

EduSawit: Implementation of Augmented Reality in Environmentally Friendly Palm Oil Plant Education

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Abstract

The palm oil industry in Indonesia continues to face serious problems related to environmental degradation and small farmers limited access to information on sustainable cultivation practices. To address these challenges, this study developed EduSawit, an Augmented Reality (AR)-based educational application that supports the implementation of environmentally friendly palm oil cultivation practices. The application was designed using the Multimedia Development Life Cycle (MDLC) method, which consists of six main stages: concept formulation, design, material collection, assembly, testing, and distribution. Its main feature is interactive 3D visualization that displays important processes such as site selection, provision of superior seeds, mixed planting patterns, use of organic fertilizers, water management, biological pest control, and palm oil waste management. Validation was carried out using Black Box testing to ensure that all functions, including AR marker scanning, 3D object display, and information panels, worked as expected. The research results show that EduSawit is a technically reliable and pedagogically relevant learning medium, with the potential to improve farmers understanding of sustainable cultivation practices. The next step is a field trial with smallholder farmers to assess the application's effectiveness in increasing knowledge, confidence, and adoption of environmentally friendly practices.

Keywords: Augmented Reality, Education, Oil Palm, Environmentally Friendly, Interactive Learning Media.

I. INTRODUCTION

Technology is now an inseparable part of agriculture, offering opportunities to improve efficiency and sustainability. However, despite the growing importance of technological innovation, Indonesian oil palm plantations continue to face numerous challenges in their cultivation practices. While the industry contributes significantly to state revenue and employment, unchecked expansion and ecologically unsound practices have caused drastic environmental impacts. Indonesian Deforestation Statistics report the loss of approximately 3.47 million hectares of forest cover to oil palm plantation during the last two decades [1]. Forest Watch Indonesia indicates that 55% of deforestation in Kalimantan and Sumatra happens because of land conversion into oil palm plantations [2]. Global Forest Watch statistics in 2024 place Indonesia as the country with the greatest loss of forest cover, thus increasing carbon emissions[3].

One of the most pressing challenges in the palm oil industry is low environmental literacy and smallholders' limited access

to information on sustainable cultivation. Most smallholders, who are the main contributors to palm oil production in Indonesia, face obstacles in the form of low levels of formal education, limited digital literacy, and minimal access to agricultural extension services. These factors limit their ability to consistently implement sustainable practices, even though various modern solutions are available. Thus, increasing the capacity of these farmer groups is a crucial step in supporting the achievement of long-term environmental goals in the palm oil sector. This situation highlights the urgent need for innovative learning approaches that can bridge the knowledge gap, such as Augmented Reality (AR), which has shown promising results in agricultural education. XR-AgriEdu, an Augmented Reality (AR)-driven agricultural education technology, can strengthen learning through interactive visualizations [4]. Technology empowers the farmers with the capability of understanding complex farming activities like land management and ecosystem integrity. Research proves that 75% of farmers who were trained through the assistance of Augmented Reality developed technical knowledge

improvement, and 60% developed confidence in applying sustainable practices [5]. This success paves the way for the latest research to use Augmented Reality to train Indonesian oil palm farmers. In addition, increased internet access across Indonesia's rural areas also presents an opportunity to extend the reach and use of digital technologies such as Augmented Reality to agricultural education and training, in a position to significantly enhance technology-based training reach and influence [6]. In response to this challenge, this study developed EduSawit, an AR-based educational application specifically tailored to the needs of smallholder farmers through a simple interface, intuitive visuals, and structured content.

EduSawit was developed following the Multimedia Development Life Cycle (MDLC), a six-step multimedia development process involving concept, design, material gathering, assembling, testing, and dissemination. The process was used because it is adaptable to enable systematic development of learning media from planning concept to disseminating the final product. Advantage of MDLC is its elasticity and capacity to accommodate assessment at every step, guaranteeing technical and pedagogical quality [7]. Application of MDLC has been successful in creating Augmented Reality (AR)-based media that increases the user experience and understanding of the content [8]. Several studies illustrate that MDLC enables the use of interactive elements, such as animations and 3D models, in order to enable complex content to [9].

II. RESEARCH METHODOLOGY

The development process used in the making of the EduSawit application is the Multimedia Development Life Cycle (MDLC) model, a multimedia development model developed by Luther and modified by Sutopo. This was used since it is systematic, flexible, and widely applied in making interactive learning media based on technology to facilitate the developmental process to advance sequentially or iteratively if there are deficiencies found [10]. The MDLC process consists of six main stages, namely concept, design, material collecting, assembly, testing, and distribution [11].

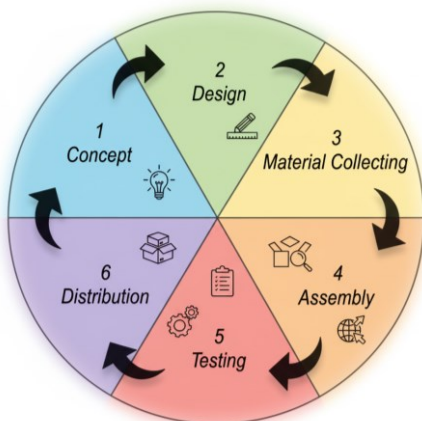


Figure 1. MDLC Development Model

Figure 1 shows the stages of EduSawit development as an environmentally friendly palm oil plant education medium consisting of five main processes, namely: Concept, Design, Material Collecting, Assembly, Testing, and Distribution. The following is a description of the stages in the application development process in accordance with the Multimedia Development Life Cycle (MDLC) sequence:

A. Concept

At this stage, the development objectives and target users of the application (audience identification) are determined. In addition, the type of application to be created (e.g., presentation, interactive, etc.) and its purpose (entertainment, education, etc.) are also determined. As a preliminary overview, a flowchart and use case diagram are created to visualize the content and flow of the application.

1. Flowchart

A flowchart serves as a graphical representation of the processes and steps in a program [12]. Its use makes it easier for researchers to break down complex problems into smaller parts, while also reviewing other possible solutions. The flowchart used in this application is as follows:

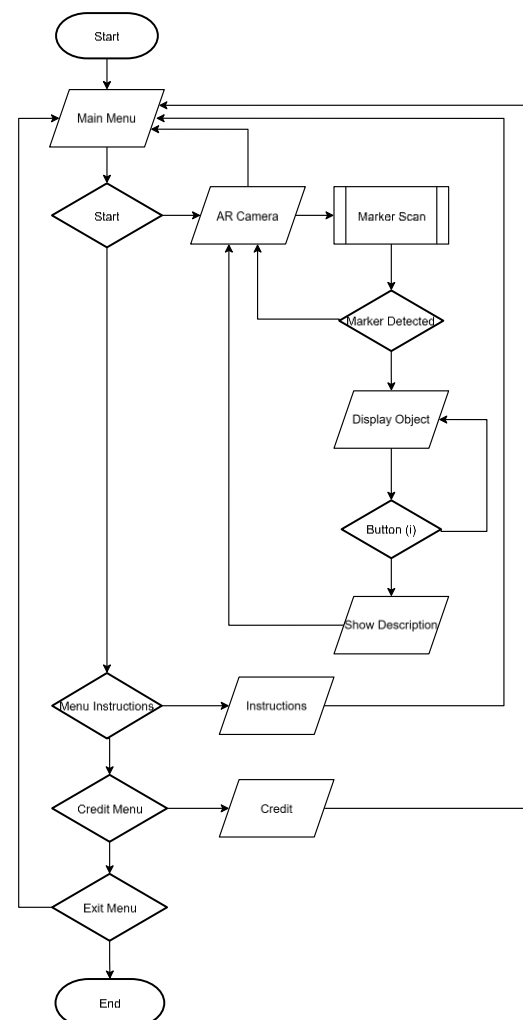


Figure 2. EduSawit Application Flowchart

Figure 2 shows the flow of interaction in the Augmented Reality (AR) application, starting from the main menu which provides several options, including start, instructions, credits, and exit. When the user selects the start menu, the system will activate the AR camera to scan the marker; if the marker is successfully detected, the application will display a 3D object accompanied by an additional option in the form of an information button (i) that displays a description of the object. Meanwhile, the instructions menu is used to provide usage guidelines, the credits menu displays developer information, and the exit menu serves to end the interaction process, so that the entire application usage flow runs systematically according to the established functional design.

2. Use Case Diagram

A use case diagram is a type of diagram in Unified Modeling Language (UML) that is used as a technical solution to object-oriented problems [13]. This diagram functions by illustrating common interaction patterns between users and systems.

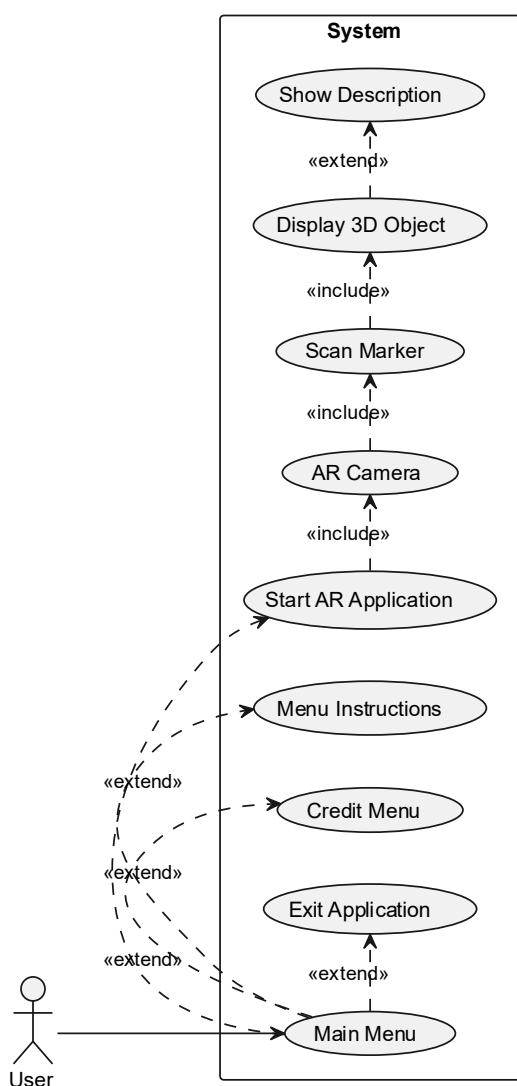


Figure 3. EduSawit Application Use Case Diagram

Figure 3 shows a use case diagram that illustrates user interaction with the developed Augmented Reality (AR) application system. The user acts as the main actor who accesses the main menu as the starting point of interaction. From the main menu, users can select several options, namely start the AR application, instructions menu, credits menu, and exit the application. Selecting to start the AR application triggers a series of include processes, starting from activating the AR camera, followed by scanning markers, until the system displays 3D objects. Furthermore, the 3D object has an extension in the form of a description that provides additional information related to the visualized object. Meanwhile, the instructions menu serves to display usage guidelines, the credits menu presents developer information, and the exit application menu ends user interaction with the system. Thus, this diagram shows the functional flow of the application in a structured and systematic manner according to user needs.

B. Design

At this stage, a 3D model, markers, and a prototype design for the application are created. The goal is to facilitate the overall application design process.

C. Material Collecting

This is the stage of gathering all the necessary materials or resources. This process can be done in parallel with the assembly stage, but in some cases, it can also be done sequentially.

D. Assembly

This stage involves the process of compiling and creating all application objects based on the design created in the design stage.

E. Testing

The testing stage is carried out to ensure that all functions run according to the design. The approach used is Black Box Testing, where the focus is on the suitability of inputs and outputs instead of looking into the program code. The test cases include the splash screen, menu navigation, marker scanning, and 3D object interaction.

F. Distribution

In the final stage, the application is stored on storage media. If the media capacity is insufficient, the application will be compressed first.

Although Black Box Testing ensures that EduSawit runs well technically, this test cannot yet assess the pedagogical effectiveness of the application for its target users. Therefore, further research is planned to include field tests with smallholder farmers as the main users. This evaluation will use a mixed approach consisting of pre-tests and post-tests (quantitative) as well as interviews (qualitative).

III. RESULT AND DISCUSSION

A. Result

The results of this study are in the form of a visualization application for environmentally friendly palm oil cultivation steps, which displays illustrations of each step in 3D and can be accessed via a smartphone. This application is equipped with various features such as 3D object selection, marker selection, sound features, and information related to the pyramid objects displayed.

Table 1 shows the results of the initial design of the EduSwit application, which was created in a structured manner so that the concept of the application is well organized. The elements formulated include the application title, target users, menu, Augmented Reality content, and the platform used.

Table 1. The EduSawit Application Concept

Concept Elements	Result
Title	EduSawit: Implementation of Augmented Reality for Environmentally Friendly Palm Oil Plant Education.
Target	All walks of life
Application Menu	Main menu, start/play (Augmented Reality camera), instructions, credits, and exit.
Augmented Reality Content	Illustration of site selection, selection of quality seedlings, intercropping patterns, water management, biological pest control, and palm oil waste management.
Platform Used	Android

The design stage focuses on creating the appearance and structure of the program to simplify the application development process. This stage includes compiling the application menu table and designing the user interface (UI).

Table 2. Application Menu

Application Menu	Description
Main Menu	A menu containing several buttons such as Start, Instructions, Credits, and Exit.
Start/Play	A menu displaying the play page that connects directly to the camera and detects markers to bring up 3D objects and supporting information related to the points in question.
Instructions	A menu displaying instructions or procedures for using the EduSawit application.
Credits	A menu displaying the application credits.
Exit	A menu for exiting the application.

Each menu is explained in Table 2, which consists of six menus that will be presented in the EduSawit application. Thus, this stage also requires the design of the user interface

(UI) for the application. Figures 4 to 9 show the User Interface design in EduSawit:

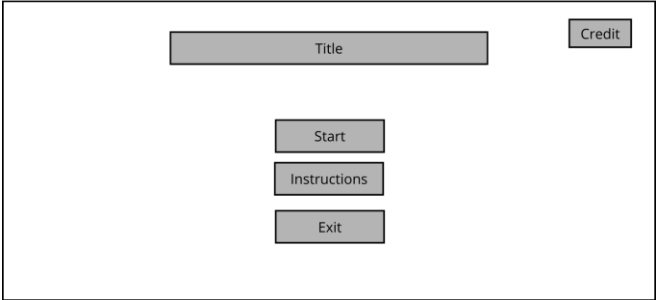


Figure 4. Main Menu Display

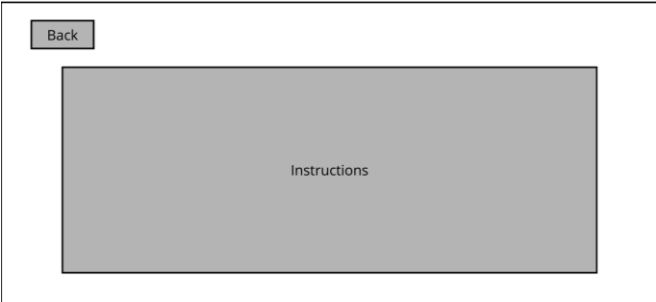


Figure 5. Instructions Menu Display

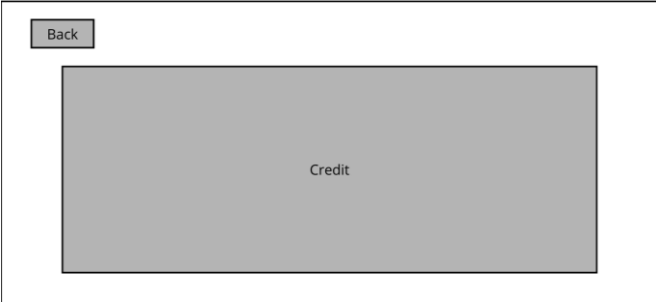


Figure 6. Credit Menu Display

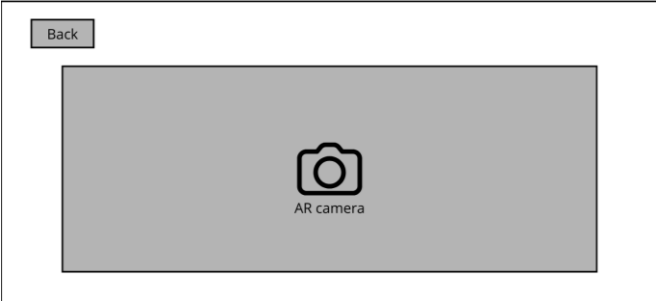


Figure 7. Marker Detection or Scanning Process

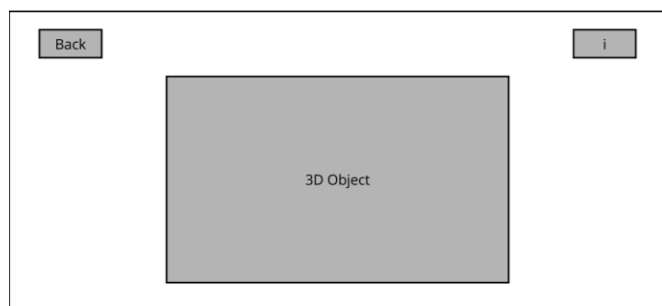


Figure 8. Displaying 3D Objects and Buttons (i)

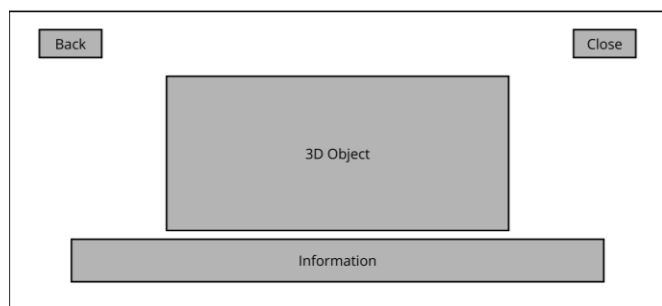


Figure 9. Display of 3D Objects and Information

The Material Collecting stage includes collecting the data, images, and 3D objects needed in the assembly stage. 2D images are generated with Canva in .png format, while 3D objects are created using Blender in .obj format. These materials are then inserted into the application scene to be displayed (Figure 10 and 11).



Figure 10. Creation of 3D Objects using Blender

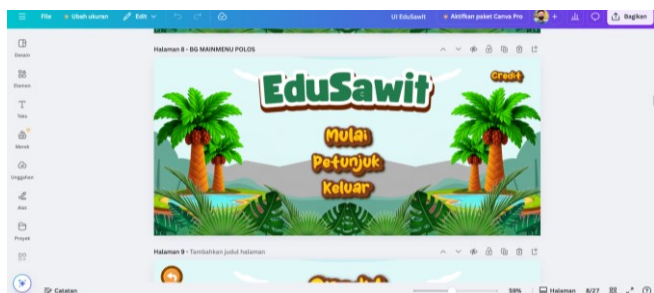


Figure 11. Creation of 2D Images using Canva

Material collecting also includes educational narrative materials based on Augmented Reality, organized into seven

main topics, each accompanied by a description presented in an information panel on the Augmented Reality camera page, all summarized in Table 3.

Table 3. Augmented Reality Content EduSawit

Title AR	Short Narrative
Selection of planting locations	Assessment of land suitability and soil organic carbon stocks are two key factors for achieving sustainable palm oil production [14].
Selection of quality seeds	The use of superior seeds based on clonal selection can increase yields and disease resistance [15].
Intercropping patterns	Agroforestry with an intercropping system between oil palm and food crops can improve environmental sustainability and increase the income of small farmers [16].
Use of organic fertilizers	The use of organic fertilizer based on palm oil waste has been proven to reduce dependence on chemical fertilizers [17].
Water demand control	Effective water management, including the use of drip irrigation and rainwater harvesting, is important to reduce water wastage in oil palm plantations [18].
Biological pest control	The use of natural enemies for oil palm pest control can reduce the use of chemical pesticides and support ecosystem sustainability [19].
Palm oil waste management (compost, biochar)	The use of palm oil waste to produce biochar can improve soil quality and reduce greenhouse gas emissions from agricultural systems [20].

The second stage of assembly brings all the images collected together into a single scene menu. It is achieved with Unity in 2022 editor version in 3D mode with Vuforia SDK as the marker database (Figure 12). To make 2D images work when Unity is operating in 3D mode, sprite functionality is used. The process includes scene creation, positioning 3D models, integrating Augmented Reality markers based on the Vuforia SDK, scripting in C#, and APK file generation for testing.

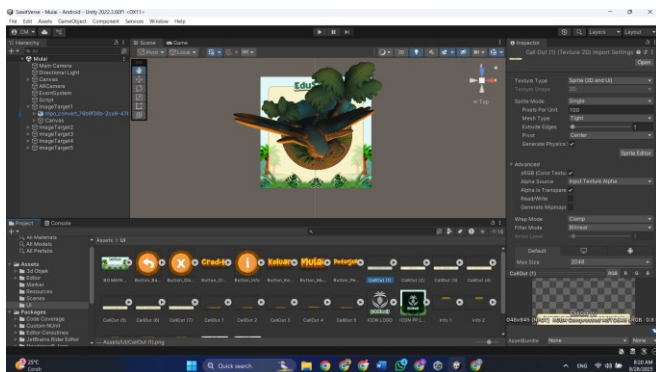


Figure 12. Creating AR Using Unity

The results of this process are menu displays such as a splash screen, main menu, start (Augmented Reality camera), information panel, instructions, credits, and exit menu. The final display and Augmented Reality implementation are shown in Figures 13 to 17.



Figure 13. Main Menu Display



Figure 14. Instruction Menu Display



Figure 15. Credit Menu Display



Figure 16. EduSawit Illustration AR Display



Figure 17. EduSawit AR Display with Information Callout

The next stage is testing, where the application is tested using the Alpha Black Box method. The main purpose of this test is to verify the performance of each button and feature to ensure that they function as intended. Details of the Alpha Black Box test results can be seen in the Table 4 below.

Table 4 shows the Alpha Black Box test conducted on an Android smartphone that was tested independently, producing a report in accordance with the table with results as expected. Test documentation is shown in Figures 18 through 22.

Next, the application is distributed to end users via physical storage media such as flash drives and online media such as Google Drive with a download link bit.ly/EduSawit.

B. Discussion

The implementation of Augmented Reality in EduSawit has proven to be an effective learning approach by visualizing 3D objects that depict the palm oil cultivation process. This method is more interactive than conventional approaches as it provides tangible representations of sustainable agricultural practices. The MDLC model applied in the development is cross-functional, enabling the seamless integration of 2D images and 3D models into an Android application. Black Box testing results confirmed that each feature such as Start, Info, Instructions, Credits, and Exit functioned as intended. These results indicate that EduSawit is not only technologically robust but also pedagogically relevant for enriching farmers' knowledge of environmentally friendly farming practices. Nevertheless, the validation of this study is limited to technical testing in a controlled environment. Without direct involvement of smallholder farmers, the pedagogical effectiveness of the application cannot yet be fully established. Therefore, future research will focus on conducting field trials with smallholder farmers to obtain quantitative evidence of knowledge improvement and qualitative insights into user experiences and perceptions.

Table 4. Black Box Testing

Component	Testing Steps	Expected Results	Testing Result
"Start" Button	Click the "Start" button on the main menu to enter the AR scan view.	The system will switch to the camera to detect the marker.	Successful
Scan Augmented Reality	Point the camera at the marker to display the 3D object.	The system will display a 3D object above the marker and display an "info" button.	Successful
"Info" Button	Click the "Info" button when the marker is detected.	The system will bring up a pop-up narrative with information about the content related to the Augmented Reality scan page.	Successful
"Close" Button	Click the "Close" button on the Augmented Reality scan view when the information pop-up appears.	The system will close the information pop-up on the Augmented Reality scan page.	Successful
"Back" Button	Click the "Back" button on the Augmented Reality scan page.	The system will return to the main menu page.	Successful
"Instructions" Button	Click the "Instructions" button on the main menu page.	The system will move to the instructions page.	Successful
"Back" Button	Click the "Back" button on the instructions page.	The system will return to the main menu page.	Successful
"Credit" Button	Click the "Credit" button on the main menu page.	The system will move to the credits page.	Successful
"Back" Button	Click the "Back" button on the credit page.	The system returns to the main menu page.	Successful
"Exit" Button	Click the "Exit" button on the main menu page.	The system responds by closing the application and returning to the phone display menu.	Successful



Figure 18. Main Menu Testing



Figure 20. Credit Menu Testing

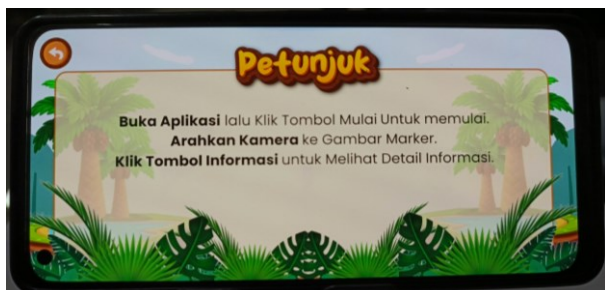


Figure 19. Instruction Menu Testing



Figure 21. AR Marker Scan Testing

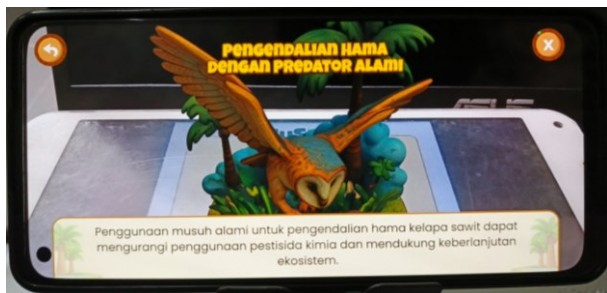


Figure 22. Button Testing (i)

IV. CONCLUSION

Based on the development and testing outcomes, EduSawit has been successfully developed as an Augmented Reality (AR)-based interactive learning application for sustainable palm oil cultivation. All application functions were verified to operate smoothly through Black Box Testing, ensuring the technical reliability of the system. The content provided aligns with sustainable agricultural principles, making EduSawit a relevant and innovative educational medium for enhancing farmers' knowledge and awareness of environmentally friendly practices. Nevertheless, the current study is limited to technical validation in a controlled environment and has not yet evaluated the pedagogical effectiveness of the application among real users.

Therefore, future research will focus on conducting field trials with smallholder farmers to obtain both quantitative data on knowledge improvement and qualitative insights into user experiences. This step is expected to provide stronger empirical evidence regarding the educational impact and adoption potential of EduSawit in promoting sustainable palm oil practices.

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