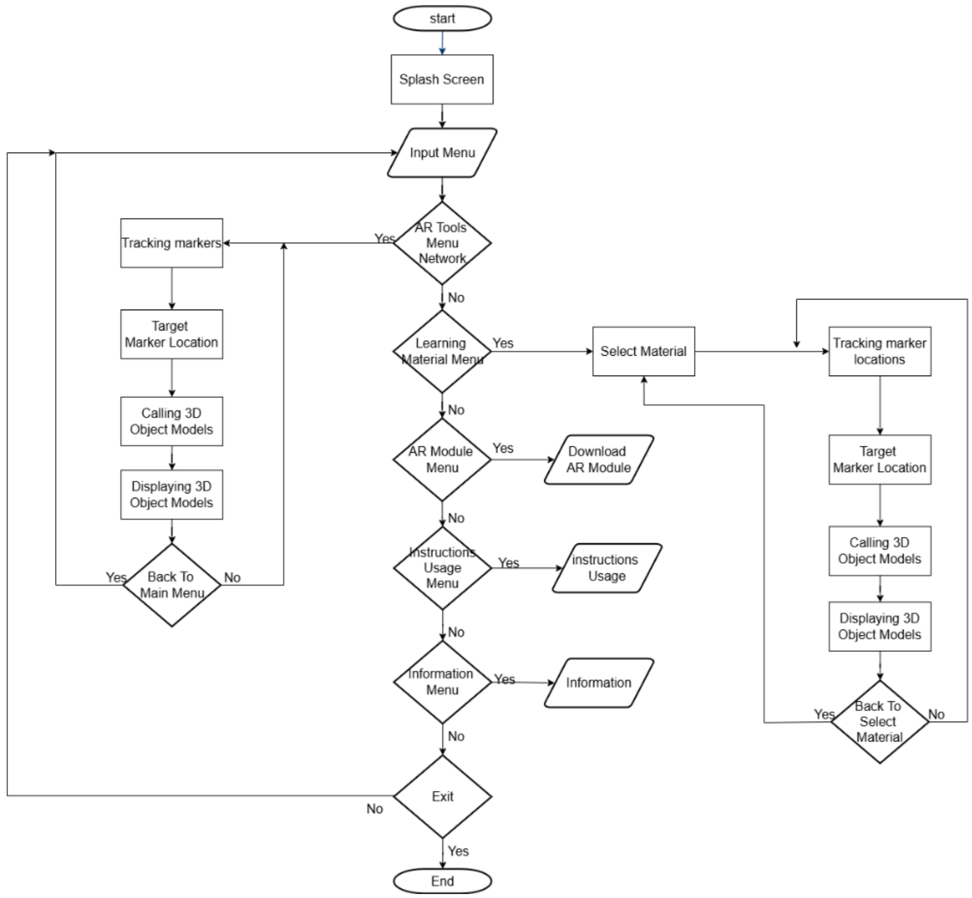

Figure 2. AR Learning Media System Flowchart

Figure 2 illustrates the system flowchart of the Android-based AR learning media. The application starts from the splash screen and proceeds to the main menu, where users can access various features such as AR Network Tools, Learning Materials, AR Module Download, User Guide, and Application Info. When accessing AR features, the system performs marker tracking, retrieves the corresponding 3D model, and displays it in real-time. Users can interact with the models or return to the main menu. For learning materials, students select a topic, scan a marker, and explore visualizations related to network topologies or the OSI Layer. The flowchart emphasizes a user-friendly and modular structure, supporting intuitive navigation and interaction at each step of the learning process.

3.2.2. Use Case Diagram

Use case diagram is a model of the results of system design analysis that aims to describe system needs. The system needs will be implemented by users so that system design can be described [17].

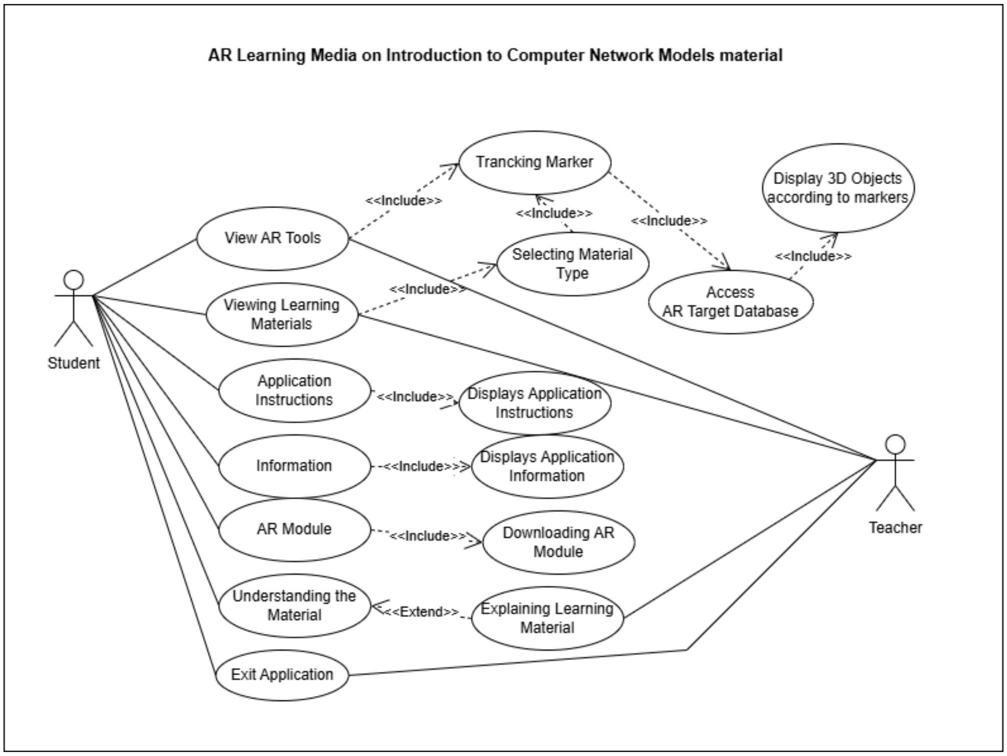

Figure 3. AR Learning Media on Introduction to Computer Network Models material

Figure 3 shows the use case diagram of the AR learning application. The main user is the student, who can access AR features, learning materials, guides, information, and download modules. The teacher supports by explaining content. Each use case involves AR marker tracking and 3D object display, supporting interactive and visual learning.

3.2.3. Class Diagram

A class diagram or Class Diagram describes the structure of a system in terms of defining the classes that will be created to build the system [18].

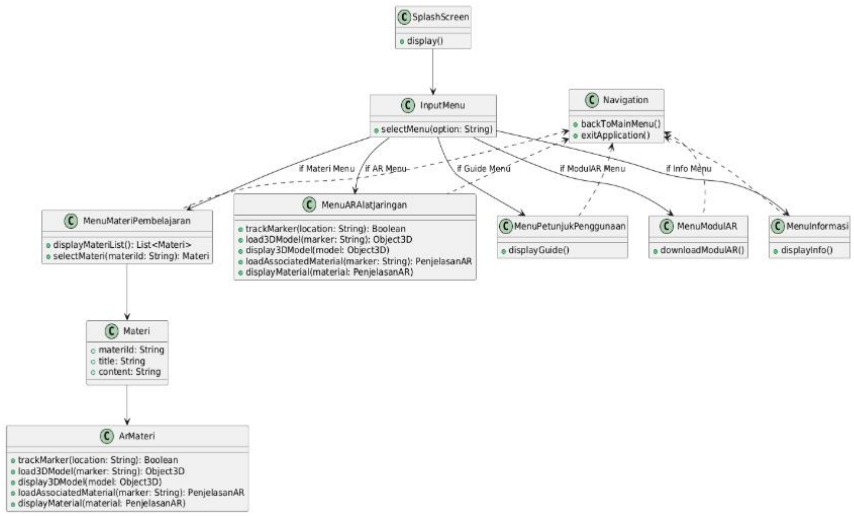

Figure 4. AR Learning Media Class Diagram

Figure 4 shows the class diagram of the AR-based learning application. It defines the system's structure, including key classes like MenuARAlatJaringan, MenuMateriPembelajaran, and Navigation. Each class handles specific functions such as tracking AR markers, displaying 3D models, accessing learning materials, and managing user navigation.

3.2.4. Component Diagram

Component Diagrams describe the structure and relationships between software components, including dependencies between them [19].

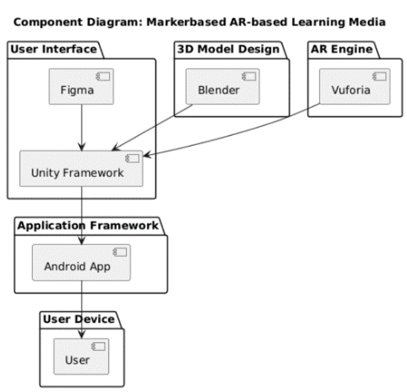

Figure 5. AR Learning Media Deployment Diagram

Figure 5 presents the component diagram of the AR-based learning application. It shows how key components interact during development and deployment. Figma, Blender, and Vuforia contribute UI designs, 3D models, and AR tracking capabilities respectively, all integrated within the Unity Framework. The final application is built and exported as an Android App, which runs on the user's device. This modular architecture ensures flexibility and ease of development across components.

3.3. Material Collecting

In the material collecting stage, various assets were prepared, including 3D models of network hardware and OSI layers using Blender, AR module and marker designed in Canva, and UI elements created with Figma. The 3D models were exported in .fbx format and integrated into Unity using the Vuforia SDK for marker-based AR interactions.

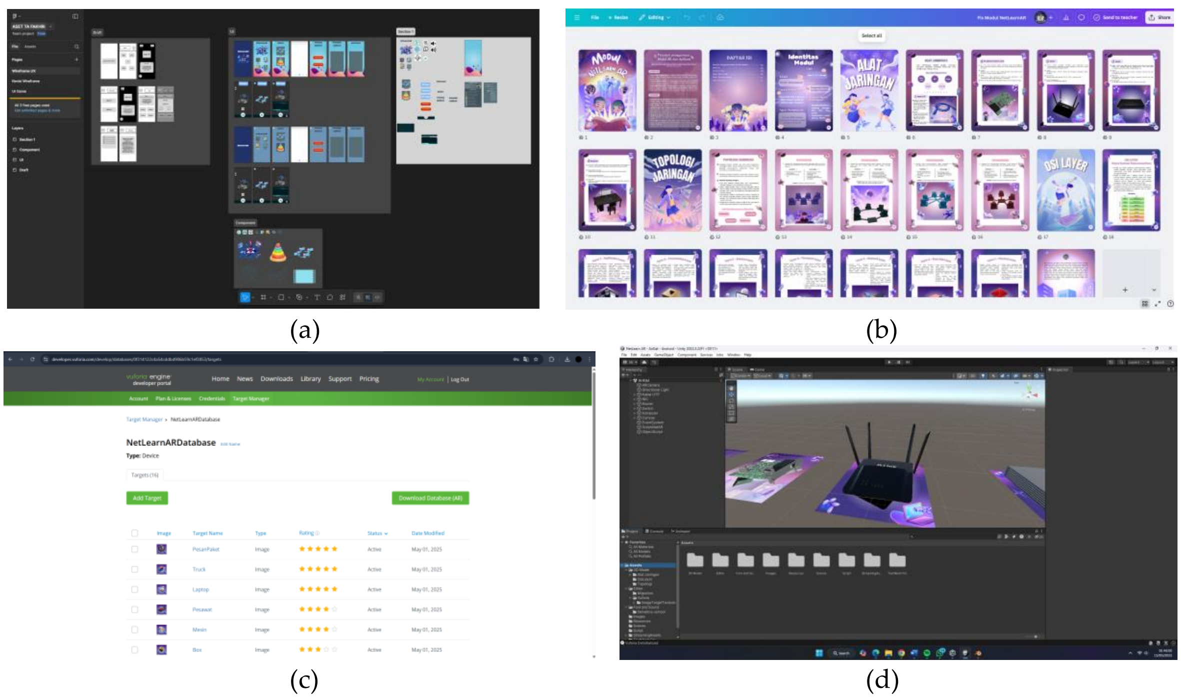

Figure 6. Material Collection Stage (a) UI elements in Figma, (b) AR module and marker in Canva, (c) Vuforia SDK and database marker, (d) Assembly Material to Unity

3.4. Assembly

In this stage, the collected materials and interface components were assembled into a functional mobile application using Unity 3D and Vuforia SDK [20], [21]. The 3D assets were integrated with image markers, enabling real-time interaction when viewed through the Android device's camera. The application featured several interactive menus, such as AR tools, learning materials, instructional guidance, and downloadable AR modules via Google Drive.

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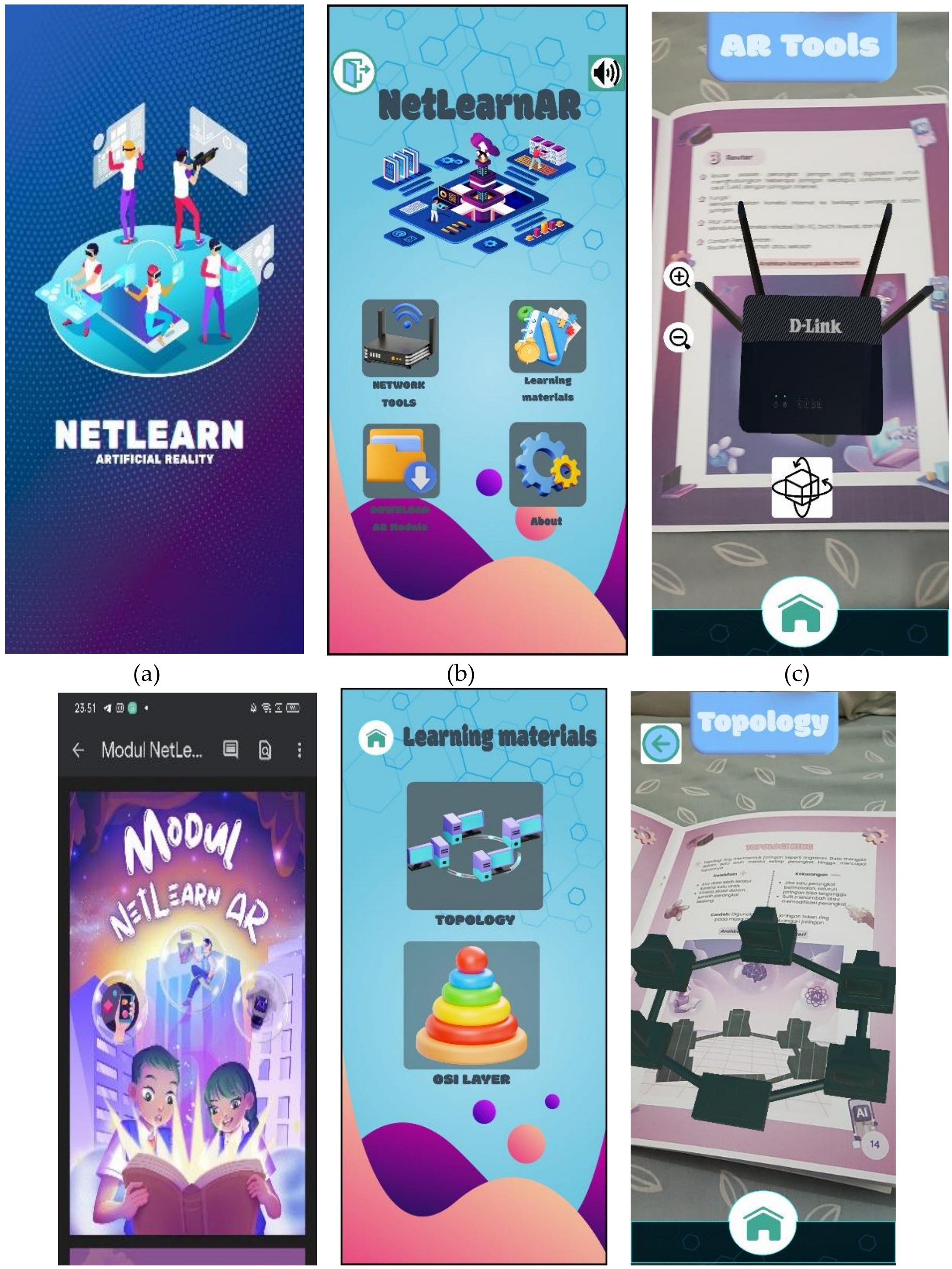
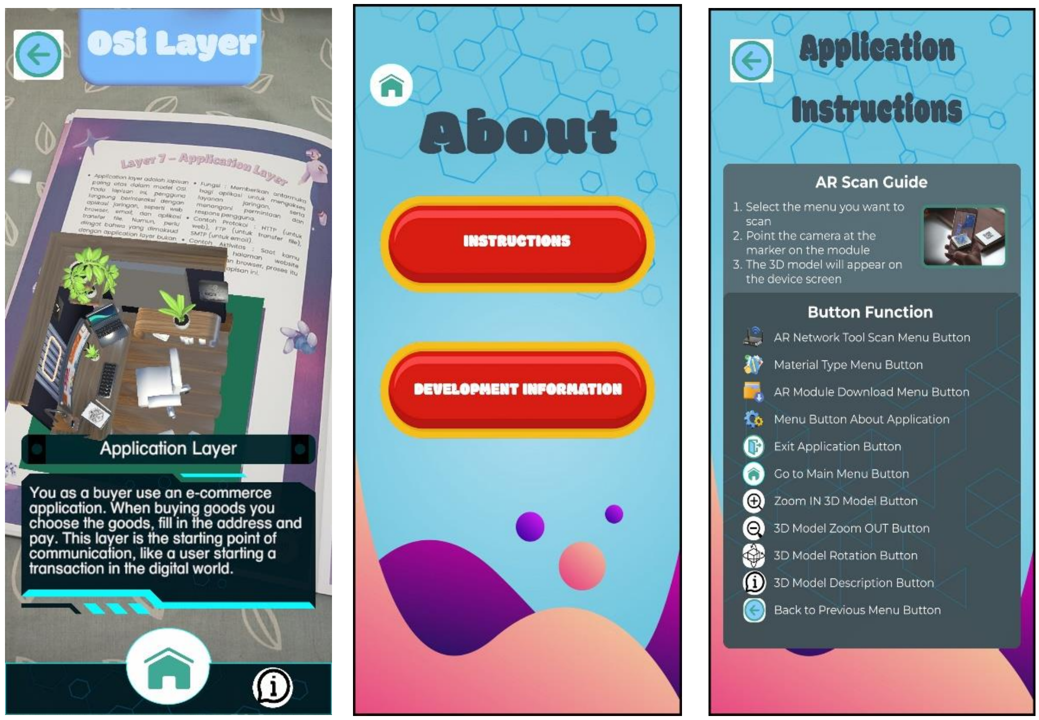


(a) (b) (c)
(d) (e) (f)



(g) (h) (i)

Figure 7. Assembly Stage (a) Splash Screen, (b) Main Menu, (c) AR Tools Menu, (d) Preview and Download Module AR In Drive, (e) Learning Materials, (f) AR Network Topology, (g) AR Osi Layer, (h) About Menu, (i) Application Instructions

The last step is shown in Figure 7, which is an Android-based learning media application based on augmented reality (AR). In addition to the OSI Layer content that can be accessed through AR markers, this application is made to show 3D models of different computer network topologies, including bus, star, ring, and mesh. This application's primary features include interactive 3D model displays, learning resources, the main menu, and the user guide menu.

3.5. Testing

Black-box testing was used during the testing phase to assess the application's functionality from the viewpoint of the user. Without examining the internal code structure, this approach concentrated on confirming that every system feature operated as intended [22]. The primary goal was to ensure that the application responded appropriately to user inputs, such as scanning AR markers, displaying 3D models, navigating between menus, and accessing learning content. By simulating real-world usage scenarios, the testing confirmed that the AR-based learning media operated reliably and could be used effectively by students in a classroom or independent learning context.

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Table 2. Black-Box Testing Results Based on Use Case

Test Case ID	Tested Feature	Description	Input / Action	Expected Output	Status
TC01	Splash Screen	Display splash screen upon launching the app	Launch the application	Splash screen appears, then navigates to the main menu	Pass
TC02	Main Menu Navigation	Access the AR Network Tools menu	Click "Alat Jaringan" button	Opens the AR camera for network hardware	Pass
TC03	AR Marker Detection	Display 3D network hardware based on marker	Point camera at marker	Correct 3D model appears	Pass
TC04	AR Zoom Functionality	Zoom in/out 3D object	Tap + or – icon	Object size increases/decreases accordingly	Pass
TC05	AR Object Rotation	Rotate the 3D object	Tap rotate icon	Object rotates and stops as expected	Pass
TC06	AR Topology Material	Display 3D model for network topology	Scan marker in Topology AR	Topology 3D model appears	Pass
TC07	AR OSI Layer Material	Display 3D OSI layer and object information	Scan marker in OSI Layer AR	3D OSI layer with detailed info is shown	Pass
TC08	Download AR Module	Access and download AR module from Drive link	Click "Download Modul AR"	Opens Drive folder and enables download	Pass
TC09	About Application Navigation	Display usage instructions and developer info	Click "Tentang Aplikasi"	Shows "Usage Guide" and "Developer Info" options	Pass
TC10	Sound Mute/Unmute	Control background sound	Tap speaker icon	App sound toggles on/off	Pass
TC11	Exit Application	Close the app	Tap exit icon (door symbol)	Application closes properly	Pass

Table 2 presents the results of black-box testing conducted using a use case-based approach. The purpose of this testing was to evaluate whether each feature in the augmented reality learning application functioned as expected from the user's perspective. The test cases were derived from typical user interactions, including navigation, AR marker scanning, 3D object manipulation, and access to learning content.

Each test case was executed by providing a specific input or user action, followed by verification of the actual system output. As shown in the table, all features responded as intended—AR components were accurately rendered upon marker detection, buttons directed users to the correct menus, and interactive elements such as zoom, rotation, and sound control worked without error. No major bugs or deviations from the design specification were observed.

The successful results across all test cases indicate that the application met its functional requirements and is ready for deployment in real learning environments. Furthermore, the smooth navigation and correct execution of each use case support the application's usability and reliability for student use in both classroom and independent learning settings.

3.6. Distribution

In the final phase, the APK file of the application was distributed to Informatics teachers at SMA Negeri 4 Padang. Teachers then delivered it to students for use in classroom and independent learning. The application was designed to be compatible with Android 8.0 and higher, promoting ease of access and portability [23], [24].

The implementation of Augmented Reality (AR) in this learning media significantly enhances students' understanding of abstract concepts such as network topologies and the OSI Layer model. Through interactive 3D visualization, students can observe the structure and relationships within networks from various angles, zoom and rotate objects, and access embedded explanations directly via a user-friendly interface. This supports spatial reasoning and promotes active engagement, which is often difficult to achieve with traditional 2D or text-based media.

The key strengths of the developed application include its integration of AR marker-based content, intuitive navigation, and compatibility with mid-range Android devices. Moreover, the results of black-box testing confirmed that all features functioned correctly without critical bugs, indicating a stable and reliable application.

However, some limitations were identified. The current version does not yet include student evaluation features, learning progress tracking, or teacher content customization options. These aspects are essential for broader implementation and long-term use in formal education. Future development should focus on adding formative assessment modules, learning analytics, and a teacher dashboard to manage and tailor content based on student needs.

4. CONCLUSION

This study aimed to address the lack of practical learning tools at SMAN 4 Padang, particularly in teaching abstract concepts related to computer network models. The developed Android-based augmented reality (AR) learning media successfully fulfilled this objective by providing interactive 3D visualizations and marker-based AR experiences that enhance student understanding.

Through the MDLC development process, the application integrates visual, spatial, and textual elements to support learning. The results of black-box testing confirmed that all system features functioned as intended, offering a stable and user-friendly experience for students.

The strengths of the application lie in its ability to visualize complex structures intuitively, operate on standard Android devices, and improve engagement in resource-limited classrooms. However, the absence of assessment tools and teacher customization features highlights the need for further development.

In conclusion, the AR-based learning media effectively meets its intended purpose and presents a promising solution for enhancing digital learning. Future improvements may include the integration of evaluation systems, student progress tracking, and content customization to support more personalized and teacher-driven learning experiences.

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