Research Article

Exploring the human digestive system through ARSIPERSIA augmented reality insights

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Abstract: As times evolve, numerous advanced technologies emerge to support human activities. Augmented reality, a technology that integrates virtual objects with real-world elements in the physical environment, is particularly noteworthy. In the field of education, augmented reality is widely applied to enhance the interactivity of the teaching and learning process. This study endeavours to create an application focused on the human digestive system, with the aim of presenting digestive organs in three dimensions. Unlike traditional learning media, which typically feature two-dimensional images or videos of digestive organs, the Augmented Reality Human Digestive System (ARSIPERSIA) application addresses the challenge of visualizing authentic human digestive organs. Unity 3D and Vuforia were employed in the development of this application. The application underwent comprehensive testing through two methodologies: black box testing and usability testing. The results of the black box testing affirm the effective functionality of the application, covering tasks such as image target scanning, information display, and interactive quizzes. Usability testing findings indicate that ARSIPERSIA facilitates students in visualizing human digestive organs, provides relevant information, enhances comprehension of the digestive system, and sparks students' interest and motivation through captivating learning media.

Keywords: augmented reality; human digestive system; ARSIPERSIA; blackbox testing; usability testing

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1. Introduction

The rapid development of technology plays a crucial role in daily activities, making it an integral part of human life. Technological advancements have influenced various aspects of life, such as business, socio-culture, economy, health, and education, requiring individuals to adapt to these changes. The advantage brought by technological progress lies in the discovery of sophisticated technologies that aid in daily activities, one of which is augmented reality (AR) technology.

Augmented reality, or AR, is a technology that combines real-time virtual objects with objects in the real world (Sukhdheve, 2021). It has gained popularity among the public and has been extensively developed to assist people in their everyday tasks. In the realm of education, where this technology has been employed, it is recognized that AR presents novel prospects for customizing diverse learning devices, thereby creating a unique learning approach capable of accommodating various types of students (Suzanna & Gaol, 2021). One notable application of AR is in the field of education, particularly as a learning tool for human anatomy.

Human anatomy is a branch of biology that studies the structure of the human body. It provides detailed explanations by breaking down the human body into smaller parts to understand the function of each component (Umar & Utama, 2021). According to Srivastava (Srivastava et al., 2020), the human body's anatomy is composed of several parts, namely the skeletal system, muscular system, circulatory system, digestive system, nervous system, respiratory system, immune system, lymphatic system, excretory system, urinary system, reproductive system, and sensory system. However, for this research, the application solely focuses on the human digestive system. The digestive system is a process carried out by the digestive organ system to process food so that the nutrients can be absorbed and converted into energy for human use (Thomson & Friendship, 2019). According to Zubaidah (Zubaidah et al., 2017), the human digestive system consists of main organs in the form of the digestive tract and accessory organs. The digestive tract is the pathway through which food passes, starting from the mouth, esophagus, stomach, small intestine, large intestine, rectum, and ending at the anus (Elgazzar & Alenezi, 2022). As for the accessory organs, they include the tongue, teeth, salivary glands, liver, gallbladder, and pancreas (McQuilken, 2021).

The development of mobile-based learning methods in the field of biology is still in progress in Indonesia. Among the six types of mobile-based learning, one is Augmented Reality (AR)-based mobile, as mentioned by Adkins (Adkins, 2014). Mobile Edu-games are also on the rise, as evidenced by a previous study conducted by Weng (Weng et al., 2016). AR development in the field of Biology began as a simulation tool to deliver educational content. When learning about the human digestive system, educational media often rely on animations or 2D images to illustrate the structure of digestive organs (Arifin et al., 2022). However, this approach has limitations as students lack a tangible representation of the human body's organs. To tackle this issue, the concept of creating an application called "ARSIPERSIA" emerged. By leveraging augmented reality technology, it is anticipated that users, particularly 8th grade students, will be able to visualize the human digestive organs. Furthermore, the application will offer detailed information on each part of the digestive system and incorporate quizzes to assess users' comprehension of the subject.

The utilization of this learning media is expected to enhance students' cognitive processes, facilitating a better understanding and recognition of the human digestive system. By providing a more captivating and interactive learning experience, students can acquire a more comprehensive grasp of the intricate concepts related to the human digestive system (Sungkur et al., 2016). The aim of this educational media is to aid students in better recognizing and comprehending the human digestive system, which, in turn, leads to an improvement in their mindset when it comes to understanding the subject matter (Mat-jizat et al., 2017).

The need to investigate the human digestive system through an augmented reality application for educational purposes encompassed both theoretical and practical aspects (Albrecht et al., 2013). Theoretical urgency arose from the prospect of enhancing the learning experience and accommodating diverse learning styles, while practical urgency was rooted in applying knowledge to real-world scenarios, preparing students for future careers, and ensuring global access to educational materials. The incorporation of augmented reality in education had the potential to significantly advance teaching and learning methodologies in the examination of the human digestive system (Fuchsova & Korenova, 2019).

2. Materials and Methods

Within the framework of the human body, the digestive system, intricately intertwined with its complement of accessory organs, encompassed an extensive array of specific components (Sensoy, 2021), meticulously delineated, and visually represented in Figure 1. This sophisticated network, characterized by its complexity, assumed a vital and multifaceted role in the intricate process of food digestion and nutrient extraction, thereby playing a pivotal part in fostering the overall well-being and physiological equilibrium of the human organism.

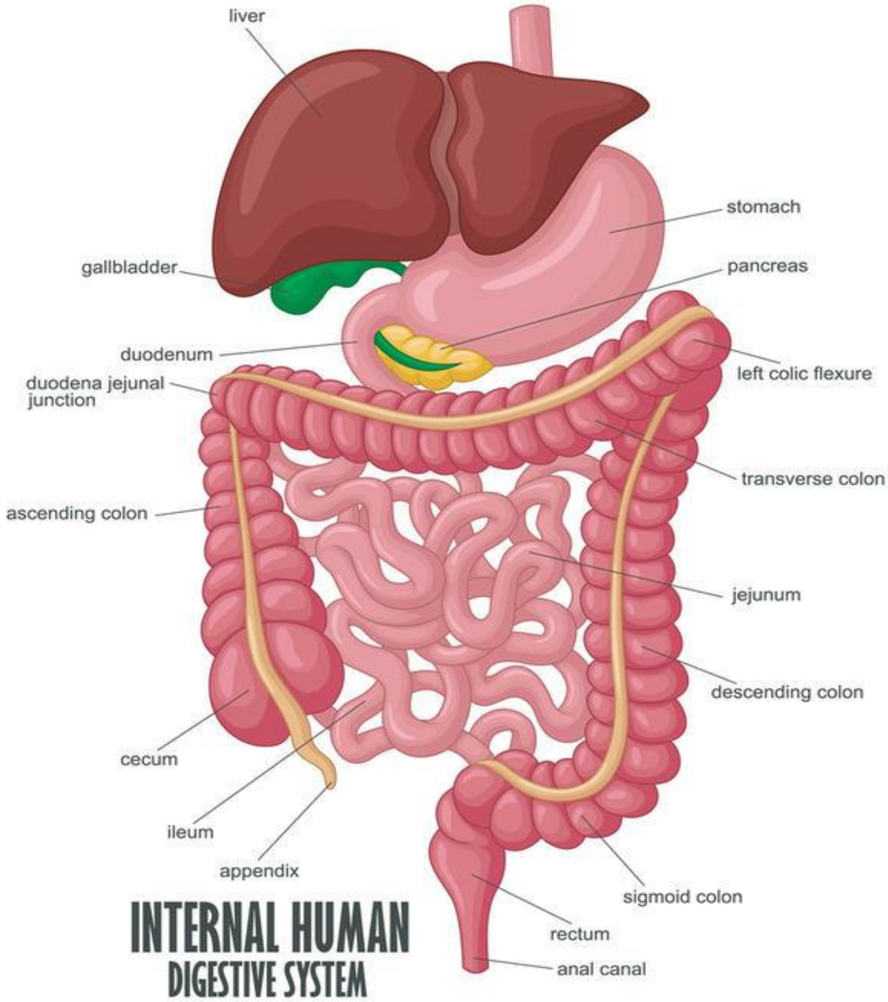

Figure 1. Human digestive system (Safitri, 2019)

The mouth, also known as the oral cavity, serves as the entry point for both food and air. Here, food undergoes initial mechanical and chemical digestion through the action of teeth (Stokes et al., 2013). The esophagus acts as a passage, carrying food from the mouth to the stomach, where no digestion occurs (Peate, 2021). The stomach, a temporary storage sac for food, is situated in the left part of the abdominal cavity beneath the chest cavity (Abed et al., 2021). Moving along the digestive tract, the small intestine, approximately 8.25 meters in length, comprises the duodenum, jejunum, and ileum (Ivanovich et al., 2017). These segments collaborate to digest food into absorbable units that enter the bloodstream (Wu et al., 2023). The large intestine, segmented into the cecum, ascending colon, transverse colon, descending colon, sigmoid colon, and rectum, primarily absorbs water and minerals, resulting in the formation of solid feces (McCoubrey et al., 2023).

The liver, positioned in the right part of the abdominal cavity beneath the diaphragm, serves as the body's largest gland. It plays a crucial role in detoxification, neutralizing harmful substances in the blood (Muriel, 2017). The gallbladder, located under the liver, stores bile produced by the liver (Qi et al., 2019). Bile aids in emulsifying fats in the small intestine, breaking them down for digestion by enzymes (Yan et al., 2023). Finally, the pancreas, situated behind the stomach, produces digestive enzymes responsible for breaking down carbohydrates, proteins, and fats (Saeinasab et al., 2023). Together, these organs ensure the effective functioning of the digestive system, allowing the body to extract essential nutrients from ingested food (Mackie et al., 2020).

The development of this educational media application is conducted using the throwaway prototyping method. In throwaway prototyping, prototypes are selected and discarded if they fail to meet the objectives or exhibit inadequate performance, rendering them unsuitable for further development (Trianto et al., 2020).

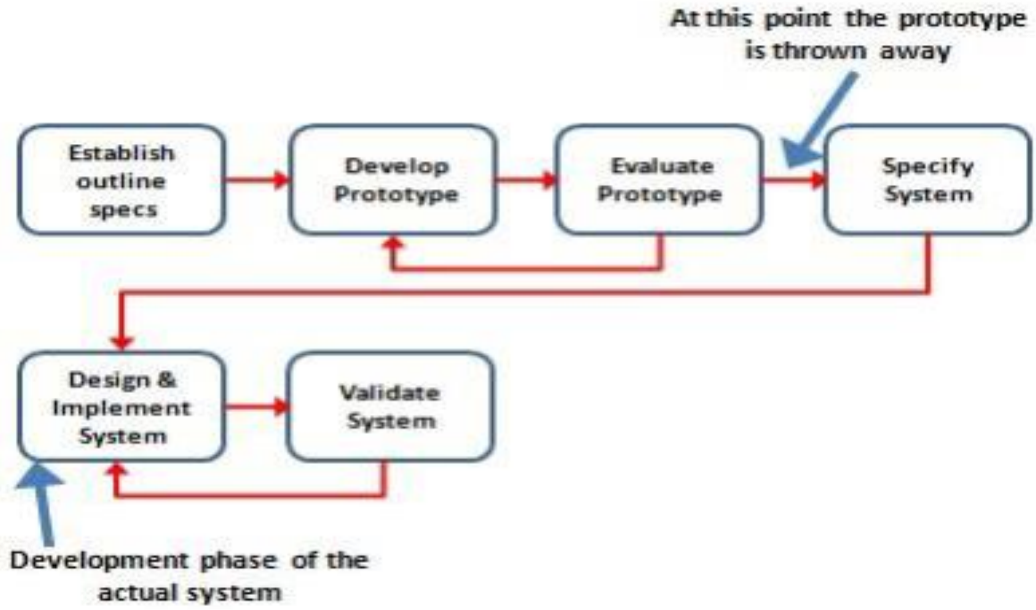

Figure 2. Throwaway prototyping (Trianto et al., 2020)

As shown in Figure 2, within this method, three main stages were utilized to obtain the design of the intended application, including system requirement gathering, prototyping design, and prototyping evaluation. The following represents the process of developing this learning application:

1. *System Requirement Gathering*

During the system requirement gathering phase, an interview process was conducted with Mrs. Rina, the teacher responsible for the natural science subject at SMP Karitas III Surabaya. This stage is essential for collecting relevant information to design and develop the application. Based on the results of the interview conducted with the informant, data revealed that 8th grade students still face difficulties in providing visual representations of the human digestive system organs located inside the body. Additionally, the appeal of learning about the human digestive system is considered insufficient due to the less engaging teaching methods. The next step in this phase is the formulation of problems and problem-solving strategies that need to be addressed through the development of the Augmented Reality (AR) application. The analysis and formulation of these problems will serve as the basis for determining the required features in the application. The design for the development of the human digestive system application will be created using Unified Modeling Language (UML), an object-oriented modeling (Alamsyah & Fauziah, 2021). The UML diagrams to be created include use case diagram, activity diagram, sequence diagram, communication diagram, class diagram, and state machine diagram. Below are several UML diagrams, as shown in Figure 3 and Figure 4.

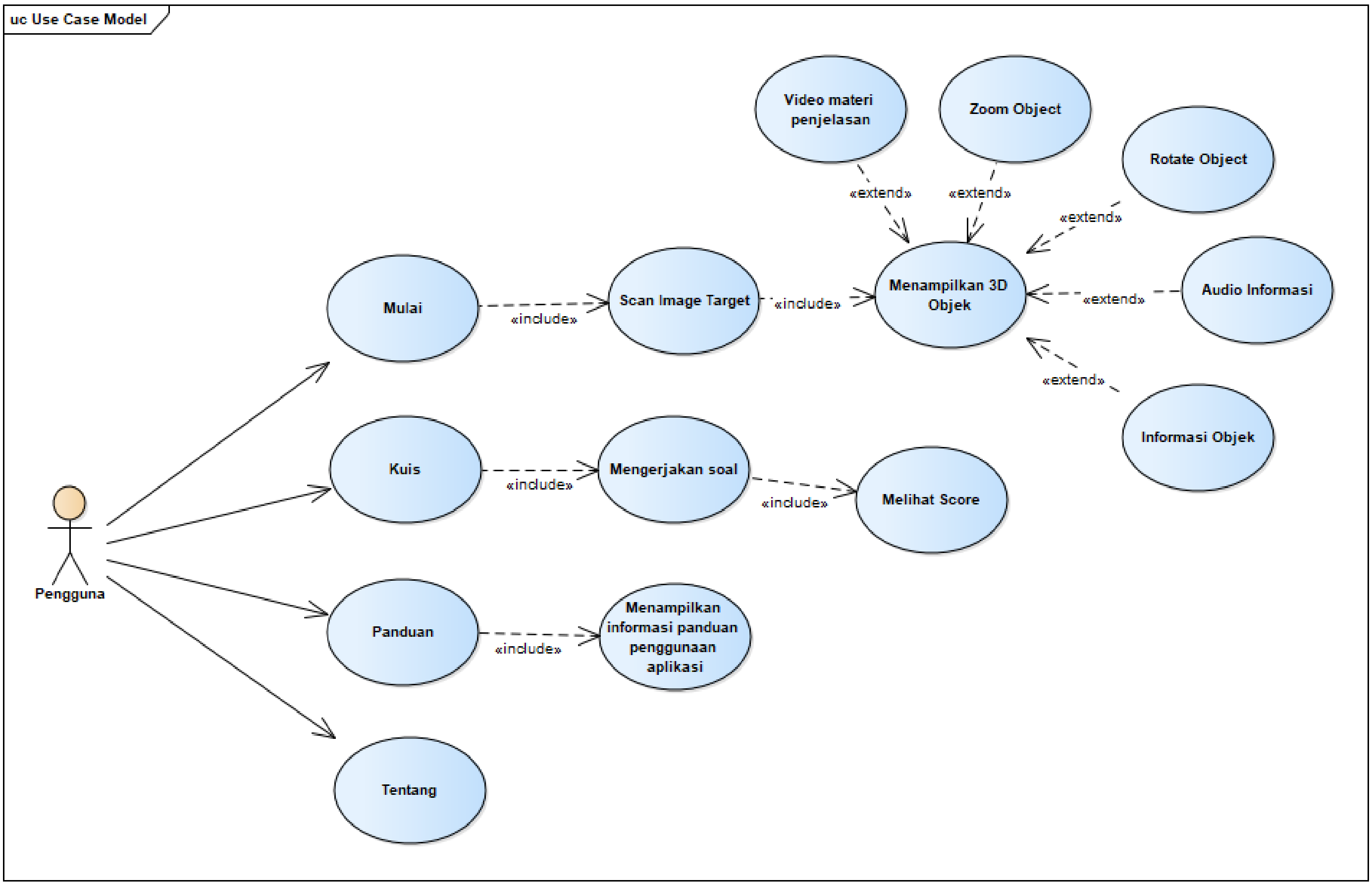

Figure 3. "ARSIPERSIA" use case diagram

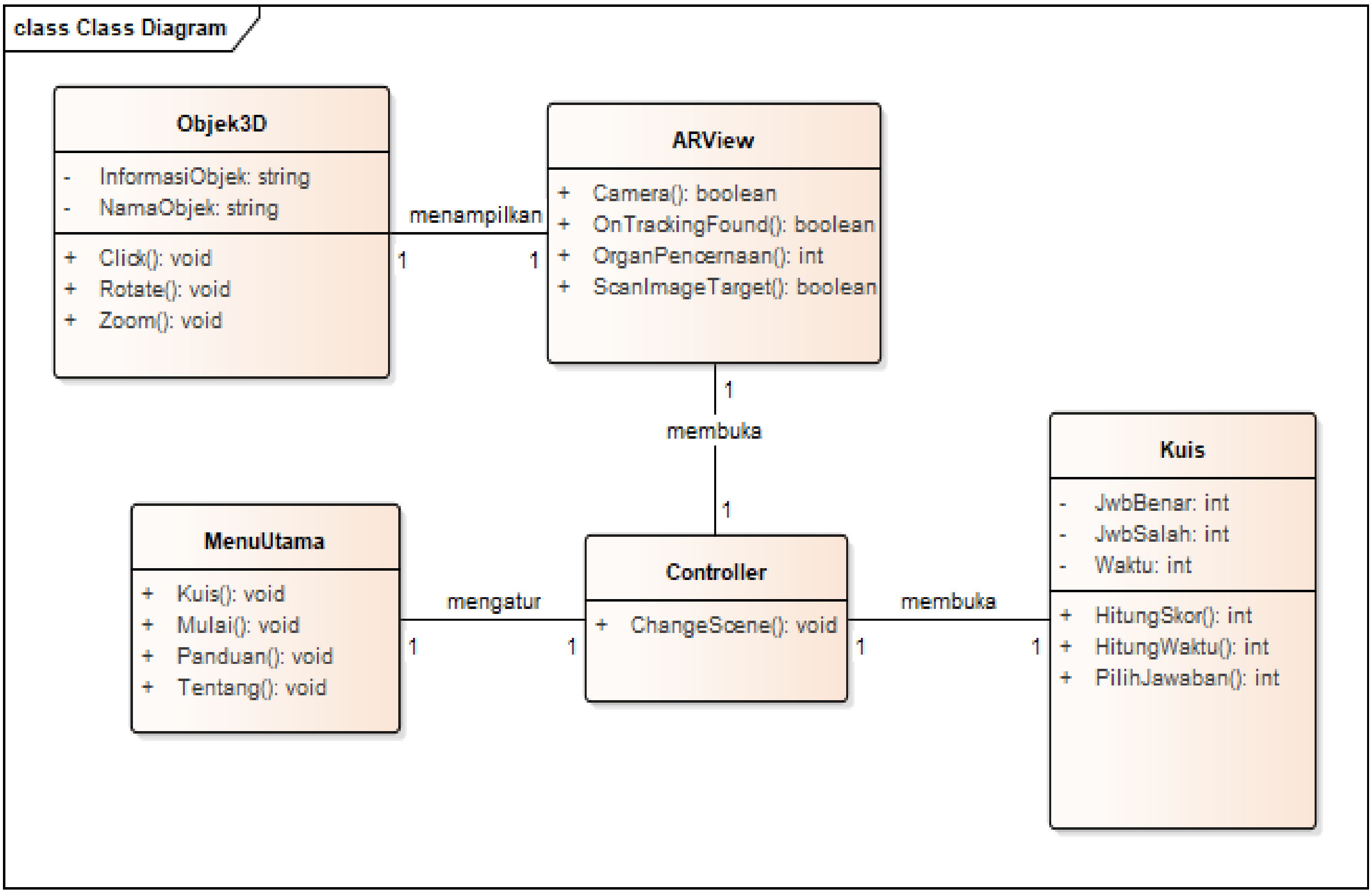

Figure 4. "ARSIPERSIA" class diagram

2. *Prototyping Design*

During the prototyping design phase, several prototypes were created for the four menu options: Main Menu Prototype Design, AR View Menu, Guide Menu, and About Menu. Multiple prototype options were developed for each menu and then presented to the application users, which include the teachers and students of SMP Karitas III. This design process was carried out to obtain a final design that suits the users' needs and can be implemented in the application. For data collection, a closed-ended questionnaire format was utilized, allowing respondents to choose a design from various provided options. This approach was employed to facilitate the respondents in selecting a design that best represents their preferences, and it also enables a swift analysis of the answers since the data obtained aligns with the provided options. In Figure 5 and Figure 6, an overview of the design options for each menu in the application is provided:

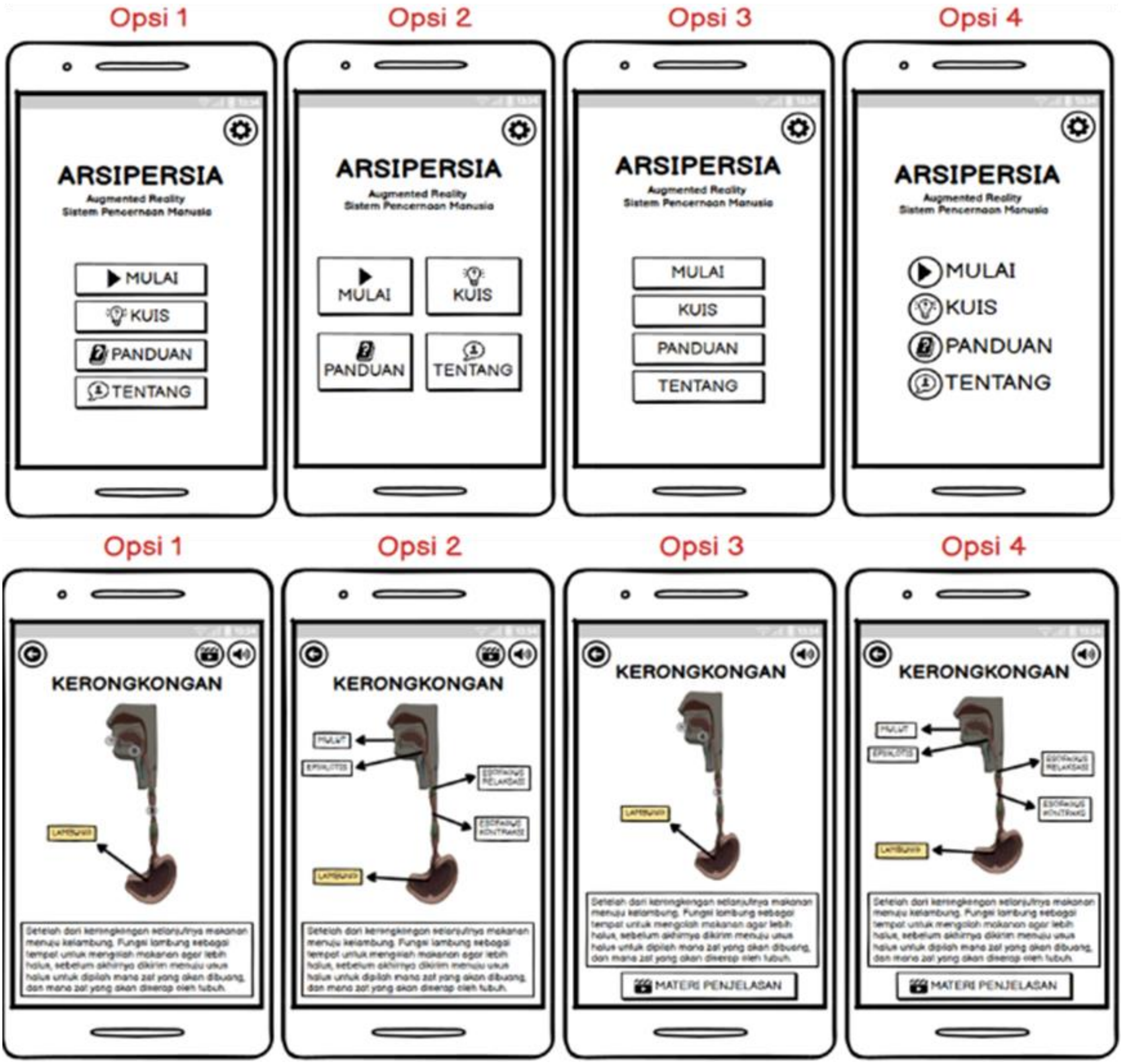

Figure 5. Design options for the main menu and AR view scene

Figure 6. Design options for the guide and about scene

3. *Prototype Evaluation*

In the prototype evaluation phase, the results of the evaluation by the respondents, including teachers and students of SMP Karitas III Surabaya, will be presented. These evaluation outcomes will serve as a reference for the development of the ARSIPERSIA learning application. The prototype design evaluation has been conducted with a total of 36 respondents, including 35 eighth-grade students and 1 science teacher.

Table 1. Evaluation results of prototype design questionnaire

Prototype Design	Option 1	Option 2	Option 3	Option 4
Main Menu	25%	47.2%	8.3%	19.4%
AR View	2.8%	27.8%	5.6%	63.9%
Guide Scene	55.6%	44.4%	-	-
About	52.8%	47.2%	-	-

Based on the results shown in Table 1, the design with the highest percentage of respondents who completed the prototyping design questionnaire for the ARSIPERSIA application pages was selected as the interface display implemented in the application.

In addition to the primary responsibility of developing the application prototype, a critical component of the project involves the meticulous determination of the design attributes for the human digestive system objects, serving as image targets commonly referred to as Augmented Reality (AR) markers, as delineated by Jangale and Awale (Jangale & Awale, 2022). Within the ARSIPERSIA application framework, these image targets, instrumental in rendering three-dimensional objects, have been sourced from the Natural Science textbooks officially published by the Ministry of Education and Culture of the Republic of Indonesia (Zubaidah et al., 2017).

In total, six distinct image targets have been strategically chosen to enhance the interactive educational experience, encompassing the depiction of anatomical structures such as the mouth, esophagus, stomach, large intestine, small intestine, and various accessory organs. The intricacies of these image targets, as elucidated in Figure 7, serve to illustrate the visual representation of markers integrated into the ARSIPERSIA application for an enhanced and comprehensive understanding of the human digestive system.

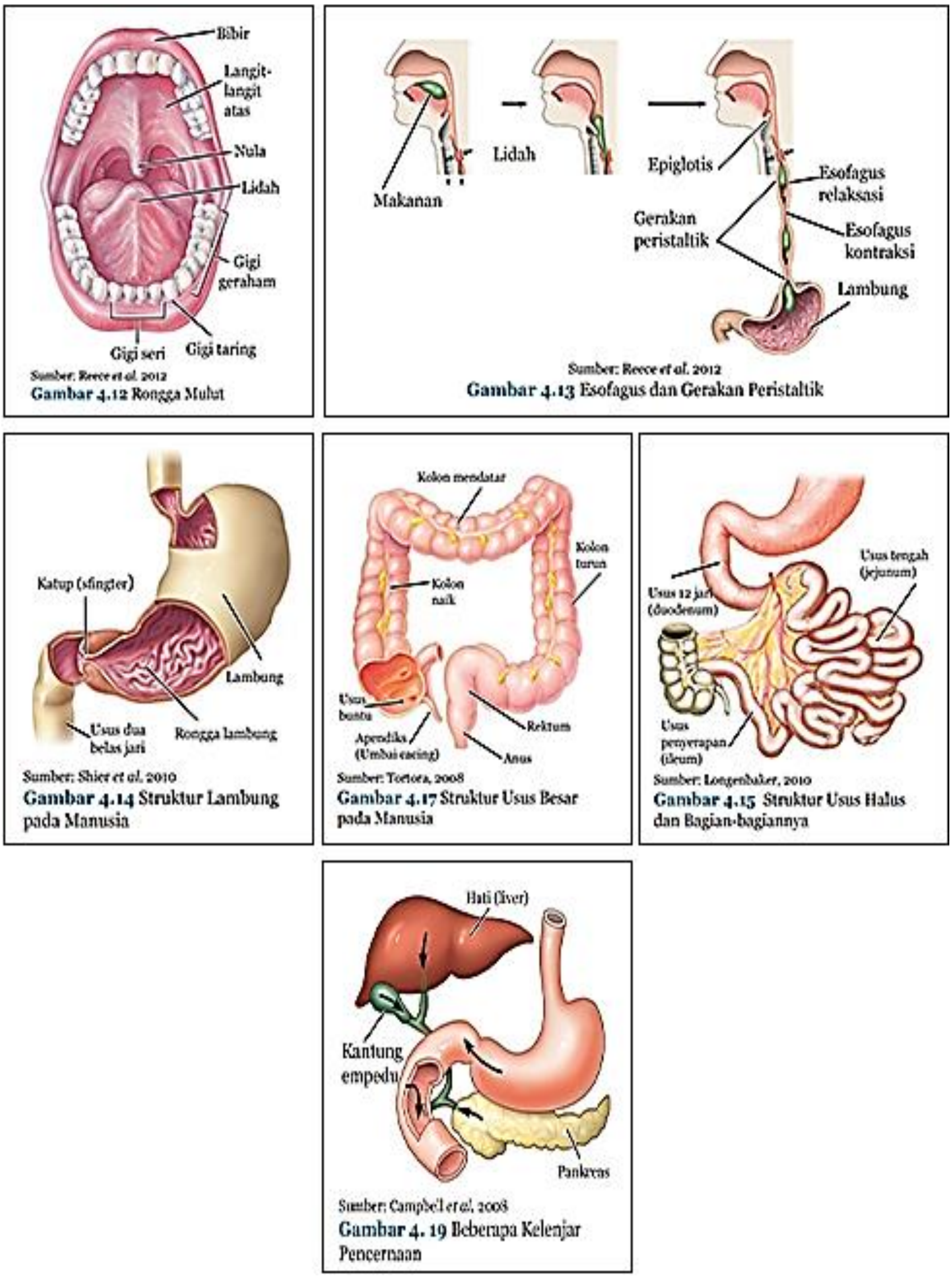

Figure 8. "ARSIPERSIA" image target/marker (Zubaidah et al, (2017)

Following the establishment of the image targets, the subsequent phase entailed the generation of three-dimensional (3D) objects, meticulously detailed as visual representations, as described by Ghotgalkar and Kubde (Ghotgalkar & Kubde, 2019). This process unfolded seamlessly once the user successfully scanned the predefined image targets, activating the immersive visualization of anatomical structures within the augmented reality environment. Here in Figure 8, the six 3D objects representing the human digestive system that were produced are displayed:

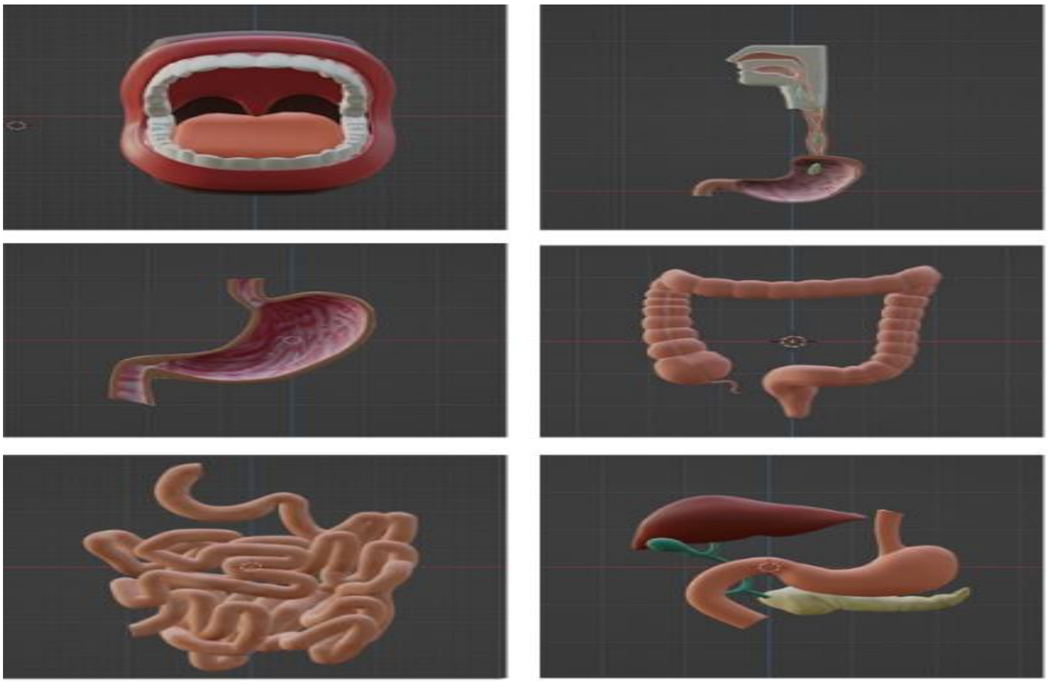

Figure 7. 3D Objects of the human digestive system

3. Results

As a result, this research successfully implemented a learning application for the human digestive system using augmented reality technology. During the creation of the ARSIPERSIA application, multiple software tools were employed, such as Unity 3D for application development, Blender for designing 3D objects, and Vuforia SDK as the marker database (Hidayat et al., 2021). Figure 9 shows the final outcome of the implementation of ARSIPERSIA as an augmented reality-based learning application for the human digestive system:

Figure 9. "ARSIPERSIA" application interfaces

The research results led to conducting testing using the black box testing method. Black box testing is an approach where end-users evaluate the functional aspects of the system. This encompassed a thorough examination of all functions without delving into the intricacies of the internal code structure (Sugarindra & Qurtubi, 2022). The utilization of black box testing allowed for a holistic assessment of the system's functionalities from a user perspective (Hadi et al., 2022). This testing aims to determine if the application's capabilities align with the expected outcomes (Xu et al., 2016). The following table (Table 2 & Table 3) are the outcomes of the black box testing performed for the Main Menu and AR View Scene in the application:

Table 2. Testing results for the main menu scene

Testing Scenario	Expected Outcome	Results
Pressing the start button	Display the loading screen scene to transition to the AR view scene	Succeed
Pressing the guide button	Displaying the guide scene.	Succeed
Pressing the about button	Displaying the about scene.	Succeed
Pressing the settings button	Displaying the sound settings pop-up.	Succeed
Pressing the exit button	Displaying the confirmation pop-up for navigation exit.	Succeed

Table 3. Testing results for the AR menu scene

Testing Scenario	Expected Outcome	Results
Directing the camera to the image target	Displaying 3D objects along with the names of organs, explanations about the organs, and reset transform button	Succeed
Pressing the name of the digestive organ part	Changing the color and displaying information about the pressed organ part	Succeed
Pressing the audio on/off button	Activating/deactivating audio, changing the button to an audio on/off button.	Succeed
Performing zoom on the object	Zooming in/zooming out the object	Succeed
Performing rotation on the object	Rotating the object	Succeed
Pressing the restart transform button	Resetting the object's transform to its default state	Succeed

Alongside black box testing, this research also employs usability testing. Usability testing is employed to evaluate the user-friendliness of the application (An et al, 2019). Test data will be gathered via questionnaires, where individuals who have used the application will answer various questions evaluating its usability (Ahmad & Hussaini, 2021). Data for the questionnaire was gathered from a total of 17 participants, consisting of 16 eighth-grade students and 1 science teacher. Using the collected questionnaire data, calculations were conducted to determine the successful implementation of the aspects used in usability testing. The usability testing for the ARSIPERSIA application focused on two aspects: learnability and satisfaction. Learnability is an aspect that defines the extent to which users can easily learn and understand the application (Weichbroth, 2020), while satisfaction is an aspect that defines the level of user satisfaction with the application. Table 4 presents the results obtained from this testing:

Table 4. Usability testing result*

Statement	Aspect	Percentage	
		Agree	Strongly Agree
The appearance is quite attractive	Satisfaction	17.6%	82.4%
The guide in the application is clear and helpful.	Learnability	23.5%	76.5%
This application is easy to use.	Learnability	29.4%	64.7%
The quality of the 3D images of the digestive organs generated by the application is good.	Satisfaction	29.4%	64.7%
The explanations provided by the application for each digestive organ easy to understand.	Learnability	17.6%	82.4%
This application motivates further explore the material about the human digestive system.	Satisfaction	29.4%	64.7%
This application can be a supportive tool about the human digestive system.	Satisfaction	41.2%	47.1%

Based on 5 Point Likert Scale Analysis: strongly disagree (1) – strongly agree (5)

4. Discussion

The usability testing conducted on the ARSIPERSIA application has provided valuable insights into its various facets, shedding light on aspects related to user satisfaction and the application's efficacy in facilitating interactive learning about the human digestive system. To commence, a significant 82.4% of respondents expressed satisfaction with the visual aesthetics of the ARSIPERSIA application design. This positive reception suggests that the application's visual appeal resonated well with users, potentially contributing substantially to heightened user engagement and overall satisfaction (Bhandari et al., 2019). The quality of the 3D images depicting digestive organs emerged as another pivotal aspect, with 64.7% of respondents expressing satisfaction. It can be inferred that the visual representation of anatomical structures achieved a commendable level of quality, a crucial factor for an effective educational tool (Mendez-Lopez et al., 2022).

Significantly, the application demonstrated motivational qualities, with 64.7% of respondents expressing that it inspired them to explore further material about the human digestive system. This suggests that the ARSIPERSIA application possesses the potential not only to disseminate information but also to kindle curiosity and enthusiasm for additional learning (Gupta & Jain, 2017). Finally, 47.1% of respondents viewed the application as a supportive tool for interactive learning about the human digestive system. While indicating a positive perception, recognizing specific aspects that users find supportive could further enhance the application's educational impact (Vlachopoulos & Makri, 2017).

Regarding learnability, respondents found the guide within the application to be clear and helpful, with 76.5% agreeing. Furthermore, 64.7% of users believed that the application was easy to use. These findings underscore the deliberate design focus on user-friendliness within the ARSIPERSIA application, enhancing its accessibility and promoting an efficient learning experience (Tsipi et al., 2023).

Moreover, in terms of learnability, a noteworthy 82.4% of respondents found the explanations provided by the application for each digestive organ to be clear and easy to understand. This positive feedback underscores the success of the ARSIPERSIA application in delivering comprehensible information, thereby enhancing the overall learning experience (Alsanousi et al., 2023).

The results obtained from usability testing and user feedback collectively underscore the positive aspects of the ARSIPERSIA application, emphasizing its appeal, user-friendliness, educational efficacy, and motivational features. These favorable results provide a solid groundwork for enhancing the application to meet the varied requirements of users engaging in interactive learning about the human digestive system.

5. Conclusions

The ARSIPERSIA as a learning application on the human digestive system for Android is developed using Unity 3D and utilizes Augmented Reality technology to display human digestive organs. The system presents 3D representations of the digestive organs along with their names and explanations in the form of text and audio when the image target is detected. Moreover, users can interact with the digestive organs by zooming in or rotating them.

In the usability testing phase, the 3D digestive organs presented in the app effectively represent the human digestive system and has the potential to enhance students' interest in learning, particularly when it comes to the human digestive system. This is supported by 29.4% of respondents who agreed and 64.7% of respondents who strongly agreed with the statement regarding the quality of the displayed 3D digestive organ images. The results of the usability testing indicate that the explanations provided for each digestive organ are clear and easily understandable.

In future research, the application will be developed with the addition of a quiz menu feature that contains questions and answers for students to work on related to learning material about the human digestive system. The quiz menu will also include instructional videos for each digestive organ, along with text included in the videos. This study will be further developed during the second phase of the National Competitive Research Scheme (Fundamental Research-Regular) grants that have been awarded.

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Conflicts of Interest: Authors declare there are no conflicts of interest.

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