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Development of ARenal Android Application: A Supplementary Tool in Learning the Human Urinary System

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ABSTRACT

Augmented reality (AR) is an interactive three-dimensional (3D) experience that uses computers to overlay virtual information in the real world. We aimed to develop an online 3D AR of human urinary system (HUS) as a supplementary tool to aid in the teaching and learning process whether via online or traditional teaching methods, particularly for undergraduate medical students. Augmented reality human urinary system (ARenal) is an Android application that implements AR for better comprehension of the HUS. It is an original work of 3D models, diagrams, pictures, notes, self-recording videos, quizzes and a manual. The AR elements will improve learning effectiveness and attention span, enabling students to comprehend anatomical principles, basic physiology, and common disorders of HUS. Instead of 3D on paper, students can access educational resources and AR tools via a detailed 3D kidney model on Android devices. The user acceptability testing (UAT) (n = 10) revealed that 60% of participants indicated it was their first experience with AR, and 60% strongly agreed that ARenal was operating well. They also strongly agreed that it is user-friendly (50%). Most participants expressed a higher level of acceptability for ARenal and recommended adding more activities, games, quizzes, and other features to the 3D model for better interaction. In conclusion, ARenal has the potential to be employed as an additional aid for learning the HUS.

Keywords: *ARenal, Android application, Human urinary system, Augmented reality, Supplemental tool*

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INTRODUCTION

Visual representations of intricate structures and systems can be used in traditional or online teaching techniques to enhance learning environments through hands-on experience (1). The usage of visual models in undergraduate lectures is not fully explored and is still quite

limited to mostly two-dimensional (2D) experiences, despite their numerous benefits. The visual representations of 3D augmented reality (AR) have great potential for a variety of uses, particularly in the teaching and learning process. Students in the medical and health sciences can especially benefit from the 3D AR photography approach, which overlays a computer-generated image over the user's perspective of the real world (2). A lot of interactive teaching materials have been developed for preschool, primary, secondary, and tertiary education. However, those teaching materials are designed for the wide-ranging population, thus the materials are too general for the medical and health sciences students. For the medical and health sciences students, the anatomical structure of the organs and systems should be more detailed, accurate, lively, and interactive to resemble a real human being.

The use of computers to overlay virtual information on the real world is known as AR and it is an interactive 3D experience (2). To expand or enhance reality, AR displays a virtual object and a semi-true image using a mobile device, tablet, or AR glasses. Through the use of tracking and virtual images superimposed on the target object, AR technology allows for the presentation of the target object's contents on a display device (3). Currently, AR is categorised into three groups: (a) marker-based AR which uses the black box as a marker for easier tracking and identification; (b) markerless AR to recognise and trace the natural pattern which can be images; and (c) location-based services AR with global positioning system (GPS) capability of a mobile device to provide users' current location information (4).

A survey of dental and medical students found that students preferred virtual learning to traditional techniques, as virtual learning is more interesting and interactive (5). Many organisations all over the world, including in Malaysia, use AR in their educational system which includes medical, dental, and health education despite the relatively expensive technology and other challenges (6). Both preclinical and clinical teaching have adopted these cutting-edge tools to enhance student's understanding and learning (7–11). The purpose of AR is to close the gaps in the current educational delivery system by allowing students to visualise abstract concepts utilising 3D graphics rather than text-based information (12). Students find it more convenient to use their smartphone devices or head-mounted display devices that offer immersive visualisation; these devices are constantly improved for better visualisation and application (13).

The traditional methods of learning anatomy such as cadaveric dissection and plastination have been replaced by more advanced methods that allow remote learning using cutting-edge technologies which include AR (14). The AR technologies provide alternatives where students can individually learn the body structure with no risk of chemical exposure and no or minimal supervisory requirement. In this regard, the use of AR is gaining much interest among students due to its convenience and exciting way of learning, accessibility, and cost-effectivity (15–17). Different AR modules such as the immersive head-mounted display AR with interactive virtual skull application for learning skull anatomy are preferred by students due to their more exciting active way and great visuality during learning (18).

Medical and health science students' preclinical years are cramped with courses covering fundamental science concepts to prepare them for the later clinical years (19). They learn about the human system body comprises several systems including the human urinary system (HUS). The HUS has many complex structures and functions that demand detailed explanations and accurate visualisation to deliver the precise information to medical students. The basic mechanism of renal function must be understood and mastered first before studying the pathological changes that occur in diseases of the urinary system. In HUS anatomy, students have to rotate and manipulate structures from various angle of views to identify anatomical structures.

The ability to mentally manipulate objects in 3D is defined as visual-spatial ability (20). Visual-spatial ability and relating the 3D structures is a critical skill for medical students in learning the human anatomy structures that are presented in various planes and positions. Although there is no previous study that mentions traditional learning for HUS is insufficient, HUS is one of the complex human systems and involves several mechanisms that can be better visualised and assimilated with an interesting and interactive supplementary tool. Therefore, 3D AR may serve as a supplementary online tool teaching method to comprehend the anatomical and physiological changes in the HUS in a normal or pathological state (21). When compared to a standard face-to-face (FTF) learning method that typically uses cadavers, this 3D AR technique will enable medical students to learn the HUS not just equivalently but more effectively (22).

This project aims to develop an online 3D AR of the HUS as a supplementary tool to aid in the teaching and learning of the HUS whether via online or traditional teaching methods, particularly for undergraduate medical students. The AR features will improve learning effectiveness and attention span, enabling students to comprehend fundamental concepts in anatomy, physiology, and common diseases in the HUS. This 3D AR application is an essential supplementary in the online learning process for medical and health sciences because the learning process could be very challenging even with FTF practical sessions. The advantage of this application is that, in contrast to standard FTF lectures or practical sessions that are entirely supervised by the lecturer, users can observe the kidney and its position through a 3D AR model rather than 3D on paper. This application will engage the students' learning, contributes to more attention span, and is easily accessible as they can utilise this application whenever or wherever they are, as this application is conveniently just at their fingertips.

METHODS

There were two stages of the development of the augmented reality human urinary system (ARenal) Android application which were application development and user acceptance testing (UAT). ARenal is a collaboration project between medical educators as the content provider from the Faculty of Medicine and Health Sciences (FMHS) and application developers from the Faculty of Computer Science and Information Technology (FCSIT), Universiti Putra Malaysia (UPM).

Development of ARenal

ARenal Android application is an original piece of work composed of 3D models, diagrams, images, text notes with voice-over, and self-recorded explanatory videos. To ensure its originality, several measures had been performed. These include acquirement of consent, alterations in model colour and labelling (3D model), adaptations and modification (diagram, pictures, and notes) from anatomy and physiology lecture notes and reference books, and authentic self-recording (video). There are four main components in ARenal: anatomy and physiology of HUS, diseases, quizzes, and manual. There will be a 3D AR feature in the segment of gross anatomy and histology, which is a subcomponent of the anatomy and physiology of HUS. Figure 1 shows the user interface flowchart for the ARenal Android application, and Figure 2 shows the storyboard.

There was several software utilised to develop ARenal which include Vuforia, Procreate, Canva, Vecteezy, Royalty Free, Sketchfab, and Unity. Vuforia is used for image target, Procreate to trace and draw the icon, Canva for marker design, Vecteezy for human kidney model image, Royalty Free for kidney 3D model, Sketchfab for nephron 3D model development, and Unity for whole project creation. Vuforia, Unity, Canva, Vecteezy, and Sketchfab have free media license agreements and Creative Commons attribution. However, Royalty-Free and Procreate need to be purchased. Furthermore, the copyright of ARenal was registered in August 2022 (CRLY2022W03516) under Section 2B, Copyright Act 1987.

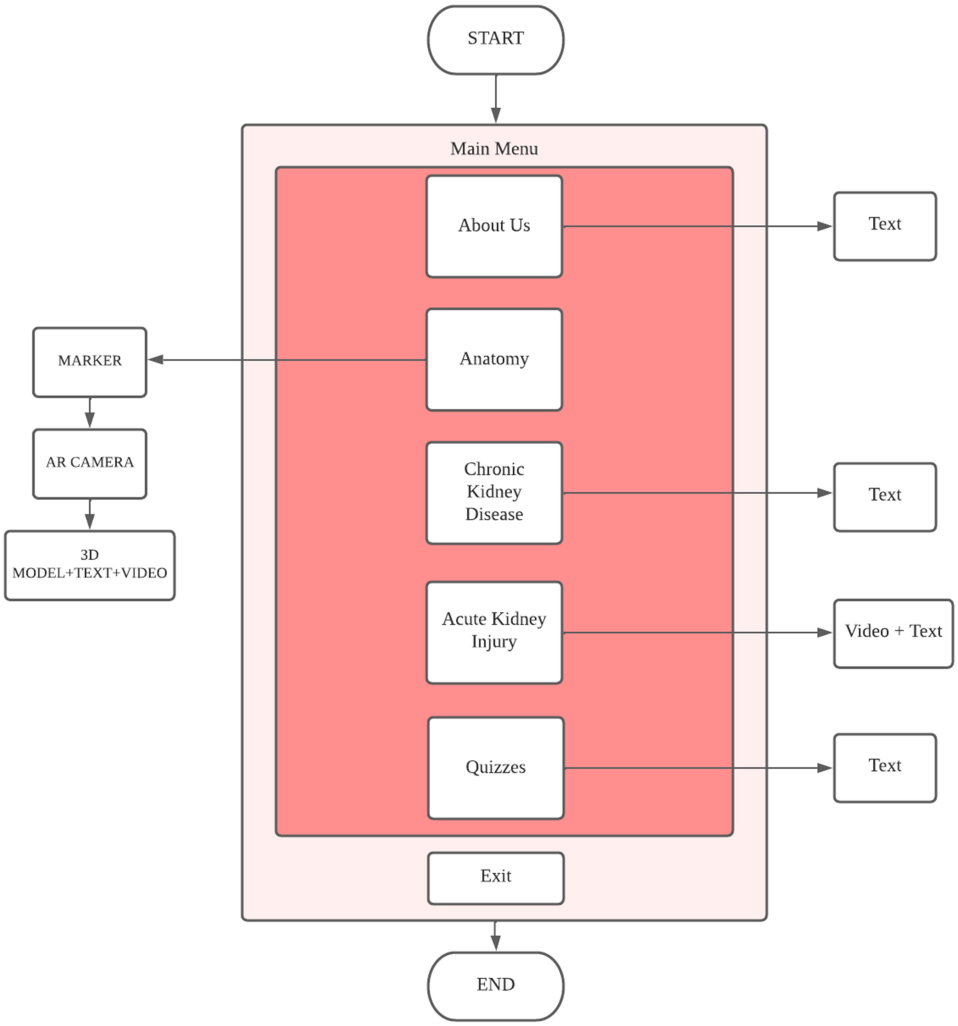

Figure 1: User interface flowchart for ARenal Android application.

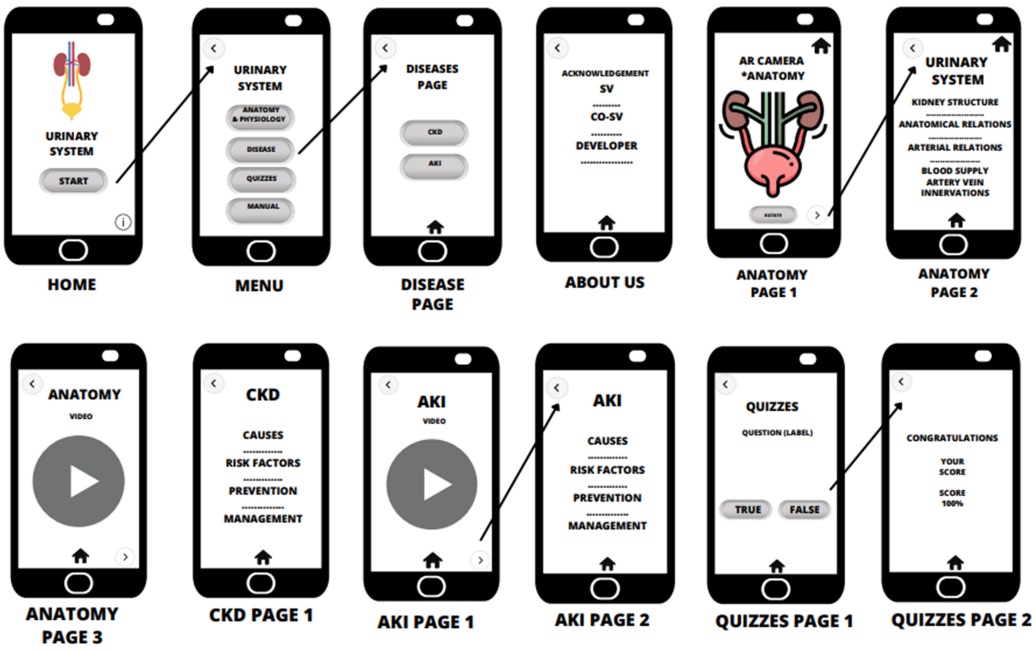

Figure 2: Storyboard of ARenal Android application.

User Acceptance Testing

The UAT, which is performed on most User Integration Test (UIT) projects, sometimes called beta testing or end-user testing, is a phase of software development in which the software is tested in the "real world" by the intended audience or business representative. This type of testing is not intended to be menu-driven, but rather to be performed by business users to verify that the application will meet the needs of the end-user, with scenarios and data representative of actual usage in the field.

The statistically acceptable UAT sample size varies. For a usability test, five is an acceptable starting point when determining a likely minimum sample size (23). The possibility that an issue will be discovered by at least one participant during a usability test is known as problem discoverability. According to Nielsen and Landauer (24), the average problem discoverability value for a basic set of projects is $p = 0.31$. It is predicted that five users will encounter 85% of the discoverable usability issues if there are any. However, according to Virzi (25), the number is between 0.32 and 0.42. It is suggested that with the assistance of four to five participants, 80% of the problems can be identified. Therefore, a minimum usability testing sample size of five is required to obtain the best feedback possible regarding the user experience. In this study, 10 participants were acquired.

This survey was performed to obtain feedback from the ARenal intended users which were the preclinical year 1 and year 2 medical students of UPM. There was no specific limited time duration to use this application and the students could use this application as many times as they prefer to. The UAT questions were prepared and validated prior to the test. The information on the UAT was shared via Google document by the class representatives to the students. The feedback and information gathered were analysed and used to modify and further improve the application. The list of the UAT questions is detailed in Figure 3.

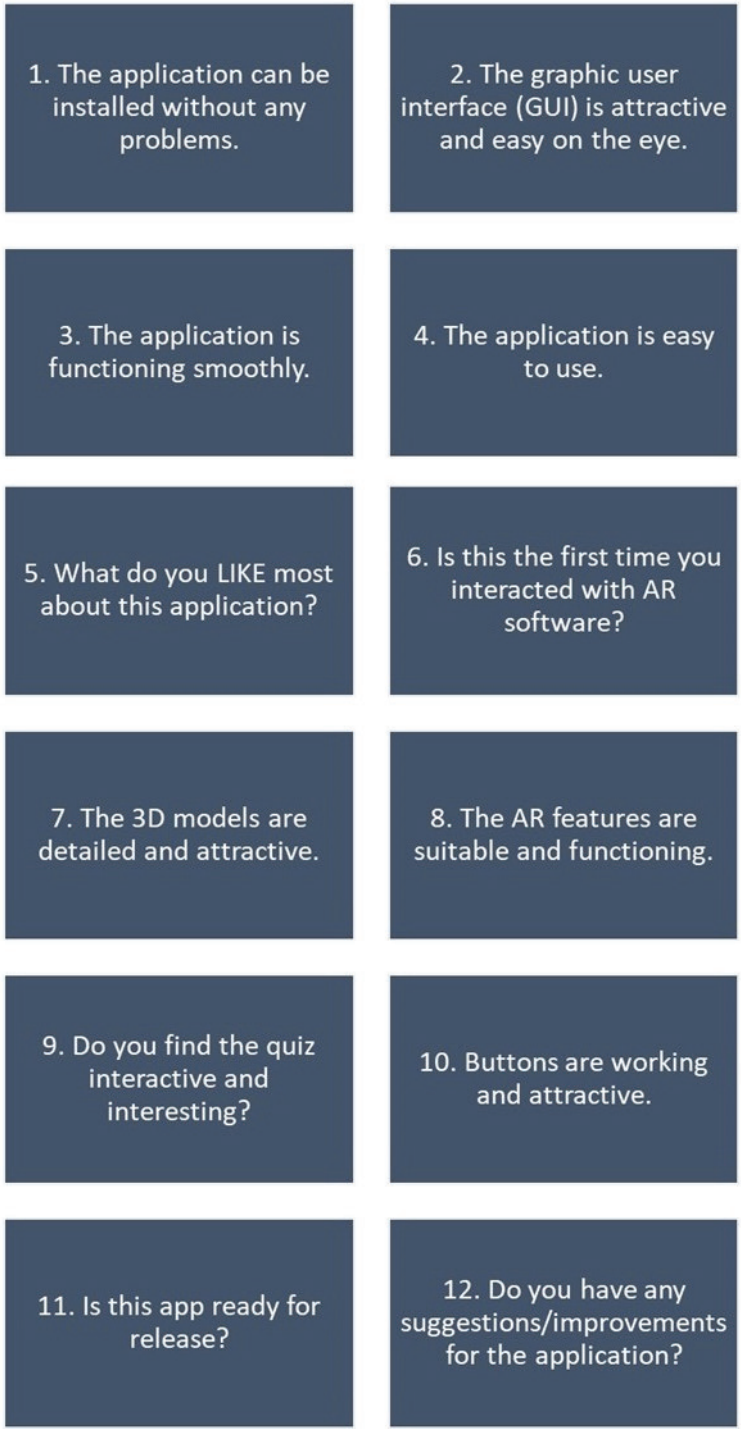

Figure 3: List of UAT questions.

Data Analysis

The collected data were analysed using SPSS version 25. A descriptive analysis of frequency and percentage was performed.

RESULTS

ARenal Android application was successfully developed within three months (18 October 2021 to 21 January 2022). Its interface is shown in Figure 4. Figure 5 displays the QR code for the ARenal video demonstration. According to the UAT (n = 10), 60% of participants indicated that this was their first experience with AR, and 60% strongly agreed that ARenal is operating without any issues. They also strongly agreed that it is easy to use (50%) (Table 1). Most participants expressed a higher level of acceptability for ARenal and suggested improving engagement by including more games, activities, quizzes, and other features in the 3D model.

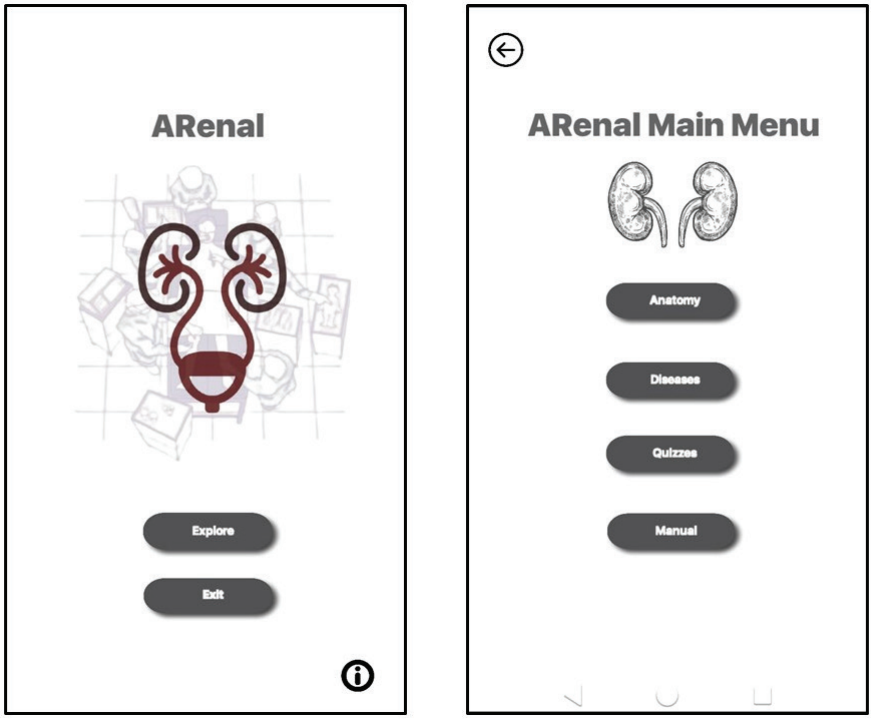

Figure 4: ARenal Android applications interface.

Figure 5: QR code for the ARenal Android application video demonstration.

Table 1: Summary of UAT for the ARenal Android application

UI and UX	Respondent response (n = 10)					
	1	2	3	4	5	
	Strongly disagree					Strongly agree
The application is functioning smoothly				40%	60%	
The application is easy to use				50%	50%	
The 3D models are detailed and attractive			10%	60%	30%	
The AR features are suitable and functioning				60%	40%	

UI and UX	Respondent response (n = 10)									
	1	2	3	4	5	6	7	8	9	10
	Not really									Yes, it's ready
Is this app ready for release?							10%	20%	50%	20%
Is this the first time you interacted with AR software?	1st interaction: 60%						Not 1st interaction: 40%			

Note: UI = User interface; UX = User experience

DISCUSSION

Our study objective was to develop an online 3D AR of the HUS as a supplementary tool to aid in the teaching and learning process. The intended users include students studying kidney anatomy and physiology in undergraduate medical or health sciences programmes. Ten medical students downloaded the ARenal Android application, used this application, and responded to the UAT questions. The UAT feedback from them was quite promising and encouraging. More than half of the participants indicated that this was their first AR experience and strongly agreed that ARenal was functioning without any major issues. Furthermore, they also strongly agreed that ARenal was handy to use. With ARenal, students were able to access learning resources as well as AR technologies to comprehend kidney anatomy on a smartphone or tablet. Due to its accessibility, ARenal allows them to improve learning as compared to only relying on traditional learning processes.

Currently, there are similar but not quite the same applications on HUS such as "Kidney Anatomy" and "All Kidney Diseases and Treatment" that are available commercially to be downloaded. However, the novelty of ARenal is the detailed AR features/images and more concise information on the physiological functions of the kidney. In contrast to traditional FTF lectures or practical classes that are entirely guided by the lecturer, the user can observe the kidney and nephron and their anatomical locations through a detailed 3D kidney model rather than 3D on paper. Because of ARenal's novelty, it has been approved for its copyright.

With ARenal, students were able to access learning resources as well as AR technologies to comprehend kidney anatomy on a smartphone or tablet. ARenal allows them to improve learning as compared to only traditional lectures. ARenal is an essential supplementary tool

in the online learning process for medical and health sciences because the learning process can be very challenging. Medical students may find AR to be a useful complementary online teaching tool for comprehending the anatomical and physiological alterations that occur in the human body system in either a healthy or unhealthy state (21).

ARenal Android application will enhance students' learning engagement and contribute to more attention span thus comprehending the fundamental anatomy and physiology of the HUS. Research has shown that AR applications have many benefits in the learning and teaching of medical students in terms of learning engagement. These benefits include experiential satisfaction, perceived learning effectiveness by enhancing engagement, a reduction in the learning curve and learning accessibility (23–29). Additionally, AR applications are generally more affordable, have fewer supervisory constraints and improve students' comprehension and learning experience (12, 13, 30, 31). Using AR in medical education has increased student engagement and enhanced their comprehension of the material (12). It is designed to close the gaps in the current medical education delivery system, enabling medical students to visualise abstract concepts more easily by utilising 3D images rather than textual information (12).

ARenal is easily accessible as users can utilise it whenever or wherever they are, as this application is convenient and just at their fingertips. Students find it easier to utilise their smartphones or a cutting-edge method like immersive visualisation with head-mounted displays, which is always being improved for enhanced visualisation and application (13). AR will also improve users' knowledge and information, making learning more flexible and accessible, and provide educators with the freedom to standardise course materials so that students learn the same skills and knowledge every time (27–29).

ARenal has numerous potential applications. In view of perceived advantages and benefits, the AR feature will aid in their learning and attract more attention spans. The factor of competitive advantage for ARenal is that it acts as students' learning aid and can be assessed whenever or wherever they are. ARenal has the potential to be marketed in the international market to undergraduate students studying renal anatomy and physiology in the fields of medicine, nursing, physiotherapy, biomedicine, and health sciences. Although ARenal has numerous beneficial advantages, the app also has several limitations that can be upgraded. According to the UAT feedback, the ARenal user suggested that the diagram and picture quality can be improved. In addition, they recommended adding more activities, games, quizzes, and other features to the 3D model for better interaction.

CONCLUSION

In conclusion, most participants were contented with the ARenal Android application based on the results of the UAT. Thus, ARenal has the potential to be utilised as a supplemental tool for learning the HUS. The future plan is to conduct further study to evaluate the effectiveness and perception of ARenal, among UPM Medical and Health Sciences students using a larger sample size.

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