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Implementation of Augmented Reality for Introducing Nutritious Food to Elementary School Children Using the Marker-Based Tracking Method

[1]Budi Arifitama, [2]Putri Nugrahayati, [3]Silvester Dian Handy Permana
[1,2,3]Program Studi Teknik Informatika, Universitas Trilogi, Indonesia
budiarif@trilogi.ac.id, putrinugrahayati@trilogi.ac.id, handy@trilogi.ac.id

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ABSTRACT

Abstract: *Pre-adolescence is a vital stage of human development, where proper nutrition significantly influences growth and long-term productivity. As children often consume snacks both at home and in school environments, ensuring they have access to safe and nutritious food is essential. This research aims to develop an educational tool to introduce healthy and balanced food choices to children using augmented reality (AR) technology. The study employs a marker-based tracking method, a widely used technique in AR development, to display interactive 3D visualizations of nutritious food items. This method was selected for its ability to provide fast and accurate marker recognition, making it highly suitable for educational use. Experimental testing demonstrated that the application effectively rendered stable and well-positioned 3D objects at a tracking distance of 10–30 cm. As a result, the AR-based learning tool successfully enhanced children's ability to recognize and understand different types of nutritious foods. The findings suggest that augmented reality, particularly through marker-based tracking, can effectively increase engagement and support nutrition education among school-aged children.*

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A. INTRODUCTION

Pre-adolescence is a stage of human development that begins after early childhood and before adolescence (Prishandani, 2022). It usually ends with the onset of puberty but can also be considered to conclude in the early teenage years. Late childhood is classified as the fourth stage, occurring between the ages of 9 and 11 (Kesavelu et al., 2021). This stage corresponds to elementary school, where children reach their highest level of objectivity. It is also known as a period of inquiry, characterized by curiosity and exploration. Following this phase, children begin to develop a sense of identity, unconsciously starting to think about themselves. Despite ongoing health campaigns, many elementary school children in Indonesia, including those at SD Negeri Pondok Bambu 13 PG, still consume unhealthy snacks purchased both inside and outside school environments (Arza et al., 2020). These food choices often lack nutritional value, undermining the efforts to meet the recommended dietary standards established through Indonesia's Balanced Nutrition Guidelines, which have been in place since 1955 (Budiyati

& Yanti, 2021). Therefore, improving nutritional awareness among school-aged children remains a pressing issue that requires innovative educational interventions. In recent years, mobile-based learning has emerged as a flexible and accessible approach to enhance educational outcomes by enabling students to learn independently through digital content (Manik et al., 2021). Moreover, integrating emerging technologies such as Augmented Reality (AR) can make learning experiences more interactive, engaging, and effective. AR combines digital information with the physical environment in real time, allowing learners to visualize 3D objects and interact with them through their devices (Cesaria et al., 2020), (Firmansyahputra & Cherid, 2020). Among AR techniques, Marker-Based Tracking stands out for its ability to render detailed 3D models using printed markers, providing a reliable and immersive educational experience(Dash et al., 2018),(Fortuna et al., 2023). The Marker-Based Tracking method is used to detect markers on illustrated cards, allowing real-time tracking and object display (Arici et al., 2019),(Arifitama et al., 2021),(Satria & Prihandoko, 2018).

Although AR has been widely used in fields such as medicine, engineering, and marketing, its application in elementary-level nutrition education remains limited. Most current digital learning materials for health education lack interactivity and visual engagement, failing to capture the attention of young learners or promote behavioral change. This gap presents an opportunity to explore how AR can be specifically tailored to educate children about healthy eating in an age-appropriate and engaging manner.

To address the issue of nutrition awareness and promote healthy eating habits, this study aims to develop and evaluate NutriPal, an AR-based educational application focused on balanced nutrition. The app aligns with the P5 curriculum under the theme Healthy Schools for Children and is designed for 4th grade elementary students. This AR application enhances interactive learning by visualizing 3D representations of healthy foods. Specifically, the research seeks to implement Marker-Based Tracking to deliver an engaging and immersive learning experience, and assess the application's effectiveness in supporting nutrition education among 4th-grade elementary school students. Through this initiative, the study contributes to the integration of innovative digital media in health education, fostering healthier habits from an early age.

B. RESEARCH METHOD

In this study, to ensure a well-structured research process that is easily understood and followed by others, clear and systematic steps are required. The method used in this research is marker-based tracking, an augmented reality technique that recognizes and identifies patterns on markers to integrate virtual objects into the real environment (Arifitama & Syahputra, 2017), (Perwitasari, 2018), (Lee et al., 2011). A marker is a black-and-white square image with thick black edges and a black pattern in the center, set against a white background. The computer detects the position and orientation of the marker to create a 3D virtual world consisting of a reference point (0,0,0) and three axes: X, Y, and Z. The research methodology stages to be conducted are illustrated in Figure 1.

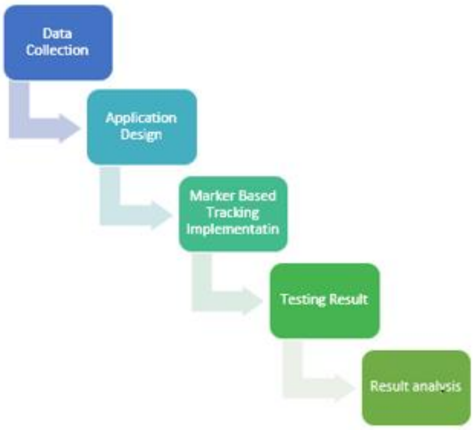


Figure 1. Research Design

In Figure 1, the Research design stages begin with a field study, which involves gathering information on issues faced by 4A grade students at SD Negeri Pondok Bambu 13 PG. This information serves as the foundation for implementing 3D objects as a learning tool for nutritious food using Augmented Reality (AR) technology (Cabero-Almenara et al., 2019),(Qorimah et al., 2022), (Desierto, 2020). Additionally, it helps determine the features to be included in the application, such as 3D representations of fruits, vegetables, staple foods, side dishes, and dairy products. Next, various objects are collected to support the study, specifically 3D objects designed as educational tools for students. The marker-based tracking method is employed to recognize markers and integrate virtual objects into the real-world environment. The application is then tested based on predefined problem constraints to ensure its effectiveness as a learning tool for 4th-grade students at SD Negeri Pondok Bambu 13 PG.

1. Data Collection

The initial stage of data collection in this study involved obtaining permission from the principal of SD Negeri Pondok Bambu 13 PG to conduct the research. Following this, an observation was carried out to identify issues related to pre-adolescents by directly interviewing the principal. The results obtained included field observations to determine the research location and identify existing problems. Additionally, data was collected on nutritious and balanced food, which would later be used as the basis for creating 3D objects to be displayed in the Augmented Reality (AR) application.

2. Application Design

In this study, a mockup design for the "NutriPal" application will be created, consisting of a Splash Screen and a Menu that includes the following options: Scan AR, Game, Tutorial, and About. Each menu option will have its own sub-menus and features.

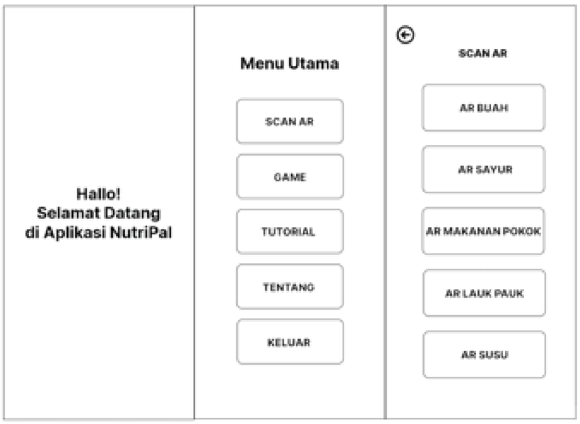


Figure 2. Splash Screen Menu

In Figure 2, the Splash Screen menu displays a title and background. Next, the Main Menu contains various options, including Scan AR, Game, Tutorial, and About. The Scan AR Menu consists of several sub-menus: AR Fruits, AR Vegetables, AR Staple Foods, AR Side Dishes, and AR Dairy.

Figure 3. Scan AR Fruit Menu

In Figure 3, the sub-menu of Scan AR is displayed when selecting "Scan AR" from the Main Menu. On the Scan AR page, users will find sub-menus for AR Fruits, AR Vegetables, AR Staple Foods, AR Side Dishes, and AR Dairy, each containing various 3D objects for scanning. On the AR Fruits page, there are sub-menus for Apple, Orange, Banana, and Papaya. Users can select one, for example, Apple, by clicking the "Apple" sub-menu, which leads to the next page. To scan, users need to point the camera at a printed marker and click the "Scan AR" button. Additionally, users can click the icon in the top-right corner to view information about the fruit's benefits or press the "Exit" button to leave the explanation.

3. Marker Based Tracking Implementation

The Marker-based tracking method is a type of augmented reality (AR) development that utilizes markers to display 3D objects. Compared to other AR development methods, this approach is relatively simple. Unity and Vuforia software are used to integrate a database of objects into the markers (Rahmat & Noviyanti, 2021), (Desierto, 2020). The combined database and marker are then built into an application. The working principle involves an AR camera scanning a printed marker, which then displays the pre-designed 3D object on the screen. Many studies have applied this method in education, conducting various trials with students to observe their reactions when AR is integrated into learning. Different educational materials have been developed, including augmented reality learning media, teaching modules, and instructional resources that leverage AR technology (Arifitama et al., 2019). In Figure 4 of this study, marker-based tracking was selected based on previous research methods.

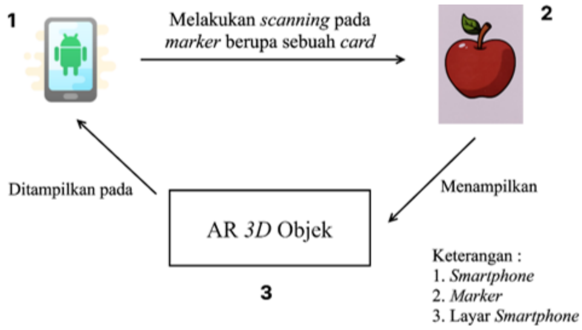


Figure 4. Marker Based Tracking Mechanism

Based on the illustration in Figure 4, the mechanism of marker-based tracking is as follows: first, a smartphone with the installed AR application is directed towards the prepared marker. If the marker is successfully detected, the augmented reality object will appear on the surface right above the marker, allowing the user to interact with it.

4. Testing Result Phase

Table 1 presents the parameter criteria used for testing and obtaining test results, with the following test result descriptions: B (Good), S (Moderate), and TB (Not Good).

Table 1. Testing Parameters

Testing		Result		
		G (Good)	**M (Moderate)**	**NG (Not Good)**
Distance	10-20 cm			
	20-30 cm			
Marker	Visible			
	Not Visible			

Based on Table 1, the first measurement testing is Distance testing that is a condition required in testing the tracking process of the marker to assess the success rate based on predetermined parameters. The distance condition set as a testing parameter is measured in centimetres (cm).

5. Analysis Result Findings

The analysis of the test results is conducted to determine the level of user satisfaction with the "NutriPal" application, which utilizes augmented reality technology with the marker-based tracking method to support more interactive and engaging learning. This testing will be carried out at SD Negeri Pondok Bambu 13 PG, focusing on the implementation of understanding healthy food and balanced nutrition in daily life, such as bringing healthy meals from home to be consumed at school. The target participants for the testing are 4A grade students..

C. RESULTS AND DISCUSSION

After conducting an analysis and understanding the research process outlined in the previous chapter, this chapter will implement these processes directly using actual data.

1. Data Collection Result

The data collection process in this study was carried out by visiting SD Negeri Pondok Bambu 13 PG, obtaining permission from the school principal, and discussing the necessary data with the 4A homeroom teacher. The data involved 24 fourth-grade students, with the assistance of the homeroom teacher. The collected data includes field observations to determine the research location in Class 4A, as well as interviews to identify issues such as students' tendency to purchase unhealthy snacks. Efforts to help students adopt healthy and balanced eating habits in their daily lives were also explored. These efforts include providing students with information on current health issues and encouraging them to bring nutritious home-packed meals to consume at school. Additionally, data was collected on healthy and balanced food options, which will be used to create 3D objects for display in the "NutriPal" application. The development of the "NutriPal" application involves the use of both hardware and software, which are essential in supporting the creation process.

2. Augmented Reality Design and Implementation

This study discusses the results of the application design plan, including a mockup for the "NutriPal" application. The application consists of a Splash Screen and a Main Menu, which includes the following options: Scan AR, Game, Tutorial, and About. Each menu contains sub-menus and various features within them.

Figure 5. Splash Screen Menu

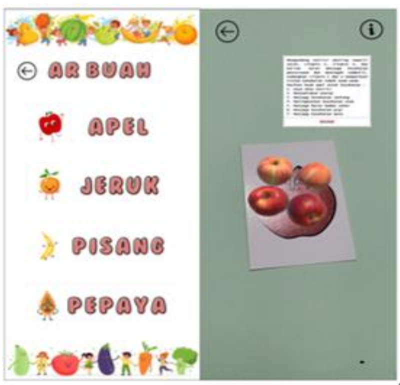
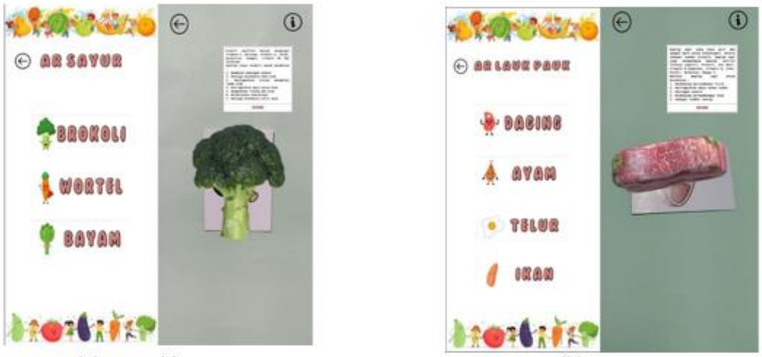


Figure 6. Splash Screen Fruit Menu

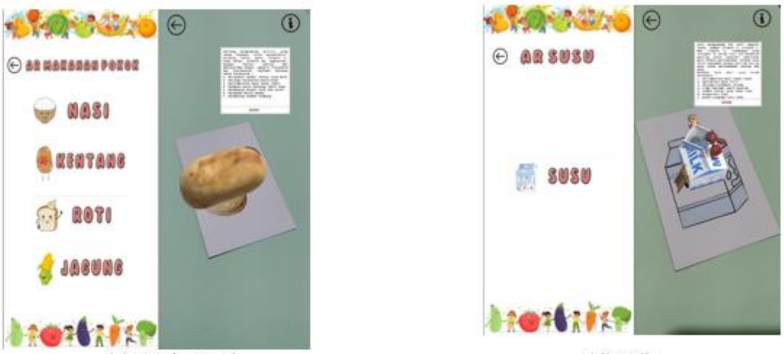
In Figure 5, the Splash Screen menu displays text and a background. Next, the Main Menu contains various options, including Scan AR, Game, Tutorial, and About. The Scan AR menu consists of sub-menus: AR Fruits, AR Vegetables, AR Staple Foods, AR Side Dishes, and AR Dairy. Each button has source code developed using Visual Studio 2022. In Figure 6. there is a sub-menu for Scan AR. When clicking "Scan AR" on the previous page, which is the "Main Menu," the "Scan AR" page will display sub-menus: AR Fruits, AR Vegetables, AR Staple Foods, AR Side Dishes, and AR Dairy. Each sub-menu contains various types of 3D objects that can be scanned. For example, as shown in Figure 4.2, the scanning process for AR Apple Fruit is demonstrated. On the "AR Fruits" page, there are sub-menus for Apple, Orange, Banana, and Papaya. Select one of these sub-menus, for instance, Apple. Click the "Apple" sub-menu, and it will navigate to the next page. To scan, show the printed marker, then click the logo in the top right corner to view information about the fruit's benefits. Click the "Exit" button to leave the explanation.



(a)Vegetables (b) Meat

Figure 7. AR scan Vegetables and Meat

Figure 7 is an augmented reality application displaying augmented reality objects in the form of vegetables and meat. Its usage is the same as previously explained, where users select the type of food they want to display, and the corresponding food object will appear on the right side of the screen.



(c) Staple Food (d) Milk

Figure 8. AR scan Vegetables and Meat

Figure 8 is an augmented reality application displaying augmented reality objects in the form of staple food and milk. Its usage is the same as previously explained, where users select the type of food they want to display, and the corresponding food object will appear on the right side of the screen.

3. Testing Results

Table 2 presents data on the distance of the 3D "Apple" object based on the test results. This table illustrates the accuracy of marker detection for the 3D object at the specified distances. The test results help evaluate the application's performance in displaying objects clearly under different conditions.

Table 2. Object Distance Testing Result

Testing Distance	Food Categories	Augmented Object	Result
Distance 10-20 cm	AR Fruit		Good
Distance 20-30 cm	AR Fruit		Good

Table 2. displays the 3D representation of an object from one of the AR Fruit menu options, specifically the "Apple". The marker detection test produced positive results. The tracking process was conducted by detecting the guiding lines on a real object that had been provided. After direct testing of the "NutriPal" application on the 3D marker object for AR Fruit - Apple, the results showed that at distances of 10-20 cm and 20-30 cm, the tracking process functioned effectively. Based on these findings, the 3D object was displayed completely, with appropriate positioning and stability, allowing students to observe and study the object with ease.

4. Analysis Discussion Findings

The analysis of student validation results was conducted to determine whether the "NutriPal" application is effective as a learning medium. The testing involved 4A grade students at SD Negeri Pondok Bambu 13 PG, under the guidance of their homeroom teacher. This augmented reality-based application utilizes the marker-based tracking method to provide an interactive learning experience about healthy and balanced nutrition through 3D object displays. Out of 28 students, only 19 brought a smartphone. Those who did not bring a smartphone shared with their classmates. Among the 19 students with smartphones, some were unable to use them due to parental restrictions, so they also had to share with their peers. In the end, only 10 students were able to try the application. Based on the class teacher's testimony, the AR application that has been developed has helped students recognize nutritious foods. It is hoped that in the future, students will be able to select food according to their needs, and they understood and applied the balanced nutrition concept in their daily lives.

D. CONCLUSIONS AND SUGGESTIONS

The development and testing of the *NutriPal* augmented reality application, utilizing the marker-based tracking method, demonstrated promising results. Technical testing showed that the application performed well in terms of marker detection accuracy and stability within an optimal camera distance range. By employing the marker-based tracking method, the application was able to accurately and efficiently render food-related 3D objects, offering an engaging learning experience tailored to pre-adolescent students. Testing results demonstrated that marker recognition was stable and effective within a 10–30 cm range, enabling consistent object display and facilitating ease of use for young learners. Furthermore, user validation confirmed that the application was well-received by both students and teachers, highlighting its effectiveness as a tool to support classroom instruction and nutritional education. In conclusion, the integration of AR technology using marker-based tracking has proven to be a valuable approach in enhancing children's engagement and understanding of healthy eating habits. NutriPal not only provides a practical solution to bridge the gap in interactive nutrition education but also shows potential for broader application within the elementary education curriculum. For future development, it is recommended to include additional features such as a download button for each marker, allowing students to access learning content beyond the classroom environment. Moreover, expanding the variety of 3D food objects to include a broader range of healthy and balanced nutrition items would improve the comprehensiveness and educational value of the application

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