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A Mobile Augmented Reality Application for Undergraduate Medical Students Using a Flipped Classroom Approach

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ABSTRACT

The flipped classroom model enables students to acquire fundamental knowledge outside of class time; thus, including reading materials or video lectures. This will be able to free up class time for knowledge application, student engagement in active learning, and higher-order thinking. The flipped classroom model is increasingly being adopted in competency-based medical education. However, the potential of flipped classrooms for enhancing medical education has not yet been proven and it poses a major challenge to students who have not mastered self-regulated learning strategies. Thus, they may not be able to understand the information presented in the course materials or to strategically use learning resources outside of class. In this project, we have created three mobile augmented reality (AR) applications for students studying anatomy to help them grasp the idea of the AR flipped classroom on three different platforms. Students were instructed to use the three mobile augmented reality (MAR) applications with different designs and approaches. To understand further, we let medical lecturers try and use the three MARs. The three types of MAR applications are — those with markers and notes on printed notebooks (BARA1), those with markers and notes on a website (BARA2), and those with all notes in the MAR application and the marker are a tangible 3D object (BARA3). From the series of experiments conducted, we concluded that most students favour the BARA3, meanwhile, the medical lecturers essentially prefer the BARA1. In this research, four things have been considered: interface design, the usefulness of Augmented Reality (AR), technical problems with the use of AR applications, and educators training on the use of AR applications. Without a well-designed interface and guidance for the students, AR technology can be too complicated to use, especially for those who are not familiar with the technology.

1. Introduction

The use of augmented reality (AR) technology has significantly impacted various industries, particularly in the educational field. It is currently widely used in teaching and learning from

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elementary school to college. AR is a low-cost technology that can readily be implemented in educational settings. Several studies have recognized the potential of AR for improving learning and teaching [1]. There are a few advantages of using Mobile Augmented Reality (MAR) applications as a medium for learning where the AR elements will help upgrade the learning experience by using 3D virtual objects for students to view using their eyesight with various mobile interfaces. This enables the student to visualize the learning material more clearly with the assistance of a 3D object and interaction to see how a specific object would react. Students can use smartphones and tablets to interact with AR objects or even use devices that they may already have, allowing them to install the application and use it virtually anywhere [2]. One of the challenges is that the stability of mobile AR technology cannot be assured, and difficulties may arise if the technology lacks well-designed interfaces and guidance, as this could make the technology too complex [3]. Users may require additional time to become familiar and comfortable with AR technology [4-6].

Meanwhile, the concept of the flipped classroom model enables students to acquire fundamental knowledge outside of class time; thus, including reading materials or video lectures. This will be able to free up class time for knowledge application, student engagement in active learning, and higher-order thinking. The flipped classroom model is increasingly being adopted in competency-based medical education. However, the potential of flipped classrooms for enhancing medical education has not yet been proven, despite significant increases in the quantity and quality of studies studying this approach in medical education [6]. The major challenge of flipped classrooms is that students must master self-regulated learning strategies. Thus, they may not be able to understand the information presented in the course materials or to strategically use learning resources outside of class, which would likely limit their ability to participate in and benefit from in-class activities. Self-regulated learning refers to the ability to understand and control the learning environments. Must set goals, select strategies that help achieve them, implement them, and monitor the progress toward their own goals. Various self-regulated learning (SRL) techniques may be advantageous for student performance in various learning environments. For instance, a study of first-year medical students taking an anatomy course discovered a positive correlation between their use of cognitive strategies like elaboration (e.g., meaning-enhancing additives, concepts, or generalizations) and critical thinking (e.g., faculty/student questioning, peer teaching) and higher academic performance. Self-regulated learning is a cyclical process, wherein the student plans for a task, monitors their performance, and then reflects on the outcome. The cycle then repeats as the student uses the reflection to adjust and prepare for the next task. The process is not one-size-fits-all; it should be tailored for individual students and for specific learning tasks. To understand further this concept towards the use of AR application, we have created a mobile augmented reality (MAR) application for students studying anatomy to help them grasp the idea of the AR flipped classroom. Students were instructed to use the same three mobile augmented reality (MAR) applications with different designs and approaches. The three types of MAR applications are — those with markers and notes on printed notebooks (BARA1), those with markers and notes on a website (BARA2), and those with all notes in the MAR application and the marker are a tangible 3D object (BARA3).

2. Methodology

2.1 Background

In education, mobile augmented reality (MAR) has the potential to improve the learning experience. It should be based on its usability and adequately incorporated into the learning environment. Furthermore, according to Kamhphuis *et al.,* [6], mobile learning activities give students the flexibility to learn whenever and wherever they want. The concept of MAR can aid learning activities in a variety of ways, including helping faster access to material, increasing student motivation, making the learning process easier and more efficient, and helping students in better understand concepts [7-8].

In 2013, FitzGerald *et al.,* [9] presented a study on augmented reality in the context of mobile learning, in which they looked at six mobile learning systems including augmented reality as a primary part. The six factors in their comparison taxonomy, which mainly focused on non-technical characteristics, were device/technology, mode of interaction/learning design, system of sensory input, personal/shared experience, fixed/static or movable experience, and learning activities. In addition to contrasting the six systems, FitzGerald et al., [9] investigated pedagogical and technical difficulties that might need to be addressed when educational mobile AR systems are deployed. In a more design-oriented examination, Kurniawan *et al.,* [10] discussed and introduced their human anatomy learning systems using augmented reality on mobile applications. They are detailing how diverse user context data might be used to contextualize the AR learning experience.

2.2 Usability

Users of AR technology may meet usability and technical challenges, and some students may find the technology confusing, according to Akçayır *et al*., [3]. They also claimed that one of the most difficult parts of AR applications is usability; yet ease of usage is also mentioned as a benefit. There is no evidence that AR technology causes usability issues; rather, it could be caused by a lack of technology understanding, interface design faults, technical challenges, or bad attitudes [3]. One of the characteristics of usability is learnability, or the ability to learn quickly. User-friendliness is described in previous studies [11,12] as the ease with which a user may start and discover new aspects of the system. The ease with which a user can use a product or system (learnability) shows how simple it is for the user to use the product or system and whether the user can readily understand how to use it. The system must be intuitive enough to be used for the first time. The efficiency of usage describes how quickly a person can complete a job after learning how to use a product or system. After not using a product or system for a certain period, the user's ability to remember its function and usage is measured.

Usability was also defined by the International Organization for Standardization (ISO) in the ISO 9241–11 standard, which was recently updated from ISO 9241–11: 1998 to ISO 9241–11: 2018. In this standard, usability is described as a system's effectiveness, efficiency, and satisfaction. These three criteria determine a product or software’s usefulness. Effectiveness refers to a user's ability to accomplish goals using a product. Efficiency is defined as the amount of effort a user spends to execute a task, which can be measured in terms of time spent on the task or speed of use. Satisfaction refers to a user's feelings about a product's usability.

Santosa [13], published the results of a usability study on Papirus, an e-learning portal developed at an Indonesian institution. The research looked at 86 replies from university students who had used the e-learning system. It was discovered that apparent usefulness was further influenced by ease of navigation, which influenced user attitude and satisfaction. In addition, Santosa [13], discovered that efficacy influenced perceived utility, which influenced user attitude and pleasure. Meanwhile, Cheon *et al.,* [14] investigated mobile learning's acceptance in higher education, whereas Harrison *et al.,* [15] offered an alternative usability model for mobile learning study that integrated Nielsen's usability model, ISO 9241–11 ease of use characteristics, and cognitive load.

2.3 The Experiments

To understand further the design of the MAR for the suitability of the apps for flipped classrooms, the work was divided into two stages. These stages are (i) the suitable interaction in MAR for medical students and (ii) the identification features in the required guideline for user interfaces, 3D model rendering attributes, and the content flow. The feature identification that is suitable for the flipped classroom also includes the type of markers; printed, digital, and object target markers.

These stages involve a series of experiments which started with the preliminary experiment and followed with the user expectation test. From these two experiments, we concluded that there is a need to develop three different MARs to observe and explore further the suitability of MAR for flipped classrooms for medical students. Our idea is to conduct a comprehensive assessment of the effectiveness of different educational aids, including printed books with MAR, websites with MAR, and an innovative technique that employs a tangible marker. From this idea, we proceeded to develop three MAR for medical students who were in the stage of studying human anatomy to help them grasp the idea of the AR flipped classroom. Students were instructed to use the three mobile augmented reality (MAR) applications that we developed with different designs and approaches. The three types of MAR applications are — those with markers and notes on printed notebooks (BARA1), those with markers and notes on a website (BARA2), and those with all notes in the MAR application and the marker are a tangible 3D object (BARA3). The experiment was carried out by giving these three BARA apps to the students to test and experience.

For BARA1, there are a total of 12 printed images identified as the AR markers. The lesson notes were printed in a booklet and students must use the notes while using the BARA1 application. Students had the advantage of using the AR 3D models by scribbling and recording additional information on their printed notes (refer to Figure 1)

Fig. 1. BARA1 printed notes as a booklet

For BARA2, partially the notes are in the created website (https://notecasd.home.blog/2019/03/26/heart/) with 12 digital images acting as AR markers. The orientation of the 3D anatomy models was changed to suit the display screen of the devices. To fully utilize the application, users have to scan the images shown in the website (refer to Figure 2).

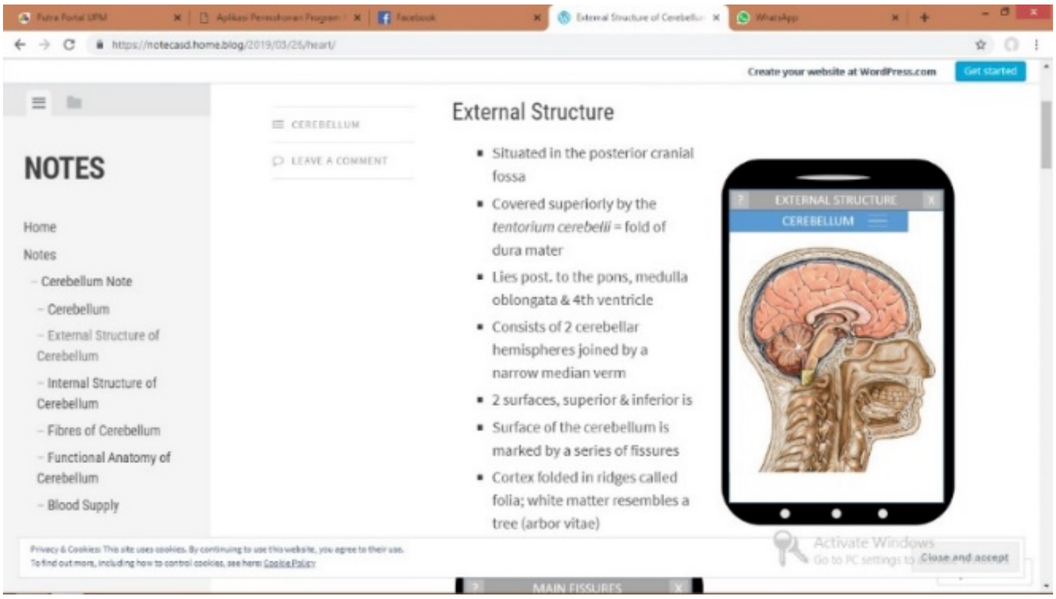

Fig. 2. Website Interfaces of Digital Marker for BARA2

BARA3 is different from BARA1 and BARA2, full notes were made available in the BARA3 mobile, and users only needed a 3D object marker (see Figure 3). To see 3D AR representations of the human brain, users must scan the chosen object marker, for this experiment, we chose an eraser because of its small size and ease of transportation. The chosen eraser was a digital scan and was inserted in the unity scripting that was used for the BARA3 application.

Fig. 3. BARA3 the Object Target

A series of experiments focusing on medical students in Medical and Health Science, Universiti Putra Malaysia as respondents have been carried out. The experiments involve the user acceptance test with the second-year medical students in the Faculty of Medical and Health Science, Universiti Putra Malaysia. After gathering feedback and suggestions from medical students who used the three MAR, a new MAR user interface guideline for flipped classroom medical learning was created. To test these guidelines, a final experiment was conducted on the medical students in the Faculty of Medical, UITM Sungai Buloh Campus. Their responses and comments were translated to attributes and specifications and added to the list of the proposed guidelines. As shown in Table 1, the extended guidelines were applied to the BARA1, BARA2, and BARA3 apps. The Unity software is responsible for many of the numbers in this table.

Table 1
BARA Specially Design for Medical Learning Applications Extended Interfaces Guidelines

Item	Description
AR 3D Model Interaction	Real time finger pinch, real time finger drag, real time finger spread
Position 3D Model	With image target position (0,0,0) and size of scale is 100: Printed Marker: (-0.002 to 0.080, 0.070 to 0.650, -0.002 to 0.00) Digital Marker: (-0.002 to 0.057, 0.007 to 0.446, -0.026 to 1.552) Object Target Marker : (0.470 to 0.720, 0.70 to 1.00, 0.320 to 0.620)
Orientation of 3D Model	With image target position (0,0,0) and size of scale is 100: Printed Marker: 90^0 on x-axis (perpendicular with image target from top view) Digital Marker: 90^0 on x-axis (parallel with image target from top view) Object Target Marker : 45^0 on x-axis
Position of AR video	With image target position (0,0,0) and size of scale is 100: Printed Marker: (-0.006, 0.009, -0.017) Digital Marker : (0.004, 0.040,0.012) Object Target Marker : (0.489,0.004,0.476)
Orientation of AR video	With image target position (0,0,0) and size of scale is 100: Printed Marker: (90,0,0) Digital Marker: (90,0,0) Object Target Marker : (45,0,0)
Level of Details 3D Model	Smooth surfaces type
Length AR video	Printed Marker: up to 2 minutes Digital Marker: up to 2 minutes Object Target Marker : up to 2 minutes
Voice assistant	Preferable UK ladies' accent (pronunciation is suitable for Malaysian student)
Colours of 3d model	Up to 15 colours (to get fast display)
Visibility of 3d model	Extended tracking

3. Results

These guidelines are accomplished by creating an initial Augmented Reality mobile application and experimenting with various positions and distances before presenting it to the respondents – a preliminary experiment and user expectation test. Each respondent's interaction with the apps has been registered, and user feedback has been solicited. This has resulted in the further development of the location and position of 3D models that were used by medical students in BARA 1, 2 and 3 in the user acceptance test, the final acceptance test, and the usability test.

As shown in Figure 4, 14-year-two medical students were chosen as participants, the final experiment took place at the Faculty of Medicine, Universiti Teknologi MARA (UiTM), Sungai Buloh Campus. The experiment's aim was to determine which edition was the most suitable and user-friendly for medical students. The experiment began with a description of how it would be carried out. Those who share desks will use the application until the end of that version. They used each version for 10 to 15 minutes before moving to another table to evaluate the other version. Three cameras were placed 1.5 meters in front of each table to capture user reactions to each edition of the BARA AR mobile application for this experiment. They were given ten minutes to complete the questionnaire for each of the versions after they had completed all the versions.

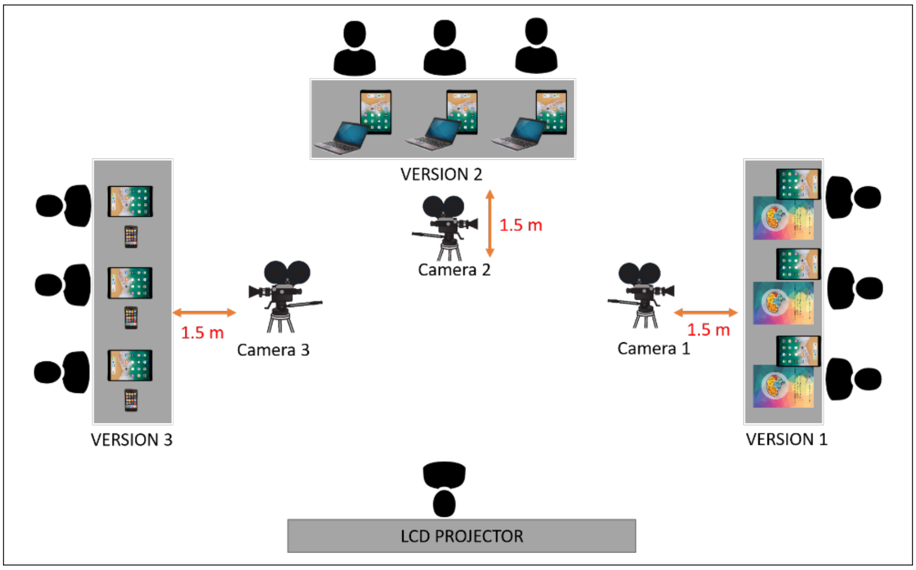

Fig. 4. Final experiment

Three cameras were used during the experiment to track student interactions with each edition of BARA's apps, and they were then given one set of question surveys. The three cameras were used to capture the students' reactions. However, the analysis of the captured video is still ongoing research. Table 2 below shows that students prefer the version of BARA 3 for ease of use, and it was also this edition that was used to apply expanded guidelines in Table 1. To further understand the expectation of using MAR for the flipped classroom, we asked five medical lecturers to use our three MARs, and we interviewed each of them in a friendly mode. From this session, we were able to conclude that medical lecturers prefer BARA 1. The main reason given was the use of printed books so students will be able to jot or write their own notes on the printed book.

Table 2
Most selected version by medical students

Which AR apps edition do you prefer to use as your learning tool?						
	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
BARA1 an apps with printed notes and markers	0	2	7	2	2	1
BARA2 an apps with web-based notes and markers	0	7	4	2	1	0
BARA3 an apps with 3D tangible object marker	0	0	1	3	2	8

4. Conclusions

Upon completion of each final experiment version, students were provided with a questionnaire to gauge their satisfaction with the interface design. The results confidently revealed that the students found the 3D model orientation and the flow of the MAR to be perfectly suited to their needs. Furthermore, the students unanimously agreed that the MAR was immensely useful for both pre-and post-class study sessions and that learning human anatomy was a much more enjoyable experience.

Since the tangible object marker to be scanned (BARA 3) was more convenient than using books and a laptop, the final experiment revealed that (Object Target Marker), BARA3 was the most popular among students. Furthermore, by simply holding and rotating the object target marker, users can rotate a 3D AR model to see a different view of the model. This BARA3 was the most convenient for learning because they only needed one device. Furthermore, as compared to BARA1 and BARA2, this edition easily detects and displays AR 3D models with a more stable display. Finally, respondents claimed that editions 1 and 2 had shortcomings in terms of 3D AR model rotation and that the bulk of the 3D AR model could not be seen in 360 degrees, forcing them to rotate their notebooks to see the entire model. We concluded from this study that BARA edition 3 with the object tangible marker was more suitable for medical students, but the study is still ongoing, and editions 1 and 2 are still being considered, especially with the COVID-19 life experienced. It appears that there is a need to further explore teaching and learning initiatives during the COVID-19 pandemic due to the absence of physical and practical learning activities [17].

Due to the COVID-19 impact, we furthered our research on the usage of flipped classrooms in medical subjects and the prospect of enhancing BARA2. We proceeded with our work by developing a new system, which we named Putra Med-hub. Putra Med-hub is an Android-based augmented reality mobile application for medical learning with the integration of a web-based file management system. We use BARA2's content and intercalate the 3D data retrieval from the cloud database and storage. Thus, we managed to produce a smaller-sized mobile application package (APK) with a compatible application edition and size. Putra Med-hub is equipped with the 3D model viewer in the web application that supports .obj file format, while the 3D model could be viewed in an augmented reality environment in the mobile application. This has achieved the objective of developing a system that will enable medical educators to deliver dynamic content within the medical learning environment and improve the learning experience of medical students. Lastly, although the retrieval of data from the web application into the mobile application has limitations, this application is still able to assist medical educators in updating teaching materials content, especially for the augmented reality content, and make it more interactive compared to BARA2.

From this extended research work, we concluded that the integration of an augmented reality mobile application with the file management system web application that also contains a 3D model viewer offers a wide range of possibilities for medical educators to broaden and increase the learning experiences of their medical students, especially in understanding the anatomy structures. For BARA 1, 2, and 3, there are still spaces for improvement and research needed.

All these results with related articles [18-22] point to one fact, augmented reality is vital to 21st-century teaching and learning and will continue to influence student achievement, motivation, and interest, whether the approach is basically web-based, printed marker-based, or tangible-based.

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