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AUGMENTED REALITY AS AN INNOVATIVE LEARNING MEDIA FOR VERTEBRATE ANIMALS FOR ELEMENTARY SCHOOL STUDENTS

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Abstract

The learning of vertebrate animals in elementary schools often faces challenges due to the limited availability of interactive media, resulting in reduced understanding and low student motivation. This study aims to design and implement an Augmented Reality (AR) application as an innovative learning medium capable of displaying 3D models of vertebrate animals in an interactive and realistic manner. The application was developed using Unity 3D and Vuforia SDK, with key features including AR Camera, Materials, Guide, Download Marker, and About. The learning materials cover various vertebrate categories such as fish, frogs, birds, lions, and elephants, with detailed information on their characteristics, behaviors, and classification. User testing demonstrated that the application runs smoothly on Android devices and successfully increases student engagement, motivation, and understanding of biological concepts. The integration of AR technology allows students to visualize animals directly in three-dimensional space, providing a more immersive and enjoyable learning experience compared to conventional methods. Additionally, the application overcomes the limitations of physical models or field visits, offering accessible and flexible learning within the classroom. The results indicate that AR can serve as an effective educational tool, enhancing both the quality and interactivity of biology learning. This study contributes to the development of technology-based learning methods in elementary education and demonstrates the potential of AR to improve students' cognitive and perceptual understanding of vertebrate animals.

Keywords: augmented reality; vertebrate animals; elementary school; interactive learning; unity 3D.

1. INTRODUCTION

The rapid development of information and communication technology has opened new opportunities for the development of innovative learning methods. One particularly interesting concept that can enrich the learning experience is Augmented Reality (AR). AR combines elements of the real world with virtual elements, creating an interactive experience that enhances students' understanding and engagement. Education is one of the sectors that can benefit greatly from the application of AR technology. In the context of vertebrate animal learning, AR can serve as an effective tool to provide students with an in-depth and engaging learning experience. Directly involving students with vertebrate animals through AR can enhance their understanding of the animals' body structures, behaviors, and habitats [1].

Learning about vertebrate animals is an important topic in biology education; however, it is often challenging to implement in the classroom without physical models due to high costs or the need to conduct field visits to specific locations, such as zoos. Therefore, by utilizing AR technology, it is expected that the learning experience can be brought into the classroom without geographical or logistical limitations. With the advancement of AR technology, we can design learning experiences that are engaging and interactive. Moreover, AR can be integrated with digital content that supports the curriculum, allowing students to explore vertebrate animals in various contexts. This can help increase students' interest and motivation in learning biology, as well as improve their understanding of biodiversity [2], [3].

In this context, the design of Augmented Reality for Vertebrate Animal Learning becomes highly relevant for advancing the way we teach biology in the digital era. By leveraging AR technology, we can create a more dynamic, enjoyable, and immersive learning experience, helping students develop critical thinking skills and strengthen their foundational knowledge in vertebrate biology [4]–[6].

To address these challenges, the design of Augmented Reality for Vertebrate Animal Learning is expected to provide an innovative solution to improve the quality of biology education, overcome resource limitations, and increase student engagement. AR can serve as an effective tool to deliver an immersive and engaging learning experience. Direct interaction with vertebrate animals through AR can enhance students' understanding of these animals. Previous research related to this study was conducted by [7], which aimed to develop the MathARbook, or Mathematics AR Book—a prototype of an elementary school mathematics book whose content is presented in AR.

The material content of this mathematics book includes flat shapes and solid shapes. Furthermore, the application development utilized AR technology combined with multimedia elements such as text, images, videos, animations, and audio. The development method used was prototyping, with the expectation that the application would meet users' needs [5], [8].

The purpose of this study is to design and develop an Augmented Reality (AR)-based learning application for vertebrate animals that can be used by elementary school students. This application is expected to provide a more interactive and engaging learning experience, enhancing students' understanding of the characteristics, body structures, behaviors, and habitats of vertebrate animals. Additionally, this study aims to offer an effective alternative biology learning medium, overcoming the limitations of conventional teaching tools, and increasing students' engagement and learning motivation through the use of AR technology [9]–[11].

2. RESEARCH METHODS

2.1. Vertebrate Animals

Vertebrate animals refer to a group of animals that possess a backbone, or vertebrae, which is the bony structure forming the spinal column. Vertebrates belong to the subphylum Vertebrata, which is one of the three main subphyla within the phylum Chordata. This group includes various types of animals characterized by a backbone that protects the spinal cord, also known as the medulla spinalis [12]

2.2. Augmented Reality

Augmented Reality (AR) is a technology that integrates two-dimensional and/or three-dimensional virtual objects into a real-world environment and projects them in real time. AR is a variation of Virtual Environments (VE), often referred to as Virtual Reality (VR). VE technology fully immerses users in a synthetic environment, preventing them from seeing the real world around them. In contrast, AR allows users to see the real world with virtual objects superimposed or composited onto it. Therefore, AR supplements reality rather than completely replacing it [7]. Several methods are used in Augmented Reality, including marker-based tracking and markerless tracking [13].

1. Marker-Based Tracking
   One of the AR methods is Marker-Based Tracking. Markers are usually black-and-white square illustrations with a thick black border and a white background. The computer recognizes the position and orientation of the marker and creates a 3D virtual world with a point (0,0,0) and three axes: X, Y, and Z. Marker-Based Tracking has been developed since the 1980s and has been used extensively for Augmented Reality applications.
2. Markerless Tracking
   Another AR method that is currently developing is markerless tracking, where users no longer need a marker to display virtual objects. For example, TotalImmersion, one of the world's leading AR companies, has developed various markerless tracking techniques as their core technology, including Face Tracking, 3D Object Tracking, Motion Tracking, and GPS-Based Tracking:
   a. Face Tracking – Using algorithms developed by TotalImmersion, computers can generally recognize human faces by identifying the positions of the eyes, nose, and mouth while ignoring surrounding objects such as trees, houses, and other items.
   b. 3D Object Tracking – Unlike face tracking, 3D Object Tracking can recognize all shapes of objects in the surrounding environment, such as cars, tables, televisions, and more.
   c. Motion Tracking – In this technique, computers capture movement. Motion Tracking has been extensively used in producing films that simulate movement. For example, in the movie *Avatar*, James Cameron used this technique to create real-time motion simulation in the film.
   d. GPS-Based Tracking – GPS-Based Tracking has recently become popular and is widely developed in smartphone applications (iPhone and Android). By utilizing GPS and compass features on the smartphone, the application collects data from these sensors and displays it in the desired direction in real-time, with some applications even presenting it in 3D. One of the pioneers of GPS-Based Tracking is an application called Layer.

2.3. Learning

Learning is a process that involves changes in behavior, knowledge, skills, attitudes, or understanding as a result of experiences or interactions with the environment. It is an active process in which individuals acquire new knowledge, skills, or understanding through various means, such as instruction, direct experience, or social interaction. Learning can occur in various contexts, including formal classroom settings, workplaces, homes, or through everyday experiences. The learning process involves receiving, understanding, storing, and applying new information or skills. Learning can be formal, such as in a classroom or training session, or informal, such as self-directed learning or experiential learning [14].

2.4. Unity 3D

Unity 3D is a software development engine (game engine) developed by Unity Technologies. This engine is designed to enable the creation and development of 2D and 3D games, simulations, augmented reality (AR) applications, virtual reality (VR) experiences, and other interactive applications. Unity 3D is highly popular among developers of games and interactive graphical applications [15].

3. RESULTS AND DISCUSSION

3.1. AR Implementation for Schools

The results of the design and implementation of the Augmented Reality (AR) system for vertebrate animal learning are presented through the user interface, main features, and tested performance of the application. At this stage, the developed system displays various menus, including AR Camera, Materials, Guide, Download Marker, and About, designed to support interactive learning. Each menu serves a different but complementary function, allowing students to have a more engaging, interactive, and easily understandable learning experience. These implementation results form the basis for evaluating the extent to which the application meets the study objectives, namely increasing student motivation and understanding of biology, particularly vertebrate animals.

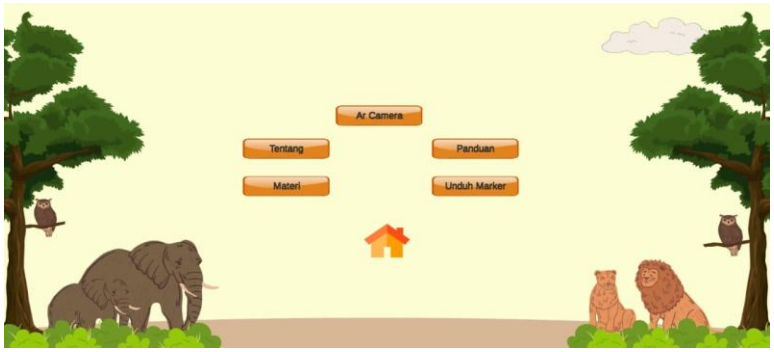
1. Home Page

   The figure below shows the initial welcome screen of the vertebrate animal learning application. The interface is designed to be simple yet visually appealing, featuring illustrations of nature such as trees, owls, elephants, and lions to provide an educational and enjoyable atmosphere. At the center, the text "Welcome To Vertebrate Animal Learning Application" serves as the main title and reinforces the identity of the application. Below it, there are two main buttons: "Start" to access learning features and content, and "Exit" to close the application.

Figure 1. Home Page

2. Main Menu Page

   The figure below illustrates the main menu page of the application. Users are presented with several main menu options according to their needs, including AR Camera, Materials, Guide, Download Marker, and About. The menu layout is simple, with orange-colored buttons for easy recognition and access. At the bottom, a home-shaped icon functions as a navigation button to return to the main page. Background illustrations of trees, elephants, lions, and owls are maintained to enhance a child-friendly and educational environment, ensuring that elementary school students feel comfortable using the application.



Gambar 2. Main Menu Page

3. AR Camera Page

   The figure below shows the AR Camera feature of the vertebrate animal learning application. On the screen, a 3D model of a lion is displayed in augmented reality on a marker labeled "LION." This feature allows users,

particularly students, to observe the animal in a more realistic three-dimensional format, providing a more interactive and enjoyable learning experience. With AR technology, students can not only read the material but also visualize the animals directly through their devices.

Figure 3. AR Camera Page

4. About Page

The About page provides an explanation regarding the background and objectives of the application. The text explains that this application was developed as part of a thesis project by students of the Informatics Engineering Program at Universitas Harapan Medan. It aims to provide easy access and comprehensive information about vertebrate animals. The page also emphasizes that the application serves not only as an interactive learning medium but also as an academic contribution supporting the development of technology-based learning methods.

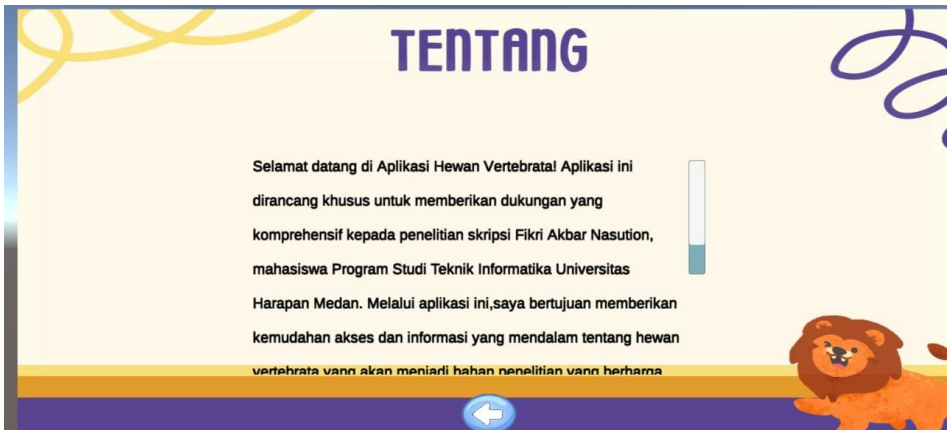


Figure 4. About Page

5. Materials Page

The Materials page presents several categories of animals, including Fish, Frogs, Birds, Lions, and Elephants. Each material button is designed simply in green for easy recognition, and when selected, displays detailed information along with a 3D object of the respective animal through AR technology. This page serves as thecore of the application, providing a primary medium for students to study the characteristics, behaviors, and classification of vertebrate animals.

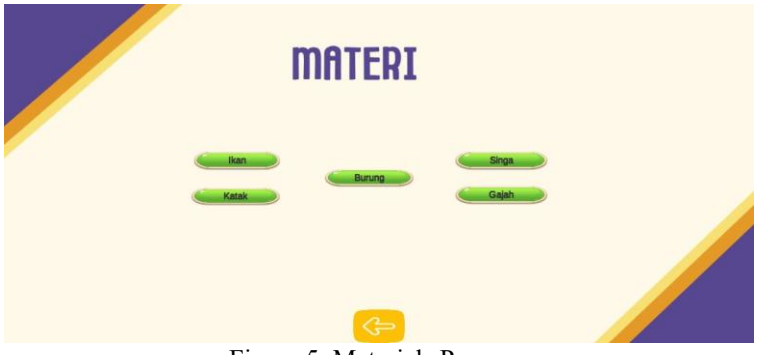


Figure 5. Materials Page

The figure below illustrates interactive learning material for the elephant. The title "Elephant" is clearly placed at the top, accompanied by a cartoon illustration to attract elementary school students. In the center, a representative gray elephant image reinforces visual identification. The description explains that the elephant belongs to the Mammalia class and is the largest land mammal in the world. Prominent physical characteristics include a large body, thick wrinkled skin, and wide ears that help regulate body temperature. Additionally, the elephant has a versatile trunk used for breathing, lifting objects, drinking, and communicating. Further information explains the tusks, modified upper incisors used for digging, peeling bark, or self-defense. By emphasizing the function of the trunk and tusks, the material provides students with an understanding of the elephant's special adaptations for survival in its environment.

Figure 6. Example "Elephant"

6. Guide Page

The Guide page serves as an instruction manual for users to operate the application correctly and easily. It explains simple steps starting from pressing the Start button, selecting the Download Marker menu, clicking the rovided link, and finally choosing one of the markers to download. This marker will then be used as a trigger for displaying the 3D animal objects via the AR Camera feature.

Figure 7. Guide Page

7. Download Marker Page

The Download Marker page facilitates users in obtaining the necessary markers to ensure the AR Camera feature works properly. Users are reminded to ensure their devices are connected to the internet before downloading. A download button is provided, which directs users to a dedicated page where the markers can be accessed and downloaded.

Figure 8. Download Marker Page

3.2. Discussion

The implementation of the Augmented Reality (AR) application for vertebrate animal learning provides significant improvements in both student engagement and understanding of biological concepts. By enabling students to interact with 3D models of animals in real-time, the application overcomes the limitations of conventional learning media, which often rely on static images or textbooks that may fail to fully convey the spatial and structural characteristics of animals. The visual and interactive nature of AR facilitates a deeper comprehension of animal morphology, behavior, and adaptations, while simultaneously increasing students' motivation to learn. Moreover, integrating multimedia elements such as text, images, and animations allows learners to explore information in multiple ways, catering to diverse learning styles and enhancing cognitive retention. From a pedagogical perspective, the application encourages experiential learning, allowing students to observe, manipulate, and investigate animal models in a controlled virtual environment, which fosters critical thinking and curiosity. However, the effectiveness of AR-based learning may be influenced by factors such as device availability, internet connectivity, and prior familiarity with technology, which should be considered when scaling the application for wider classroom use. Overall, the study indicates that AR can serve as an innovative educational tool that not only enriches the learning experience but also bridges the gap between theoretical knowledge and real-world understanding of vertebrate animals.

4. CONCLUSION

Based on the design and implementation of the Augmented Reality (AR) application for vertebrate animal learning, several key conclusions can be drawn. First, the application successfully integrates AR technology into biology learning, providing an interactive, visual, and engaging experience that enhances students' understanding of vertebrate animals. The main features, including AR Camera, Materials, Guide, About, and Download Marker, function complementarily to support the learning process and allow students to explore animal characteristics, behavior, and classification in a three-dimensional environment. Second, the application demonstrates potential as an alternative learning medium by overcoming the limitations of conventional methods, which often lack interactivity and engagement. Third, testing shows that the application performs well on Android devices and is effective in increasing student motivation and participation. Overall, this study confirms that AR can serve as an innovative educational tool that improves the quality of biology learning in elementary schools, offering a more immersive and meaningful learning experience for students.

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