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REVOLUTIONIZING BIOLOGY LEARNING THROUGH AR: THE CASE OF LEAFCAPTURE APPLICATION DEVELOPMENT

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Abstract: This study aims to produce learning media in the form of a Leafcapture Identification Application Based on Augmented Reality (AR) in plant morphology courses with accuracy, user interface, and good content. The research method used in this study is Research and Development (R&D) with the The ADDIE approach involves a systematic process for designing learning media. In the Analyze stage, the focus is on identifying the need for new learning media, specifically the Leafcapture Identification Application Based on AR, and assessing its feasibility and requirements. In the Design stage, activities include application design, interface design, 3D image creation, and marker design. The Development stage involves gathering relevant content, such as plant leaf images and names, and setting up the application interface. During Implementation, the developed media is used and evaluated by experts and users to assess its impact on learning quality. Media experts validated the product with a 75% approval rating, while subject matter experts found it 88.89% valid. Evaluation was conducted by surveying students in plant morphology courses, with results confirming the product's effectiveness. Through AR, students can directly engage with three-dimensional (3D) models of various parts of plants, such as roots, stems, leaves, flowers, and fruits. They can manipulate and examine each part more deeply, enhancing their understanding of the relationships between parts and the functions of each component. Additionally, AR makes learning plant morphology more engaging and lifelike.
Keywords: *Augmented Reality; biology; Leafcapture identification.*

INTRODUCTION

Indonesia indeed possesses an extraordinary wealth of biodiversity, particularly in terms of plant diversity. It is estimated that there are around 40,000 plant species in Indonesia, encompassing various types from tropical forests, mangrove forests, grasslands, savannas, and more (Elfrida et al., 2021). However, ironically, many of these plant species have not been scientifically identified or well-documented. There are still many plant species in Indonesia that have not been thoroughly studied or documented by scientists. This can be attributed to various factors, such as Indonesia's vast territory consisting of numerous islands with diverse environments, limitations in human and financial resources for conducting research, and challenges in accessing remote areas that serve as habitats for rare plant species (Navia et al., 2020). Additionally, many plants in Indonesia face the risk of extinction due to human activities, including changes in land use, deforestation, climate change, and illegal plant trade (Supiandi et al., 2019). Some plant species may be at risk of extinction before they are fully identified or comprehensively documented.

The limited exploration outside Java raises hopes for increased biodiversity in Indonesia, with the potential discovery of new species that have not yet been documented. These areas encompass 93.33% of Indonesia's land area, including Papua, Sumatra, Kalimantan, Sulawesi, the Maluku Islands, and the Lesser Sunda Islands which include Bali, Lombok, Sumbawa, Flores, Sumba, Timor, Alor Islands, Southwest Islands, and Tanimbar Islands (Subositi & Wahyono, 2019). Currently, plant identification is still done manually, using a determination key book, which takes a long time, while botanists are racing against time to catalog plant species before they become extinct. Thus a technology-based identification system is needed in plant identification, which, when supplemented with raw visual plant data, will extract many descriptive features and use them to determine and produce suitable plant species (Zhang et al., 2021).

Skills in identifying these plants are not only possessed by botanists. Lecturers are also required to have the ability to identify plants to assist lecturers in providing students with an understanding of plant taxonomy. Of course, this ability must be adapted to developments in the digital era (Dewi & Utomo, 2021; Kala & Viriri, 2018). The development of science and technology in the field of education is a challenge to create learning media that can assist the learning process to improve the quality of education. This encourages lecturers to create science and technology -based media following technological advances that make it easy for lecturers and students to explore knowledge . One of the learning media that can help the learning process is technology-based plant identification

Apart from their obvious contributions to taxonomy and aiding learning processes, automated plant identification systems have considerable commercial potential, for example in the form of smartphone applications that can be used in the wild to identify dangerous or edible plants. Motivated by the potential of this application and recent advances in technology - based plant identification, the computer vision community's interest in identifying plants continues to increase (Hidayat & Ramadona Nilawati, 2018; VijayaLakshmi & Mohan, 2016). Plant identification applications used on smartphones have increased their availability, accuracy, and utilization in everyday life. This plant identification application that can be used on smartphones is an alternative learning media that can be used easily by students. Considering that the use of smartphones has become an inherent thing for students Android-based learning media is the choice (Huixian, 2020; Vilasini & Ramamoorthy, 2020).

Identification of plants can be done based on fruit, flowers, or leaves. Identification based on leaves is easier identification because leaves will be there all the time, while flowers and fruit may only be there at certain times. Identification of plants using leaves can be done based on the shape, texture, or color of the leaf image (Beghin et al., 2010). Leaves are one of the main characteristics of plants. Leaves are not only a key differentiator between species because of their shape, size, and advantage of being easy to observe, capture and describe clearly. Identification of leaves is commonly used as a guide in the field of plant taxonomy by botanists. Image-based identification of plant leaves usually uses morphological characteristics (shape, texture, color, and outline). Many studies have developed mobile applications for plant identification based on leaf images.

Digital-based (automatic) identification can be done using an application, namely Leaf Capture Identification (Olshannikova et al., 2015; Park et al., 2020). The Leafcapture Identification application is an Android-based smartphone application where the use of Android-based learning media is one of the applications of 21st-century learning styles (Bellalouna et al., 2022; Schäfer et al., 2022). This Leafcapture Identification application is combined with Augmented Reality technology. Augmented Reality (AR) is a technology that combines virtual information with the real world (Baragash et al., 2022; "Definitions and Applications of Augmented/Virtual Reality: A Survey," 2021). AR is an active technology that enables users to build new understandings based on virtual objects that animate the underlying data. AR is used in education to attract audiences to actively engage with the material in the learning. AR is also used to increase students' motivation in exploring and learning about plants (Ara et al., 2021; Billinghurst et al., 2014; Boboc et al., 2022).

Biology is the science that studies living things including the morphological structure of plants and how to identify them. To understand biological material, especially the morphological structure of plants and how to identify it, technology-based learning media such as the Leafcapture Identification application is needed which is easy for students to use during learning both in class and in the open air because it can be accessed using cell phones. This Leafcapture

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Identification application contains information on how to identify plants based on pictures of leaves taken via a cell phone camera (Android cellphone) (Amin et al., 2022; Park et al., 2020; Schäfer et al., 2022). Leafcapture Identification application Based on Augmented Reality helps students to recognize the types of plants based on the morphological characteristics of the leaves.

The objective of this research is to revolutionize biology learning through the development of the LeafCapture application based on Augmented Reality (AR). This study aims to develop, implement, and evaluate the LeafCapture application as an innovative learning tool that utilizes AR technology to facilitate better understanding of plant morphology and identification. The hypothesis of this research is that the development of the LeafCapture application based on Augmented Reality (AR) will enhance the effectiveness of biology learning in the following ways: Firstly, the use of AR technology will allow students to interact directly with three-dimensional (3D) models of various plant parts such as roots, stems, leaves, flowers, and fruits, thereby enhancing conceptual understanding. Secondly, the LeafCapture application will increase student engagement in learning by making typically abstract material more engaging and realistic. Thirdly, with this application, students will be able to manipulate and examine each plant part in depth, thus improving understanding of the relationships between components and their functions. Lastly, the use of AR technology in biology education will provide an interactive and enjoyable learning experience, ultimately boosting students' interest in the subject. Therefore, this research aims to test the hypothesis that the development of the LeafCapture application based on AR can revolutionize biology learning by enhancing student understanding and engagement in studying plant morphology and identification.

METHOD

The research method used in this research is Research and Development (R&D) with the design of the ADDIE approach (Analyze, Design, Development, Implementation, Evaluation) which aims to develop learning media in the form of Leaf Capture Identification which in this study, then will use Visual Studio Code or Android Studio on Biology material that is well qualified by paying attention to two components of feasibility, namely content feasibility and design feasibility, each of which includes quality aspects, namely accuracy, user interface, and content. The design of this development approach is structured programmatically with systematic sequences of activities to solve learning problems related to learning media that suit the needs and characteristics of students during the co-19 pandemic. This development approach design consists of five stages (Lodico et al., 2010), namely: (1) analysis, (2) design, (3) development, and (4) implementation. , and (5) evaluation. Visually, the ADDIE stages can be seen in Figure 1.

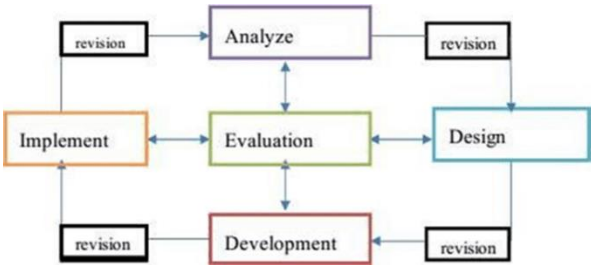

Figure 1. *ADDIE development approach design*

The population and sample in this R & D research are software application products, which in the development and implementation stages of the application product in the form of leaf capture identification are evaluated by expert test subjects and limited trial subjects. The expert test subjects consisted of two experts, namely media experts and material experts, while the limited test subjects consisted of students as users of the leaf capture identification application in learning plant morphology.

In this development research, there were several stages carried out according to the research design used, so the main instrument in developing the application was made in the form of validation sheets from 3 sources including media experts, material content experts, and students as product trial users. This main instrument is used in the Development, Implementation, and Evaluation stages. On the instrument validation sheet, aspects of the assessment indicators are determined using a checklist sheet. An overview of the instruments referred to in this study can be seen in table

Table 1. *Product assessment aspects of the developed Leafcapture application*

No.	Validator	Aspect
1.	Media Expert	Presentation Aspects

No.	Validator	Aspect
		Display Screen/Visual Communication Design Media Aspects
2.	Material Content Expert	Material/Content Quality Aspects Language Quality Aspects Learning Alignment Aspects Feedback and Adaptation Aspects
3.	User Student	Relevance Aspects Display Screen/Visual Communication Design Media Aspects Aspects of Application of Augmented Reality Technology Aspects of Learning Motivation

The procedure in this development research followed the steps of the ADDIE research design approach used, covering the following five stages:

Analyze, the main activity is to analyze the need for developing new learning media in identifying plants, namely Leaf Capture Identification, and analyze the feasibility and requirements for developing new learning media. After analyzing the problem of the need to develop new plant identification media, researchers also need to analyze the feasibility and requirements for developing these new learning media. For example, the analysis process is carried out by answering the following questions: a) is Leaf Capture Identification able to overcome learning problems faced by students; b) does Leaf Capture Identification have facilities to implement it; c) are lecturers and students able to apply the Leaf Capture Identification. Analysis of Leaf Capture Identification learning media needs to be done to find out the feasibility of the new learning media applied in identifying plants.

Design, the design stage is similar to designing Google Lens products. This activity is a systematic process that contains the content and construction of the Leaf Capture Identification application starting from establishing the application design, designing the raw image structure of the leaves, designing the leaf identification parts, as well as the interface on the Leaf Capture Identification product. The Leaf Capture Identification product design will form the basis for the next development process. At this design stage researchers also collaborate or solicit advice and input and even services from IT experts and education experts to consult related to product design and feasibility.

Development, At the development stage, the conceptual framework is realized into a product that is ready to be implemented. During the development stage, several activities were carried out such as: searching for and collecting various relevant sources to enrich Leaf Capture Identification content, taking pictures of plant leaf shapes, inputting data on scientific names and local names of existing plant leaf types, editing, and arranging Leaf Capture Identification interface. The development of this leafcapture identification application uses Visual Studio Code or Android Studio. Researchers also need IT experts in the process of developing this Leaf Capture Identification product. In addition, at this development stage validation activities are carried out for product development drafts and revisions according to input from experts (Judgers). So at the development stage, assessment instruments are also prepared to test the content feasibility and design feasibility components including aspects of accuracy, user interface, and product content.

Implementation, Leafcapture identification. Product designs and methods that have been developed are implemented. During implementation, the Leaf Capture Identification design that has been developed is applied to actual conditions. At this stage the results of the development are applied, namely assessed by experts (Judgement experts) and users (students) to determine the effect on the quality of learning which includes the components of content feasibility and design feasibility including aspects of accuracy, user interface, and Leaf Capture Identification content. Application is carried out in small groups to get input from students as users and experts/judgers as material for improving product drafts. After the implementation stage, an initial evaluation is carried out to provide feedback on the feasibility of using the next Leaf Capture Identification product.

Evaluation, the Leaf Capture identification. Product design that has been developed is applied to actual conditions, namely a limited scale trial on users, namely students. Evaluation is conducted to provide feedback on the application of the Leaf Capture Identification product. In this study, only an initial evaluation was carried out, because this type of evaluation relates to the stages of development research to improve the resulting Leaf Capture Identification product development. Evaluation in the development research design with the ADDIE approach is carried out step by step to collect data at each stage used for improvement so that the quality of the new learning media product in the form of Leaf Capture Identification is known. The final results of this evaluation phase are analyzed to determine product quality including a) content feasibility components and b) design feasibility, in terms of accuracy, user interface, and Leaf Cap ture Identification product content.

Overall the research data is in the form of quantitative data obtained by using descriptive statistics, including descriptive statistical calculation techniques and data visualization such as tables.

The data that has been collected in the validation questionnaire is qualitative data, because each statement point is divided into categories of strongly disagree = 1, disagree = 2, agree = 3, and strongly agree = 4. To calculate it, the data is transformed into quantitative data according to score weights of one, two, three, and four. After the data is transformed, then the calculation is done with the following formula.

$$V = \frac{TSEV}{SMAX} X\ 100\%$$

Where V is the percentage of validity, TSEV is the total empirical validator score, and SMAX is the expected maximumscore. The formulation of the validity of the media assessment is calculated using the percentages. Table 2 shows the criteria for the validity of learning media.

Table 2. *Learning media validity criteria*

No	Criteria	Validity Level
1	75,01% - 100,00%	Very Valid (can be used without revision)
2	50,01% - 75,00%	Valid (can be used with revision)
3	25,01% - 50,00%	Invalid (Cannot be used)
4	00,00% - 25,00%	Totally Invalid (Forbidden to use)

The trial of this application was carried out using a questionnaire in the form of a Google form which was distributed to 16 students of the Biology Education Study Program, Faculty of Teacher Training and Education, Kuningan University, namely first-semester students who were taking plant morphology courses. The calculation is done by the following formula.

$$V = \frac{TSEV}{SMAX} X\ 100\%$$

Where V is the percentage of validity, TSEV is the total empirical validator score, and SMAX is the expected maximumscore. The formulation of the validity of the media assessment is calculated using the percentages.

RESULTS AND DISCUSSION

The study of plant morphology is closely related to the activity of identifying specimens, one of which is the subject of plant morphology is leaf morphology. Leaf morphology includes leaf parts, leaf tip shape, leaf base, leaf vein arrangement, and leaf edges (Hidayat & Ramadona Nilawati, 2018; Zhang et al., 2021). These leaf parts can be studied through the Augmented Reality-based Leafcapture Identification application.

The Leafcapture Identification Application Based on Augmented Reality is a development of the Augmented Reality application itself. This application was created as a medium for learning biology, especially plant morphology in the classroom. Augmented Reality itself utilizes smartphone camera features to display three-dimensional objects that are in the virtual world in the real world (“Definitions and Applications of Augmented/Virtual Reality: A Survey,” 2021; Mahenthiran et al., 2021). This technology is a very important social need for change in the world of education through the implementation of innovative educational practices. Using Augmented Reality technology shows the educational value which makes the learning atmosphere more interesting, stimulating, and exciting for students (Schäfer et al., 2022; Syawaludin et al., 2019).

This Leafcapture Identification Application Based on Augmented Reality is a development of a combination of printing technology in the form of markers and technology on smartphones. This application contains ten three-dimensional object models, namely the morphological structure of cocor duck leaves, orange leaves, water hyacinth leaves, jackfruit leaves, noni leaves, rose leaves, strawberry leaves, grape leaves, pumpkin leaves, and lamtoro leaves. Three-dimensional models will later appear above the marker with the help of a smartphone camera. When the smartphone camera is pointed at the marker, models of these objects will appear (Olshannikova et al., 2015; Yuen et al., 2011).:

The procedure in this development research follows the steps of the ADDIE research design approach, namely.

Analysis stage

Based on the application needs analysis, we have planned the subject matter, collected data and needs analysis, and software systems such as Blender and Unity for making this application through books and internet media.

Design stage

At this stage, we have designed the application program including interface representation, 3D object design, splash screen design, description of each leaf , and making leaf markers. This Augmented Reality-based application utilizes smartphone camera features to display three-dimensional objects in the virtual world in the real world. Augmented Reality itself is the concept of merging the virtual world into the real world. The creation of a virtual world is done to evoke user perceptions to understand information from recognized objects (Muhammad et al., 2022; Zagorc & Bernik, 2022). The Leafcapture Identification Application Based on Augmented Reality is the development of a combination of printing technology in the form of markers and technology on smartphones. At this stage, it was also difficult to find, namely when making a 3D design, to find real photos of each leaf, because if you use images from Google it is still not clear. So the improvement must be a direct photo of the leaves so that it can be clear, for additional applications uploaded on the apps store or using the website.

Menu interface display design

An interface Menu is a list of commands in an application that when executed will carry out a certain command from the application. The options given by the menu can be selected according to the user's wishes. The interface usually contains the main page, cop categories, crop types, crop information, and an AR camera view (Bellalouna et al., 2022; Dick, 2021; Yoon et al., 2017). In this application, there are only two buttons, namely the Scan AR button and the Hint button. If you press the Scan AR button, it will enter the main program, namely the identification of plant leaves and if you press the Instructions button, instructions for using this application will appear.

Figure 2. *Menu interface design process*

3D design process

At this stage, 3D drawings were made of 10 types of plant leaves, namely *cocor bebek* leaves, orange leaves, water hyacinth leaves, jackfruit leaves, noni leaves, rose leaves, strawberry leaves, grape leaves, pumpkin leaves, and *lamtoro* leave.

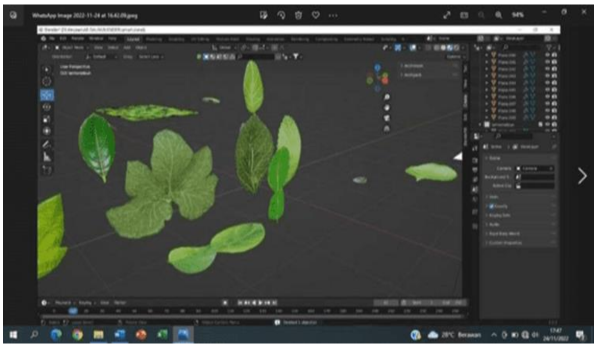

Figure 3. *3D design process*

Marker design

At this stage, a marker design was made from 10 types of plant leaves, namely cocor duck leaves, lime leaves, water hyacinth leaves, jackfruit leaves, noni leaves, rose leaves, strawberry leaves, grape leaves, pumpkin leaves, and lamtoro leaves. Images act as markers and will be recognized using the phone's camera and then trigger content that will be computer generated. Markers are designed to track from any distance and angle of the designed object (Usada, 2015; Utami & Trisnani, 2021).

Figure 4. *Marker design process*

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Development stage

The results of the analysis and design stages are used as the basis for making The Leafcapture Identification Application Based on Augmented Reality. This stage begins with making morphological structure objects from 10 types of leaves, making the main menu and main application using unity. At this stage, one obstacle was encountered, namely the lack of match between the marker and the original leaf image, so revisions were made by making re-markers for the leaves in question

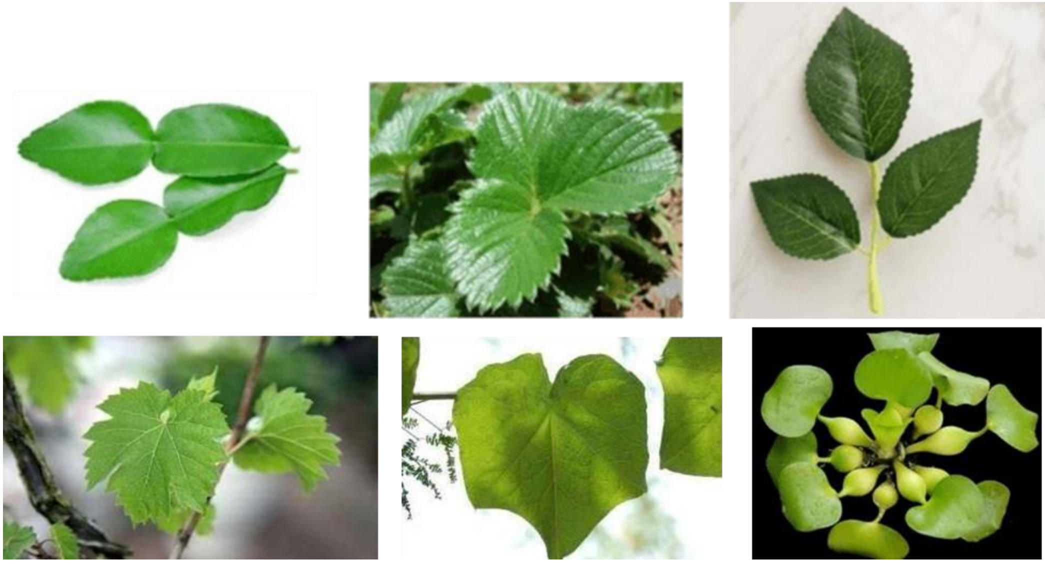

Figure 5. *Leaf object image*

Implementation stage

This application contains ten three-dimensional object models, namely the morphological structure of cocor bebek leaves, orange leaves, water hyacinth leaves, jackfruit leaves, noni leaves, rose leaves, strawberry leaves, grape leaves, pumpkin leaves, and *lamtoro* leaves. Three-dimensional models will later appear above the marker with the help of a smartphone camera. When the smartphone camera is pointed at the marker, models of these objects will appear.

The results of the development then enter the implementation stage by content experts and media experts by getting some input from media experts including: a) Application Launching animation (made with unity) can be replaced with developer/application maker information; b) About Application does not yet exist to provide information about Application version; c) consistency of language use (English/Indonesian). While the validation results frommaterial experts are appropriate, nothing has been revised. The following are the results of assessments from media expert validators, material experts, and students.

Table 3. *Validator assessment 1 development stage*

	Aspects	Validity (%)	Information
Media Experts	Presentation Aspect	75	Valid
	Display Screen Design/Visual Communication	75	Valid
	Media Aspect	75	Valid
Average		75	Valid

Table 4. *Validator assessment 2 development stage*

	Aspects	Validity (%)	Information
Material Content Expert	Content Quality Aspect	85	Very Valid
	Language Quality Aspect	93.75	Very Valid
	Learning Alignment Aspect	89.29	Very Valid
	Feedback and Adaptation Aspect	87.5	Very Valid
Average		88.89	Very Valid

Table 5. *Validator assessment 3 implementation stage*

	Aspects	Validity (%)	Information
Students (Implementation Stage)	Relevance Aspect	92.19	Very Valid
	Display Screen Design/Visual Communication	91.99	Very Valid
	Media Aspect	91.67	Very Valid
	Aspects of Application of Augmented Reality Technology	91.41	Very Valid
	Learning Motivation Aspect	90.62	Very Valid
Average		91.42	Very Valid

Evaluation stage

After implementation, The Leafcapture Identification Application Based on Augmented Reality was tested on semester 1 students taking plant morphology courses. The evaluation was carried out to provide feedback on the application of The Leafcapture Identification Application Based on Augmented Reality. This feedback is necessary given a large number of plant identification applications. Each plant identification application will provide benefits and different ways of using it according to the design made (Walvoord et al., 2008; Wu et al., 2013).

Based on the results of trials on students, the results obtained a validation level of 91.42% with very valid criteria. This means that students feel that this application is very relevant to their needs in learning plant morphology. Besides that, it is easy to use, the appearance of the application is good, and attracts interest and motivation for student learning, as well as fosters positive emotions

and improves learning outcomes. This is in line with the opinion of Xiang Zhou that applications based on Augmented Reality can foster positive emotions, motivate learning and improve learning outcomes (Mahenthiran et al., 2021). In line with the opinion of Wang (2017) students who use plant identification, mobile applications have higher levels of satisfaction, interest, and motivation (Wang & Dunston, 2011). However, from the results of the student trials, there is one input, namely more types of leaves that can be identified. These results will be followed up by continuing to add crop data on an ongoing basis.

Application output display

After the application is installed on the smartphone device, the application will read the marker and will display a three-dimensional model. To use The Leafcapture Identification Application Based on Augmented Reality, make sure your smartphone supports Android version 8.0 (Oreo), which is the minimum specification for the operating system. The application output display includes the Splash Screen Output display, the Interface menu output display, the marker detection output display, and object output accompanied by a description (Meng et al., 2015; Wu et al., 2013).

Display the output splash screen

When the application is run, the first thing that appears is the Splash Screen. The Splash Screen display is the screen display to wait for the next page. In this view, it takes approximately 7 seconds to go to the next page, namely the display interface menu

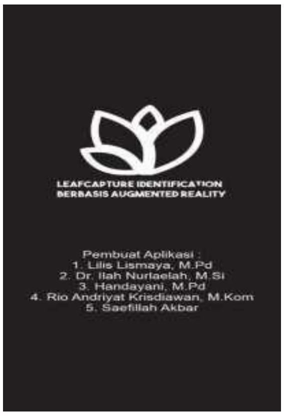

Figure 6. *Splash screen display*

Display the output interface menu

The Interface Menu displays two buttons, namely the Scan AR button and the Instructions button. If you press the Scan AR button, it will enter the main program, namely the identification of plant leaves. And if you press the Instructions button, instructions for using this application will appear.

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Figure 7. *Display menu interface*

Marker detection output display

When entering the main program, by clicking the AR scan button, the author directs the camera to the marker that has been printed out and places the marker somewhere. The marker will perform the detection and will display a 3D object (Desai et al., 2022; Kwakye, 2010). In the main program, there is also a Description button which functions to display a description of the detected leaf image.

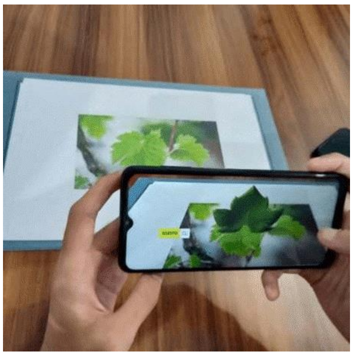

Figure 8. *Marker detection display*

Object output display accompanied by a description appearance

After the marker is detected, a 3D image of the leaf will appear. We can enlarge or reverse the 3D image by sliding the 3D image to the right or left, up or down. In addition, a description button is also visible, when the Description button is touched, it will display leaf material information based on the object detected by the application

Figure 9. *Object display accompanied by the display of a description*

Figure 10. *Implementation of the leafcapture application on a small scale in the classroom*

CONCLUSION

The Leafcapture Identification Application Based on Augmented Reality is an alternative learning media that can be used by students in learning biology such as plant morphology, as well as a substitute for props. This learning media is more attractive to students because the new learning method and the objects displayed are 3D objects from leaf objects that are almost the same as real ones, as well as the addition of material information about each object will make it easier for students to understand it. Hopefully in the future, this application can be further developed by increasing the number of plants that can be identified through the addition of plant data sources, enabling the integration of this application into other courses related to plant identification.

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