Development of Geo-based Augmented Reality Learning Media on the Distribution of Endemic Animals around the World

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ABSTRACT
Over time, learning media has evolved into more effective and efficient forms in its function as a means of distributing knowledge. One popular digital technology currently implemented in interactive learning media is Augmented Reality (AR). In line with the trend of technological advancements, this research aims to develop an augmented reality-based application to be implemented as a learning media for geography subjects, specifically focusing on the topic of the distribution of endemic fauna in various countries, which is quite challenging to learn solely through descriptions or two-dimensional images. The application, named ARFANA, utilizes markers as tracking media for its models. To ensure that the application can be used effectively, a feasibility test was conducted at the end of the research using a questionnaire instrument adapted from ISO 9241:11 2008 on usability tests, and it received a highly feasible rating. With the development of this learning media application, it is hoped to assist teachers and students in the teaching and learning process of fauna distribution in the geography subject.

Keywords: *Augmented Reality (AR), Endemic Fauna, Learning Media.*

1. INTRODUCTION

Learning media is a tool that aids in teaching and learning by distributing knowledge from the source to the users. It has been mentioned in a journal article [1] that innovation in learning media is necessary to allow users to interactively utilize the current technological advancements. Augmented Reality (AR) is one of the innovations offered to users, enabling continuous connection with systems and benefiting from the development of technology itself.

Augmented Reality is a rapidly developing new technology in various disciplines, including learning media. Besides being attractive and engaging [2], users can easily grasp the knowledge being taught, making AR a potential solution to the limitations of conventional learning through digital media in the form of augmented reality. Examples of developed Augmented Reality-based applications include the smart Hijaiyyah app developed by [3] and AR-based learning media developed by [4]. The development of Augmented Reality (AR) in learning media has progressed significantly, with various implementations supporting users in teaching and learning activities. Research conducted by [5] has demonstrated that the presence of AR can enhance students' achievements. Additionally, [6] developed an AR-based smart book to improve students' concentration on learning in the Prambanan region, Central Java. Furthermore, research conducted by [7] revealed that the presence of AR learning media significantly influences students' learning outcomes.

Based on the statements above, the researcher conducted a survey at SMA Negeri 1 Karanganyar, one of the senior high schools. From the survey, several findings were identified, such as the learning process still relying on textbooks, and teachers explaining the material repeatedly. This also applies to the geography subject, where students learn based on the teacher's explanation and have to search for reference materials on their own. From an efficiency standpoint, this approach can be considered inefficient and less engaging, as teachers sometimes have to repeat the material multiple times, and students struggle to find reference materials on their own. Another issue is that students at SMA Negeri 1 Karanganyar have limited knowledge of illustrations of endemic fauna in the

A. Kusumastuti et al. (eds.), *5th Vocational Education International Conference (VEIC 2023)*,
Advances in Social Science, Education and Humanities Research 813,
https://doi.org/10.2991/978-2-38476-198-2_95

world, such as 3D images and the sounds of endemic fauna.

Considering the described issues, there is a need to develop learning media that is more acceptable and understandable for students at SMA Negeri 1 Karanganyar, especially for the 11th-grade social science stream (IPS) students, whose learning process heavily relies on the teacher's oral explanations and students independently searching for reference materials to study the topics taught by the teacher.

Based on the aforementioned discussion, the author sees a promising potential to address the issues at SMA Negeri 1 Karanganyar. To fulfill the requirements of the thesis course and graduation, the author has chosen the title "Development of Geography-Based Augmented Reality Learning Media on the Distribution of Endemic Fauna Unique to Countries Around the World".

2. REVIEW OF THEORY

2.1. Augmented Reality Learning Media (AR)

The Learning is a process that students go through to acquire knowledge with the assistance of educators/teachers. Educators/teachers employ methods to ensure that learners can collaborate in their emotions, thoughts, and understanding of students' interests and problems in pursuing knowledge. This aims to facilitate effective learning [8].

Augmented Reality is one of the technologies in the field of education that can spark students' curiosity and eliminate boredom in delivering instructional materials by teachers. Furthermore, AR technology has significantly aided the education sector in various fields of study, leading many educational institutions to adopt AR as a mandatory tool in teaching and learning activities [9].

From the aforementioned perspectives, it can be concluded that Augmented Reality learning media can serve as an alternative to facilitate students' learning process and ignite their enthusiasm for learning.

2.2. Marker Based Tracking

The Marker-based tracking is a technique used by augmented reality to identify and track virtual objects in the real world. The fundamental principle of marker-based tracking involves using markers or symbols recognized by AR devices as references to place virtual objects in the real world [10].

Augmented Reality can be applied in various research studies. For example, research conducted by [11] utilized Augmented Reality technology in a learning media for the human skeleton, employing a marker-based method to locate the position of a QR code that displays a 3D object [10].

Markers can take the form of QR codes or barcodes, specific color patterns or shapes, or even real-world objects such as buildings or paintings. When the AR device recognizes these markers, it can overlay virtual objects onto them according to their positions in the real world [10].

The use of markers can simplify the tracking process because markers often have high color contrast and are easily recognized by AR devices. However, marker-based tracking also has its limitations, as it relies on the presence of markers in the real world. If a marker is absent, it cannot be recognized by the AR device [10].

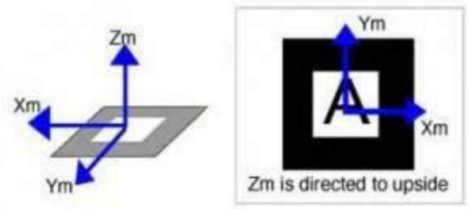


Figure 1 Marker Based Tracking.

2.3. Unity Engine

Unity is one application that is closely associated with Augmented Reality due to its popularity as a game engine and widespread usage. Unity has two versions: an open-source (free) version and a proprietary (paid) version. Unity also allows for exporting built games, providing development capabilities across various platforms such as Unity Web, Windows, iOS, Mac, Android, Playstation 3, Wii, and Xbox. Unity supports multiple programming languages such as C#, JavaScript, and BootScripts [1].

2.4. Learning about Endemic Fauna Worldwide

In the geography learning module for 11th-grade students published by the Ministry of Education and Culture in 2020, the study focuses on the distribution of flora and fauna in Indonesia and the world.

Understanding the material is crucial as it explains the distribution of endemic flora and fauna in Indonesia. Students will also become more aware of endangered species, particularly rare species whose habitats need to be preserved. Indonesia is a country that produces food and has a great wealth of biodiversity, including various beneficial flora and fauna that will not deceive you. It is the responsibility of future generations to ensure the survival of these flora and fauna [11].

2.5. Evaluation Techniques for Learning Media

Evaluation techniques for learning media are carried out to measure or assess the learning media applications developed by researchers.

For the evaluation instrument of the material based on the National Education Standards Agency (BNSP) in 2008, the evaluation focuses on the content presented in the learning media that has been created [12]. The indicators for evaluating the material, which will be filled out by content experts, are described in the following table:

Table 1. Instruments for Expert Content Validation [12]

No	Aspect	Indicator	Item
1	Relevance of Content to Learning Objectives and Competency Standards (SK and KD)	The completeness of the presented content	1
		The breadth of the elaborated content	2
		The depth of the presented content	3
2	Accuracy of Material	Accuracy of concepts and definitions when delivering the content	4
		Accuracy of facts and data presented in the material	5
		Accuracy of examples and cases presented	6
		Accuracy of images in the material and 3D models	7
		Accuracy of terminology used in accordance with the material	8
3	Fostering Curiosity	Android-based applications foster curiosity.	9
		Android-based applications enhance students' learning interest.	10
		Android-based applications create students' questioning abilities.	11

The media evaluation instrument based on ISO 9241:11 in 2008 regarding usability tests will be filled out by media experts based on the evaluation of a user-friendly application [6], as presented in the following table.

Table 2. Instruments for Media Expert Validation [11]

No	Aspect	Indicator	Item
1	*System*	The AR Endemic Fauna Distribution application has a clear and understandable interface.	1
		The AR Endemic Fauna Distribution application is easy to operate.	2
		The AR Endemic Fauna Distribution application has high-quality graphics and layout.	3
2	*User*	The menu interface of the AR Endemic Fauna Distribution application is easy to understand.	4
		The 3D models in AR are easy to understand.	5
		There are start AR, quiz, download module, and profile menus that can be used effectively.	6
3	*Reliability*	The AR Endemic Fauna Distribution application is capable of accurately processing data (navigating through menus, returning to the home page, playing music and sound, calculating quiz scores, and operating AR).	7
		The AR Endemic Fauna Distribution application can handle errors that occur during login or learning processes.	8
4	*Integrity*	The AR Endemic Fauna Distribution application can provide clear error messages.	9
5	*Interaction*	The AR Endemic Fauna Distribution application is easy to operate.	10
		The AR Endemic Fauna Distribution application has a well-established security system.	11

For the user response instrument based on the research conducted by Sopa [13], it will be filled out by the students. This instrument aims to determine the suitability of the learning media that has been created and tested on the students. The instrument is presented in the following table.

Table 3. Instruments for User Response Validation [13]

No	Aspect	Indicator	Item
1	Application Interface	The ARFANA application has an attractive interface design.	1
		The text in the ARFANA application is easy to read.	2
		The text in the modules is easy to read.	3
		The layout of the text in the modules is well-organized.	4
		The buttons for menus and navigation are	5

No	Aspect	Indicator	Item
		clearly visible.	
		The instructions for using the ARFANA application are displayed clearly.	6
		The ARFANA application can be easily operated without any issues.	7
		The marker scanning process can be easily done.	8
		The 3D objects of rare animals can be clearly seen on the marker.	9
2	Presentation of Content	The learning material aligns with the learning objectives.	10
		The practice questions displayed are in line with the material.	11
		The instructions for answering the questions are displayed clearly.	12
		The practice questions can serve as an assessment tool for students' understanding of the material.	13
3	Benefits of the Application	The displayed 3D images provide new insights into the forms of rare animals.	14
		The ARFANA application improves students' understanding of rare animals.	15
		The ARFANA application helps students recognize rare animals.	16
		The ARFANA application is engaging and enhances students' enthusiasm for learning about rare animals.	17

3. RESEARCH METHODS

3.1. Research Location

The research will be conducted at SMAN 1 Karanganyar. The researcher chose this location because there is currently no Android application-based learning media available at the school to assist the teaching and learning process for the subject of geography.

3.2. Research Type

The research will be conducted using the R&D (Research and Development) approach. The process of developing new products, procedures, technologies, or systems through research and development is known as the development method. This technique is commonly used by organizations or associations that aim to develop or work on a product or existing innovation [13]. The application that will be developed by the researcher is an application that runs on the Android platform.

3.3. Research Method

The research method used in the development of a mobile-based application for the distribution of endemic animal species worldwide is demonstrated by the following waterfall system development model.

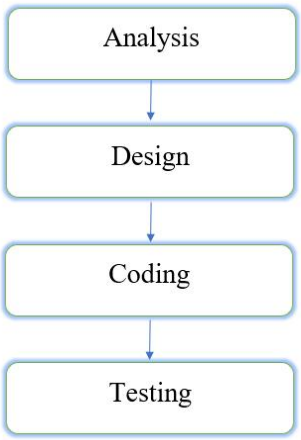


Figure 2 Development of Information Systems using the waterfall method.

3.3.1. Analysis

During the Analysis phase, a needs analysis was conducted using the literature study method, which resulted in identifying functional and non-functional requirements [13]. Functional requirements are the needs that must be fulfilled by a system or product to function according to the desired objectives. These requirements are typically related to the features or functions that the system or product should possess.

On the other hand, non-functional requirements are unrelated to the specific features or functions of the system or product but rather focus on the qualities or characteristics that the system or product should possess. For example, non-functional requirements for a smartphone would include fast performance, good battery life, and an appealing design.

Functional and non-functional requirements are often considered together in the system or product development process because they are interconnected and influence each other. However, non-functional requirements are typically more challenging to measure and evaluate compared to functional requirements since

they lack clear specifications and can vary significantly based on different user needs.

In the analysis phase, business process identification, business process modeling, and behavioral modeling were also performed [13]. Business process identification can be done using UML tools such as a use case diagram. Business process modeling can utilize UML tools like an activity diagram. Behavioral modeling can be achieved using UML tools like a sequence diagram [13]. By conducting business process identification, business process modeling, and behavioral modeling in the mobile application for the distribution of endemic animals worldwide, the application can be illustrated and analyzed, enabling effective and efficient business processes to be achieved when implementing the system.

3.3.2. Design

In the Design phase, the design is created based on the findings from the analysis phase. In this stage, a specific type of design called User Interface (UI) design is implemented [13].

User Interface design involves creating the visual and interactive layout of the system. For the mobile application focused on the distribution of endemic animals worldwide, the design will prioritize user-friendliness, ensuring that the interface is intuitive and easy for users to navigate.

3.3.3. Coding

In the Coding phase, the implementation of the designed system is carried out based on the prior design stage [13]. The mobile application focusing on the distribution of endemic animals worldwide will be developed as a system running on the Android platform, utilizing Augmented Reality technology [14], [15]. This phase involves writing the necessary code to bring the designed system to life on the Android platform, incorporating the functionalities and features required for the application's purpose.

3.3.4. Testing

The testing to be conducted on the developed learning media, based on the analysis and design, will utilize black box testing methodology. This includes validation testing by subject matter experts, validation testing by media experts, and user response testing during the testing phase. Black box testing is one technique used to evaluate the functionality of developed software. The content and media presented in the augmented reality learning media will undergo validation testing by media experts and subject matter experts. Additionally, user response testing will be carried out with students to measure their evaluation of the developed application.

3.4. Data Collection Techniques

In this research, the researcher employed various data collection techniques as references in the development of learning media and as evaluations of the created learning media. Some of the data collection techniques used by the researcher include:

3.4.1. Literature Review

The researcher conducted a literature review to gather references for the development of learning media. The literature review involved searching for information in relevant journals, internet sources, and articles.

3.4.2. Interviews

The researcher conducted interviews with various individuals to gather information about the development of learning media and to evaluate the created learning media.

3.4.3. Questionnaires

The researcher administered questionnaires to different types of respondents as an evaluation of the developed media. The questionnaires were used to gather feedback on the created media.

3.5. Data Validation Analysis Techniques

Descriptive statistical analysis is a valid data analysis approach to assess the suitability of learning media. Descriptive statistics summarize data in a way that makes it easily understandable, without attempting to make general conclusions or generalizations. The findings from data analysis will serve as a guide for revising future learning media applications (Burhanudin, 2017). A 4-point scale method is used to measure and analyze the questionnaire results. The 4-point scale method and the corresponding scores are described in the table below.

Table 4. Categorization of Validation Scores on a 4-point Scale.

Scale	Interpretation
4	Very Good
3	Good
2	Fair
1	Poor

Table 5. Categories of Assessment.

Score Intervals			Categories
55.25	$< x \leq$	68	Very Good
42.5	$< x \leq$	55.25	Good
29.75	$< x \leq$	42.5	Fair
17	$< x \leq$	29.75	Poor

The obtained scores in data validation results can be calculated for standard deviation (SD) and ideal mean (Me) using the following formula:

$$\text{Me} = \frac{(highest\ score + lowest\ score)}{2}$$

$$\text{Sd} = \frac{(highest\ score - lowest\ score)}{6}$$

The Categories of validation results based on standard deviation and ideal mean are shown in the following table.

Table 6. Categories of Assessment.

Score Intervals	Categories
Me+1.50 Sd < X ≤ Me + 3 Sd	Very Good
Me < X ≤ Me + 1.50 Sd	Good
Me – 1.50 Sd < X ≤ Me	Fair
Me – 3 Sd < X ≤Me – 1.5 Sd	Poor

4. RESULT AND DISCUSSION

4.1. Analysis

In the analysis phase of the mobile application for the distribution of endemic animals worldwide, several requirements are needed, including functional requirements and non-functional requirements. To identify these requirements, the author conducted a literature study, reviewing various journals and articles. The study aimed to gather information on both functional and non-functional requirements for the application.

4.1.1. Functional Requirements

Here are the functional requirements of the application to be developed:

No	*Actor*	*Description*
F1	*User*	Viewing Main Menu
F2		Answering Quiz
F3		Viewing Augmented Reality
F4		Viewing Profile
F5		Viewing Module

Figure 3 Entity Relationship Diagram.

4.1.2. Non-functional Requirements

The The non-functional requirements of the mobile application for the distribution of endemic animals worldwide include a simple and uncomplicated system interface design that is informative and not overly complex.

In the analysis phase, the author also conducted business process identification, business process modeling, and behavioral modeling activities. These processes were employed to identify and model the business processes related to the application.

4.1.3. Business Process Identification

In the Business Process Identification phase, the author utilized the Usecase tool. Usecases were created to assist in understanding the steps involved in achieving the goals of the application. Usecases provide a visual representation of the interactions and actions within the system, helping to identify and define the various processes and functionalities required to achieve the desired outcomes.

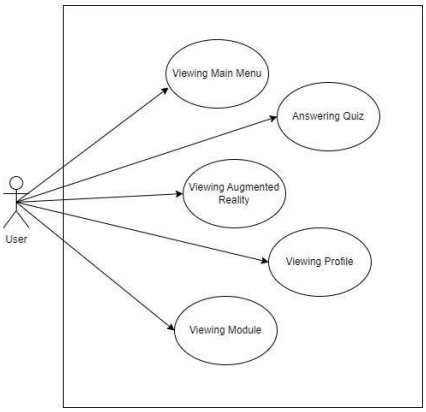


Figure 4 Use Case Diagram ARFANA.

4.1.4. Business Process Modeling

The tools used in business process modeling are activity diagrams. Activity diagrams depict the flow of business processes that occur within the system.

4.1.4.1. Augmented Reality Menu Activity Diagram

For the augmented reality feature, an activity diagram will be created to explain the flow of processes. The following is the implementation result of the augmented reality activity diagram.

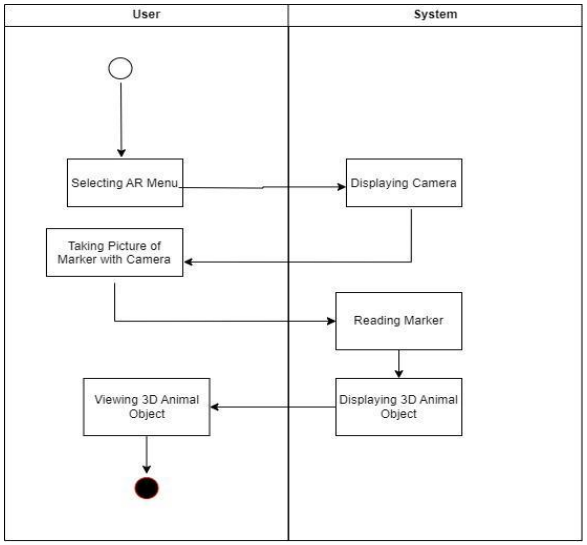


Figure 5 Activity Diagram for the Augmented Reality Feature.

4.1.4.2. Activity Diagram for the Main Menu

The activity diagram for the main menu can be seen in the following image.

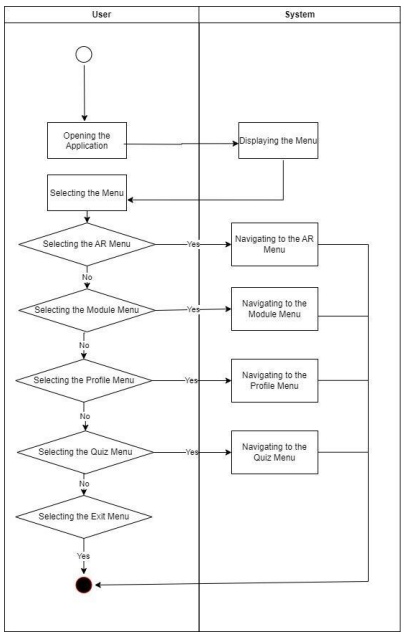


Figure 6 Activity Diagram for the Main Menu of the Mobile Application on the Distribution of Endemic Fauna Worldwide.

4.1.4.3. Activity Diagram for the Module Menu

Activity diagram for the module menu can be seen in the following image.

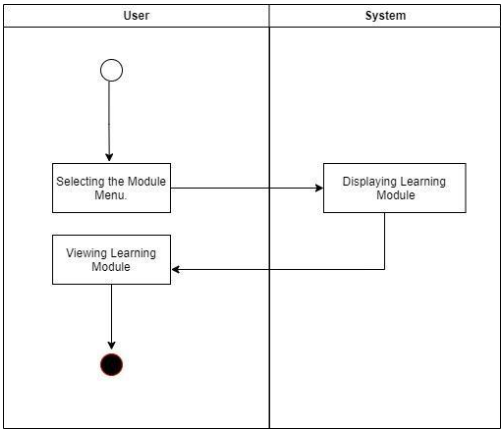


Figure 7 Activity Diagram for the Module Menu of the mobile application on the distribution of endemic fauna worldwide.

4.1.4.4. Activity Diagram for the Profile Menu

Activity diagram for the profile menu can be seen in the following image.

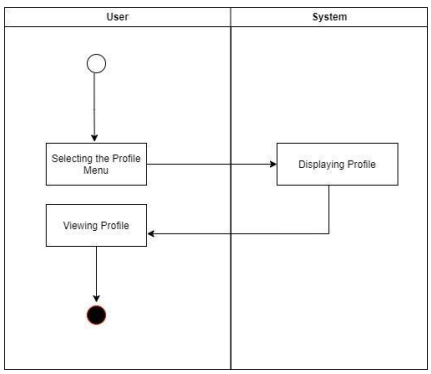


Figure 8 Activity Diagram for the User Profile Menu of the mobile application on the distribution of endemic fauna worldwide.

4.1.4.5. Activity Diagram for the Quiz Menu

Activity diagram for the quiz menu can be seen in the following image.

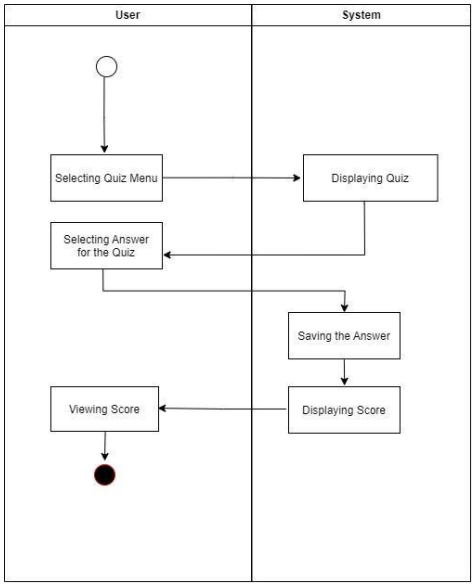


Figure 9 Activity Diagram for the Quiz Menu of the mobile application on the distribution of endemic fauna worldwide.

4.1.5. Behavioral Modeling

The tools used to implement behavioral modeling using sequence diagrams are:

4.1.5.1. Sequence Diagram for the Augmented Reality Menu

The sequence diagram for the augmented reality menu can be seen in the following image.

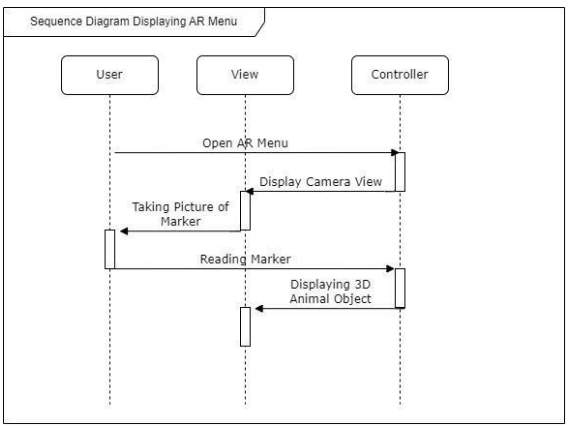


Figure 10 Sequence Diagram for the Augmented Reality Menu of the mobile application on the distribution of endemic fauna worldwide.

4.1.5.2. Sequence Diagram for the Main Menu

The sequence diagram for the main menu can be seen in the following image.

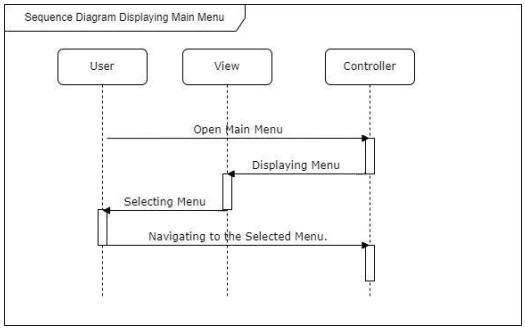


Figure 11 Sequence Diagram for the Main Menu.

4.1.5.3. Sequence Diagram for the Module Menu

The sequence diagram for the module menu can be seen in the following image.

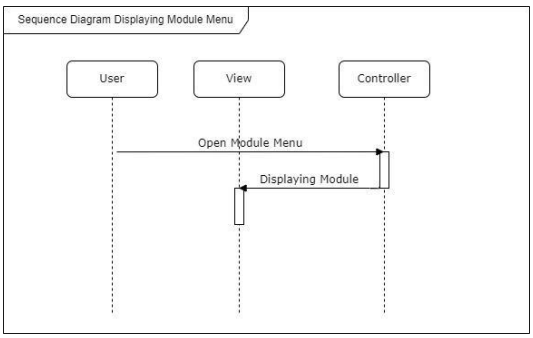


Figure 12 Sequence Diagram for the Module Menu.

4.1.5.4. Sequence Diagram for the Profile Menu

The sequence diagram for the profile menu can be seen in the following image.

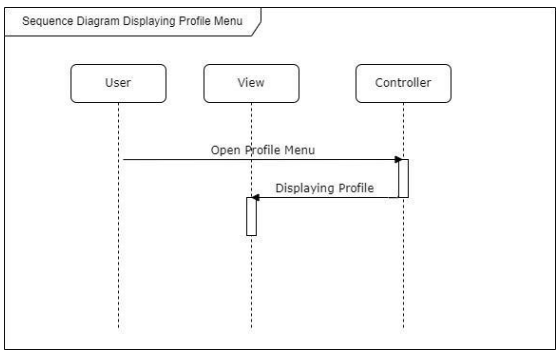


Figure 13 Sequence Diagram for the Profile Menu.

4.1.5.5. Sequence Diagram for the Quiz Menu

The sequence diagram for the quiz menu can be seen in the following image.

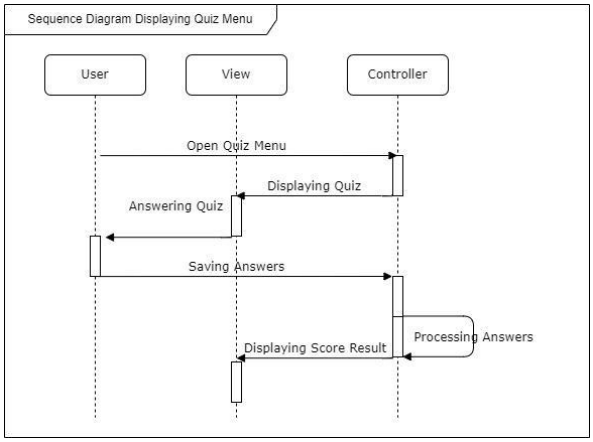
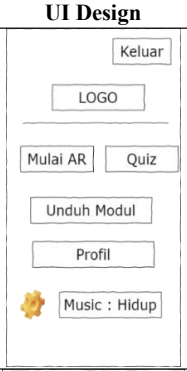
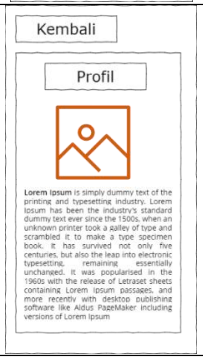


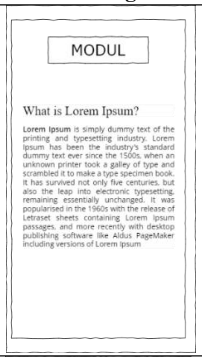
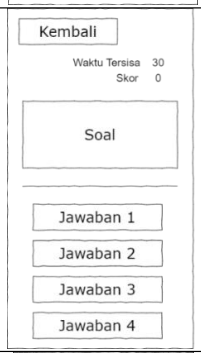
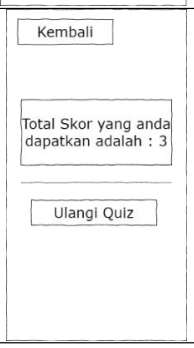
Figure 14 Sequence Diagram for the Quiz Menu.

4.2. Design

In the Design phase, the design is created based on the findings from the preceding Analysis phase. This stage includes User Interface (UI) design, where the visual and interactive aspects of the application are designed. The UI design focuses on creating an intuitive and user-friendly interface that enhances the overall user experience and facilitates efficient interaction with the mobile application.

Table 7. The user interface of the mobile application for augmented reality learning on the distribution of endemic fauna worldwide

No	Name	UI Design	Description
1	Main Menu		In the main menu, an exit button is displayed in the top right corner. This is followed by the application logo image and several other buttons, such as the Start AR button, Quiz button, Download Module button, Profile button, and music configuration button.
2	Augmented Reality Menu		In the Augmented Reality menu, the camera view will be displayed, revealing 3D objects when the user places the camera on a provided marker. There is a "Back to Main Menu" button located in the top left corner.
3	Profile Menu		In the profile menu,information and an image of the application's creator will be displayed..

No	Name	UI Design	Description
4	Module Menu		In the module menu, information about the distribution of endemic fauna specific to different countries around the world will be displayed.
5	Quiz Menu		In the quiz menu, questions about the distribution of endemic fauna specific to different countries around the world will be displayed, along with answer choices for the user to select. There will be information about the remaining time and the score earned when answering the quiz.
6	Quiz Result Menu		In the quiz result menu, the total score obtained from the answered quiz will be displayed. There will be a "Back" button to return to the main menu and a "Retry Quiz" button to restart the quiz.

4.3. Coding

The author incorporates the design and previous analysis into action during the Coding phase. The application will focus on the distribution of endemic fauna worldwide and will be developed using Unity and programmed using the C# programming language. The application will be executed on the Android platform, utilizing augmented reality technology to enhance the learning experience.The researcher then established standard specifications for the Android smartphones and computers used in the development process. Here are the specifications:

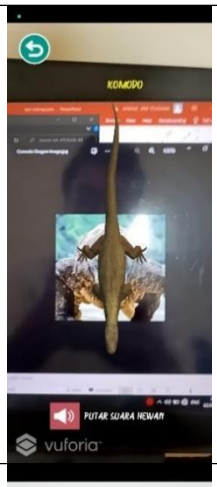
Table 8. Computer Specifications and Android Smartphone Specifications.

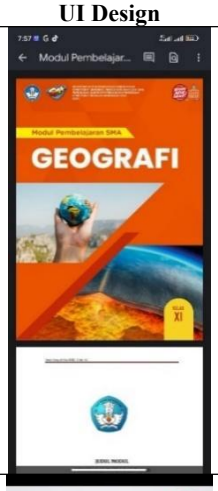
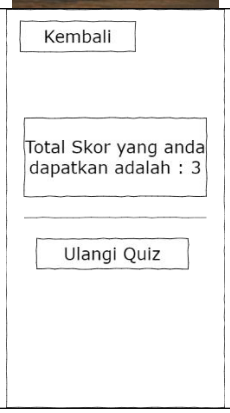
Computer Specifications	
Sistem Operasi	Windows 10
Processor	Intel(R) Core(TM) i7-7700HQ CPU @ 2.80GHz 2.80 GHz
RAM	8 GB
VGA	nVidia GeForce GTX1050Ti
HDD	1 TB

Android Smartphone Specifications	
Sistem Operasi	Android 11, MIUI 13
Processor	Mediatek Helio G96
Memory	RAM 6GB, ROM 128GB
Display	6.67 inches, 1080x2400 pixels
Camera	108 + 8 + 2MP

Table 9. The results of the implementation in the augmented reality educational media application for the distribution of endemic fauna.

No	Name	UI Design

No	Name	UI Design
1	Main Menu	
2	Augmented Reality Menu	
3	Profile Menu	

No	Name	UI Design
4	Module Menu	
5	Quiz Menu	
6	Result Quiz Menu	

4.4. Testing

After the implementation is completed, the results will be tested using the following methods: Black Box Testing, Subject Matter Expert Validation, Media Expert Validation, and Student Response Testing.

4.4.1. Black Box Testing

Black box testing aims to test the performance and functionality of the developed application. All the features within the application will be tested along with their functions. Here are the results of the application testing using black box testing:

No	Function	Tester	Test Date	Result	
				Functional	Non-Functional
1	Successful Installation of the Application on Android Device	Brilyan	3 October 2022	v	
2	Music sound appearing in the main menu	Brilyan	3 October 2022	v	
3	Click the "Start AR" menu button	Brilyan	3 October 2022	v	
4	Click the "Download Menu" menu button	Brilyan	3 October 2022	v	
5	Click the "Quiz" menu button	Brilyan	3 October 2022	v	
6	Click the "Profile" menu button	Brilyan	3 October 2022	v	
7	Camera appears in the Augmented Reality menu	Brilyan	3 October 2022	v	
8	Camera can capture markers and display 3D objects	Brilyan	3 October 2022	v	
9	Click the back button	Brilyan	3 October 2022	v	
10	Click on the selected answer	Brilyan	3 October 2022	v	
11	Click the "Retry Quiz" button	Brilyan	3 October 2022	v	
12	Score corresponds to the selected answers.	Brilyan	3 October 2022	v	

Figure 15 The results of testing using the black box testing method.

4.4.2. Expert Content Validation

The validation conducted by subject matter experts aims to validate the content of the created application to determine its appropriateness. In this stage, the researcher collaborated with an education expert named Ms. Eka Candra S, S. Pd., who teaches Geography at SMAN 1 Karangnyar school.

According to the National Education Standards Agency (BSPN), expert content validation has three attributes: Relevance of the Content, Accuracy, and Stimulating Curiosity component. Here are the instruments used for the conducted validation test.

No	Aspect	Indicator	Item
1	Alignment of Material with Standards and Learning Objectives	Completeness of the presented material	1
		Comprehensiveness of the elaborated material	2
		Depth of the presented material	3
2	Accuracy of Material	Accuracy of concepts and definitions when delivering the material	4
		Accuracy of facts and data presented in the material	5
		Accuracy of examples and cases presented	6
		Accuracy of images in the material and 3D models	7
		Accuracy of the terminology used in accordance with the material	8
3	Promoting Curiosity	Android-based applications encourage curiosity.	9
		Android-based applications enhance students' learning interest.	10
		Android-based applications foster students' questioning abilities.	11

Figure 16 List of instruments used for expert content validation.

Based on the 11 indicators mentioned above, they should be tested by subject matter experts. Considering the number of indicators, the maximum score that can be obtained is 44, with each instrument being evaluated on a 4-point scale.

Table 10. Explanation of Scores in Expert Content Validation.

Scale	Interpretation
4	Very Good
3	Good
2	Fair
1	Poor

Table 11. Assessment Categories.

Score Intervals			Categories
35.75	$< x \leq$	44	Very Good
27.5	$< x \leq$	35.75	Good
19.25	$< x \leq$	27.5	Fair
11	$< x \leq$	19.25	Poor

Here are the scores obtained from the expert content validation test.

Table 12. Assessment from content experts in the material validation test.

No	Aspect	Score	Categories
1	Relevance of Material	11	
2	Accuracy of Material	20	
3	Stimulating	12	
	Curiosity Total	43	Very Good

4.4.3. Expert Media Validation

Expert media validation is necessary to determine the feasibility of the developed application. Media validation test was conducted by Mr. Moechammad Alvan Prastoyo Utomo, a Software Developer from Sebelas Maret University.

There are 5 main aspects that are subject to validation, namely System, User, Reliability, Integrity, and Interaction. The following is a table of assessment instruments that we have created based on the International Standard - ISO 9421-11.

Table 13. List of Expert Media Validation Instruments based on ISO 9421-11.

No	Aspect	Indicator	Item
1	*System*	The AR Fauna Endemik Distribution application has a clear and easily understandable interface.	1
		The AR Fauna Endemik Distribution application is easy to operate.	2
		The AR Fauna Endemik Distribution application has good graphic resolution and layout.	3
2	*User*	The menu interface of the AR Fauna Endemik Distribution application is easy to understand.	4
		The 3D models in AR are easy to understand.	5
		The application includes well-functioning menus such as AR Start, Quiz, Module Download, and Profile.	6
3	*Reliability*	The AR Fauna Endemik Distribution application is capable of processing data accurately, including navigating menus, returning to the home page, playing music and sounds, calculating quiz scores, and operating AR.	7
		The AR Fauna Endemik Distribution application functions properly even in the event of login or learning process errors.	8
4	*Integrity*	The AR Fauna Endemik Distribution application provides clear error messages when errors occur.	9
5	*Interaction*	The AR Fauna Endemik Distribution application is user-friendly and easy to operate.	10
		The AR Fauna Endemik Distribution application has a well-secured security system.	11

Out of the 11 indicators above, they must be tested by content experts. Based on the number of indicators, the maximum score that can be obtained is 44, with each instrument being rated on a 4-point scale.

Table 14. Score Assessment on a 4-point scale.

Scale	Interpretation
4	Very Good
3	Good
2	Fair
1	Poor

Table 15. Assessment Result Categories.

Interval Skor			Kategori
35.75	$< x \leq$	44	Very Good
27.5	$< x \leq$	35.75	Good
19.25	$< x \leq$	27.5	Fair
11	$< x \leq$	19.25	Poor

Here are the assessment results from the media expert validation.

Table 16. Score Assessment on a 4-point scale.

No	Aspect	Score	Categories
1	*System*	11	
2	*User*	11	
3	*Reliability*	8	
4	*Integrity*	3	
5	*Interaction*	8	
	Total	41	Very Good

From the above test results, then analyzed by the expert, there are several recommendations given to the researcher, as explained below:

1. Addition of remaining time information in the quiz
2. Improvement of the Flores eagle 3D model
3. Correction of typographical errors in the quiz

4.4.4. User Response Test

After researcher implemented the recommendations from the expert and updated them into the application, the researcher conducted a final test, namely the user response test. This user response test involved 32 students from grade XI IPS 1 at SMAN 1 Karanganyar school. There are three main aspects of concern, namely the application aspect, the content presentation aspect, and the material benefits aspect.

Table 17. List of Instruments for User Response Validation.

No	Aspect	Indicator	Item
1	Application Interface	The design of the ARFANA application is appealing.	1
		The text in the ARFANA application is easy to read.	2
		The text in the module is easy to read.	3
		The layout of the text in the module is well-organized.	4
		The appearance of menu buttons and navigation is clear.	5
		User instructions for using the ARFANA application are displayed clearly.	6
		The ARFANA application can be easily operated without any malfunctions.	7
		The process of scanning markers can be easily done.	8
		Rare animal 3D objects can be viewed clearly on the marker.	9
2	Presentation of Material	The learning material is aligned with the learning objectives.	10
		The practice questions displayed are relevant to the material.	11
		Clear instructions for solving the practice questions are provided.	12
		The practice questions serve as a tool for evaluating students' understanding of the material.	13
3	Application Benefits	The displayed 3D images provide new knowledge about the shape of rare animals.	14
		The ARFANA application enhances students' understanding of rare animals.	15
		The ARFANA application helps students recognize rare animals.	16
		The ARFANA application is engaging and enhances students' enthusiasm for learning about rare animals.	17

Out of the 17 indicators mentioned above, they need to be tested by content experts. Based on the number of indicators, the maximum score that can be obtained is 68, with each instrument being assessed on a 4-point scale.

Table 18. Scoring Categorization for Validation from a Scale of 4.

Scale	Interpretation
4	Very Good
3	Good
2	Fair
1	Poor

Table 19. Assessment Result Categories.

Interval Skor			Kategori
55.25	$< x \leq$	68	Very Good
42.5	$< x \leq$	55.25	Good
29.75	$< x \leq$	42.5	Fair
17	$< x \leq$	29.75	Poor

Out of a total of 32 students who participated in the user response feasibility test, the mobile application "ARFANA: Fauna Endemik Distribution in the World" obtained an average total score of 57.72. Based on this evaluation, the application is recommended as highly suitable. However, there are some weaknesses identified by the users during the validation process, specifically in the following areas:

1. The ease of operation of the ARFANA application scored 105.
2. The readability of the text in the ARFANA application scored 102.

This indicates the need for further development based on the test results obtained.

5. CONCLUSIONS

5.1. Conclusion

Based on the research results that have been conducted, the researcher draws the following conclusions:

1. A mobile-based application for the distribution of endemic animals in the world has been developed on the Android platform, using C# programming language and Augmented Reality features to display 3D objects of endemic fauna typical of countries around the world. The application aims to assist students and educators in understanding endemic fauna and provides a more efficient alternative to conventional learning, creating a self-operated learning media in the teaching and learning process.
2. The feasibility of the geography media learning application "ARFANA" was assessed through three evaluations: the expert content validation received a score of 43 with the category "very feasible." The expert media validation resulted in a score of 41 with the category "very feasible." The user response

evaluation received a score of 57.72 with the category "very feasible." Based on the results of these three evaluations, it can be concluded that the "ARFANA" application is highly suitable for use in teaching and learning activities.

5.2. Implication

The implications of the conducted research are as follows:

1. The application can be used by students to assist them in understanding the subject matter about endemic fauna specific to different countries around the world.
2. Teachers can utilize this application as a teaching resource since it aligns with the learning objectives and competencies stated in the geography textbook published by the Ministry of Education.
3. It serves as a visualization tool for presenting the 3D models of endangered endemic fauna that are difficult to encounter in real life.
4. With the development of the "ARFANA" learning media application, students no longer need to go through the hassle of borrowing limited copies of textbooks from the library published by the Ministry of Education.

5.3. Recommendations

The research results that have been conducted, the researcher draws the following:

1. Continuously improve the existing application, such as enhancing the control of 3D objects generated through Augmented Reality.
2. Add moving 3D objects to enhance user engagement and interaction.
3. Provide detailed views or sections of the displayed 3D animal models to offer a more comprehensive learning experience.
4. Further develop the application by ensuring that the text is easily readable and user-friendly, with minimal bugs or glitches during operation.

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