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The Development of Mobile Augmented Reality: 3-Dimensional Video

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ABSTRACT

Augmented reality has become one of the learning processes applicable through mobile devices, called Mobile Augmented Reality (MAR). Learning and service experiences can be enhanced using mobile devices such as those offered by MAR, an innovative learning space providing active interaction of superimposing digital content into the real world. Previous studies have discussed the importance of the MAR system in various domains, especially in education, as it led students to achieve higher levels of engagement in their learning process. However, there are limitations in highlighting the importance of the development process for MAR. Therefore, this present study describes the development process of MAR through the AREM model, which aimed to exhibit the systematic guidelines in producing a practicable MAR. It also highlights the preferable learning content and media component based on the respondents' responses in the survey questionnaire. Data gathered from questionnaires were analysed by using descriptive statistics. The guideline in developing MAR can benefit students and educators in producing a MAR for learning purposes.

Keywords: *Mobile augmented reality; 3D video development*

INTRODUCTION

The 21st century witnessed a radical penetration of technology in every level of education setting. This scenario has encouraged higher institution students' learning methods to evolve, parallel with the advent of technology. New digital technologies have increased in education, especially among the young generation (Kpolovie & Lale, 2017). It provides students with the opportunity to grab as much information at their fingertips and gaze at other learning opportunities through the use of mobile devices (Issham et al., 2016). Mobile learning incorporates the use of mobile devices and the Internet into the learning process (Usal & Sirin, 2015). Since then, many researchers have started exploring and expanding the use of the mobile learning approach.

As part of the technology evolution today, mobile learning enables adaptation of the use of augmented reality (AR) technology in students' learning process, namely, Mobile Augmented Reality (Adnan et al., 2019; Chan et al., 2019). Previous researchers (Adnan et al., 2019; Khairuldin et al., 2019; Omar et al., 2019; Zulfabli et al., 2019) explore the advantages of mobile augmented reality (MAR). In general, AR provides a novel learning environment through the active engagement of superimposing digital information into real-world contexts to improve learning experiences (Azuma, 1997). In other words, it enables students to interact with digital content that would not be possible in the actual world. Concurrently, previous studies have found that AR benefits students in flexibility in learning (Ismayatim et al., 2019), achieving higher levels of engagement in the learning process (Adnan et al.,2019) and promoting active learning (Mat-jizat et al., 2016). Although there are numerous AR devices, mobile devices are considered a more familiar AR device for academic purposes because most students own mobile devices (Kljunic & Vukovac, 2015; Pullen et al., 2015). Undoubtedly, mobile devices are recognisable among students because they are already necessary in today's world. The exploration of AR in education is also in accordance with the 'Malaysia Education Blueprint 2013-2025' that emphasised Higher Education institutions to improve students' learning experiences through technology to facilitate more personalised learning (Ministry of Education Malaysia, 2015).

The popularity of AR has increased in recent years (Low et al., 2019). However, the potential remains underexplored, especially in education, and even if it has been explored, Malaysia is still at the initial stage (Nizar et al., 2019a). This is proven when numerous past researchers, regardless in Malaysia (Chan et al., 2019; Ismail et al., 2019; Khairuldin et al., 2019; Low et al.,2019) or other countries (Jung et al., 2020; Saez-Lopez et al., 2020) agreed that there is a limitation of getting MAR resources that fit their users or students' need. They believe that users' or students' need is vital to consider as it would influence their acceptance of MAR (Binyamin et al., 2019). Another factor that contributed to the limited resources of MAR is the critical lack of expertise in working on the development of AR, especially in terms of theoretical, design and technical skills (Kerr & Lawson, 2019). The lack of expertise in developing MAR leads to the limitation of MAR resources.

Considering the mentioned challenge raised by past researchers, it provides ample room for this present study to develop MAR that would directly contribute to the addition of MAR resources, especially for learning purposes.

RELATED WORKS

Augmented Reality

Augmented reality (AR) is one type of learning process that may be implemented via mobile learning, namely Mobile Augmented Reality. Due to the rapid changes in technology, the teaching and learning processes should operate in tandem with the development of technology and its peripherals. Generally, AR has always been associated with Virtual Reality (VR) because it was the starting point for the evolution of AR. VR allows users to completely immerse themselves in a synthetic world that exceeds the constraints of physical reality environments. On the other hand, AR focuses on the integration of a physical and virtual environment.

AR enables students further to enjoy learning (Low et al., 2019), increase engagement (Adnan et al., 2019), provide active and flexibility in learning (Ismayatim et al., 2019) as well as help to improve students' visualisation skills and interest in learning a challenging course (Omar et al., 2019). Simply put, AR helps to minimise students' cognitive load in grasping a lesson compared with the conventional way and thus directly improve students' performance in learning.

Despite the emerging advantages in AR, there are several limitations in getting MAR resources due to the lack of expertise in working on the development of AR technology, especially in terms of design, theoretical and technical skills (Kerr & Lawson, 2019). Concurrent with the scenario in Malaysia, there is a lack of facilities and technical support to encourage students in using AR (Nizar et al., 2019b). Undoubtedly, the development of AR requires extensive computer skills and is short of budget, primarily when researchers intend to publish the AR application on mobile device platforms. The challenges highlighted by past researchers conclude that AR has excellent potential, but these obstacles directly lead to difficulties in developing MAR resources, especially for learning purposes. In addition, there are also limitations in getting the systematic process in developing MAR resources. This study, therefore, attempts to address the process of developing MAR resources through a systematic approach.

System Design

Generally, the development of MAR can be divided into three types of systems: location-based, image-based, and markerless systems. Considering mobile devices as the primary devices, this study highlighted an image-based system design through the image recognition technique. The application of such a technique requires the position of physical objects to be determined to obtain virtual information. Virtual information bursts on the screen shortly after being generated by the AR software due to pointing the trigger image captured by the mobile device. Various elements of media such as videos, 3D models, texts, audios and images address the content of virtual information. Nevertheless, the purpose of the students' learning process remains the key to selecting elements in AR.

This study focuses on using AREM (Wojciechowski, 2012) as a theoretical grounding in developing MAR. This model was intended to provide a guideline for those who decided to design and develop an AR technology. This model projected two main concepts, AR-Class and AR-Object, according to the object-oriented paradigm. AR-Objects are representations of virtual objects, physical objects, and environmental

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scenes composed of both types of objects. Meanwhile, AR-Classes refers to the underlying class characteristics derived from the object-oriented paradigm, such as attributes. The attributes of AR-Classes are utilised to parameterise their geometry and behaviour. Since different AR-Objects are instances of an AR-Class may have distinct attributes; thus, the appearance of different AR-Objects may vary in behavioural and visual aspects (Wojciechowski & Cellary, 2013). In the context of education, AR-Classes are used for modelling learning concepts.

For this study, AR Class would help in the early design stage to determine the attributes of MAR technology in terms of learning content and the best media object to be used. Media objects can be in the form of 3-dimensional (3D) models, video, visuals, sounds and their peripherals. On the other hand, AR object refers to the AR learning content divided into virtual and physical objects. In addition, mobile devices are needed as assisting aid to access virtual information. In the context of this study, all these attributes have been determined by the respondents of the study.

METHODOLOGY

This research employed quantitative research to identify the multimedia characteristics in designing MAR (AR Class). Data of the study were collected through a questionnaire among 389 pre-service teachers from three different public universities. The questionnaire structure was formulated by considering the pre-service teachers' preferences towards the learning content and main media component for MAR. Data gathered from the questionnaire were analysed through descriptive statistical analysis using IBM SPSS software. Feedback from this questionnaire has been utilised as the main driver in the development of MAR. Considering users' suggestions can prevent them from having initial negative assumptions before using learning tools (Dudley & Kristesson, 2018). For this study, it is crucial to get an initial opinion from pre-service teachers to reduce their initial negative assumptions as they can get involved from the initial process of designing MAR.

Besides pre-service teachers' responses in the questionnaire, the development of MAR also considered the Augmented Reality Environment Model (AREM) as the theoretical grounding of the study that focuses on AR

Object. In this study, a 3-Dimensional model represented the AR object. The development of the 3D model was presented based on the adaption of 3D computer workflow by Winder & Dowlatabadi (2001). The rationale for selecting the 3D model as one of the AR objects is discussed in the next section.

FINDINGS

AR Class

In this section, AR Class highlighted the pre-service teachers' preferences in learning content and media component for the development of MAR resources.

The selection of learning content in MAR is crucial to determine since it involves pre-service teachers from various fields. Undoubtedly, not all content is suitable for implementing the augmented reality approach. Previous researchers have gained more attention in human anatomy, historical and astronomy topics (Hannah et al., 2019; Chow et al., 2017). These three topics have been subjected to the use of AR due to its capability of placing 'information in the environment where the user is' (Hannah et al., 2019). In other words, users need to immerse themselves in the virtual environment to experience AR. Hence, these three topics were selected for pre-service teachers to choose based on their preferences of content in MAR. As a result, in Table 1, most pre-service teachers (44.5 per cent) chose human anatomy as their preferred topic in MAR.

Table 1
Selection of Learning Content in MAR

Topic	Frequency *(f)*	Percentage (%)
Human Anatomy	162	44.5
Historical	113	31.0
Astronomy	68	18.6
Others	21	5.7

Studying all components of human anatomy is crucial. Therefore, the present study chooses the human heart as part of the human anatomy topic. In specific, a cardiovascular topic was selected in highlighting human heart-related information. The selection of cardiovascular topic follows the concern that this disease ranks the highest cause of mortality in Malaysia since 2000, and the number also increased to almost double in 2019 (Jay, 2019). This study takes the initiative to highlight cardiovascular topics in developing MAR and create awareness about health. The Ministry of Health Malaysia believes that awareness about cardiovascular can reduce the mortality rate caused by cardiovascular disease by 2030. Therefore, the term MARLCardio would be used throughout the process to exemplify the use of MAR.

Table 2 shows the most preferred media component to develop MARLCardio among pre-service teachers. Their decision was expected to facilitate them in comprehending learning content efficiently. Response from pre-service teachers nominated video (35.1 per cent) as the most preferred multimedia component. This is followed by visual (26.3 per cent), animation (24.1 per cent), text (10.7 per cent), and the least are audio (3.5 per cent). Hence, the development of learning content in MAR would be transmitted in the form of a video.

Table 2
Main Media Component

Media component	Frequency *(f)*	Percentage (%)
Texts	39	10.7
Visuals	96	26.3
Video	128	35.1
Audio	13	3.5
Animation	88	24.1

Data gathered in the AR Class section indicated that pre-service teachers chose human anatomy as learning content for MARLCardio, and the cardiovascular topic was chosen. In terms of the media component, most of them chose video as their primary preference. Hence, these two attributes would be applied during the development process of MARLCardio.

AR Objects

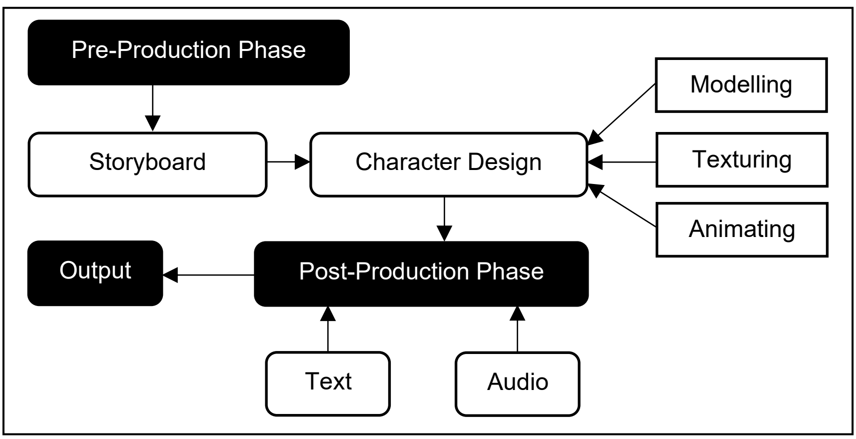
This section addressed the development of AR objects in form of virtual through the use of video as it is the most preferable media component chosen by pre-service teachers. Video can be defined as any electronic media format that employed ‘motion pictures’ to deliver a message

(Smaldino et al, 2012). The production of video in MARLCardio focused on the 3-dimensional (3D) video. The process in developing each video has been addressed separately in the next sub-section as it required different procedures.

3-Dimensional Video

In MAR, the use of 3D video emphasised the process of how the human heart functions. The process engaged with the circulation of blood flow through the human heart. The development of 3D video is based on the adaption of 3D computer workflow by Winder and Dowlatabadi (2001) as shown in Figure 1. It was divided into two phases which are pre-production and post-production. The pre-production phase involved a storyboard and character design while the post-production phase focused on the composition of text elements together with the audio element.

Figure 1
3D Video Workflow



The pre-production process of the 3D dimensional video begins with the sketches of a storyboard to demonstrate the workflow in the video production. The idea, movement and type of audio for each frame were written to accelerate the 3D video production. The ideas on the storyboard are used as a guide to disseminate information in video form more effectively. After the storyboard was completed, the pre-production process moved on to the development of character design. The main character design emphasised the human heart anatomy and its works. The character

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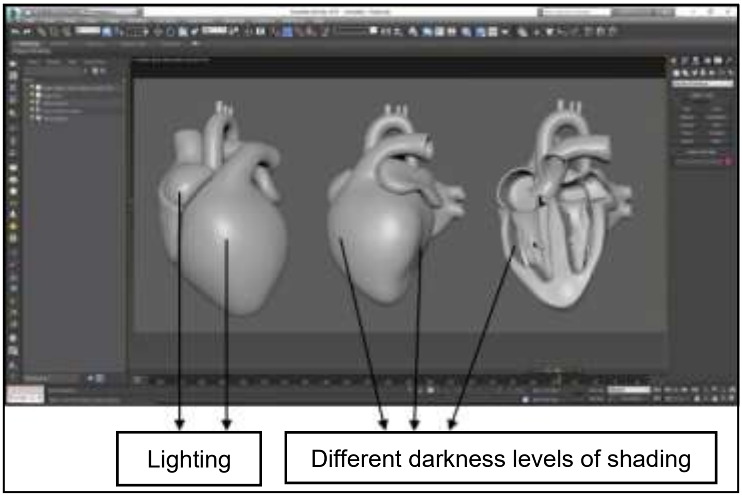
design was divided into three stages: modelling, texturing and animating digitally. These processes were completed by using Autodesk 3D max software.

The first process of character design started with modelling. Modelling is the process of creating objects that are going positioned in front of a virtual camera (Koeva, 2017). The modelling of the human heart concentrated on the human heart compartments and blood vessels in the form of 3-dimensional. To ensure the accuracy of the human heart, numerous related images were collected as a reference. Forming 3D models begins by outlining the human heart based on the reference images. Some of the parts were modified to reduce the complexity of the modelling process while maintaining the shape's accuracy. The human heart was formed in three different angles: interior, exterior and side view (Fig. 2). In addition, the element of lighting and shading were also considered to enrich the realistic shape of the 3D model (Wisessing et al., 2016). Adjusting the darkness levels of shading and adding light sources targeting specific areas can help shape the human heart model.

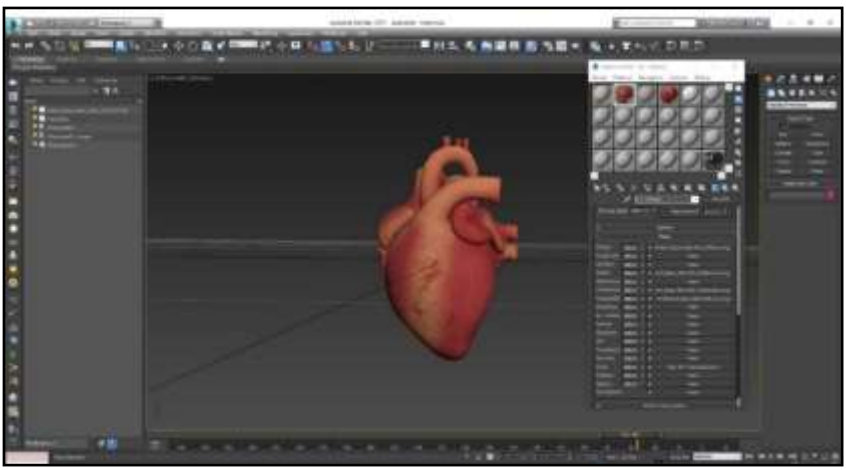
Figure 2
Modelling Process of the Human Heart for 3D Video



These three different views are essential for use during the production process of animation video after completing the texturing phase. The modelling of the human heart focuses more on the heart compartments and blood vessels involved in the blood circulation to reduce the complexity in understanding the content. In addition, the element of shading and lighting were also considered to enhance the realistic shape of the 3D model (Wisessing et al., 2016). To achieve the shape of the 3D model, different darkness and brightness levels of shading are adjusted with light sources are added in certain particular areas.

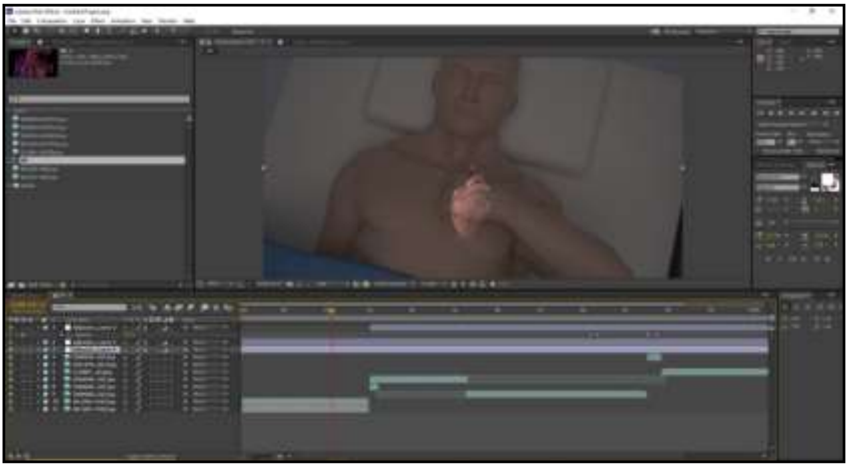
After the modelling process was completed, the character design continues with the texturing process. Texturing is a process to reconstruct the 3D model of an object through the utilisation of 2D images to form the texture on the model (Lai, et al., 2018). In other words, the texturing process is important to create the exterior of the 3D object look. As shown in Fig. 3, the textured images and colour mapped to wrap on the human heart in creating the exterior of the 3D model. The combinations of colours, splashes of lighting, reflections of objects and opaqueness were considered to enhance the realistic look of the human heart.

Figure 3
Textured Model of the Human Heart



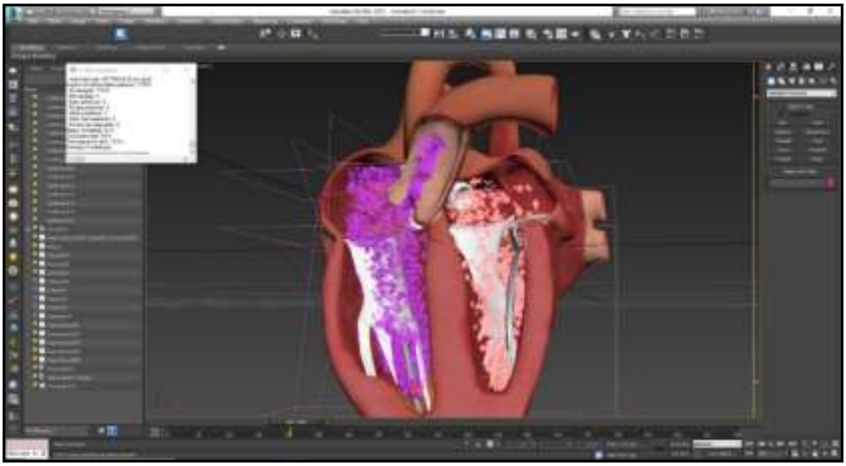
After completing the texturing process, the 3D model was subsequently continued with the animating process. Animation is a process to generate an animated sequence using multiple still images (Kushwaha, 2015). This is the crucial part of 3D video production. It requires the imagination of every motion of the 3D model along with the information to be delivered. Keyframes in the timeline panel were used to set motion parameters, effects, time and other properties.

Figure 4
Animating Process of the Human Heart



In animating the 3D model, the motion was determined based on the information to be conveyed. For example, the 3D model of the human heart was placed overlay on top of a human fist in the initial 3D video production (Fig. 4). The idea of this layer is to convey the fact that the size of the human heart is about the size of our clenched fist. The motion in this part is where the hand shows the human heart's position where it lies behind and slightly to the left of the human breast bone. The human heart beating motion aims to demonstrate how it pumps blood. The intersect view of the human heart in Fig. 5 helps to explain the scenario. The particulars in purple colour demonstrate the motion when the blood is pumped to the lungs to lose carbon dioxide and gain oxygen. Meanwhile, the particulars in red explain the motion of oxygenated blood pumped to the aorta and the rest of the body. Based on the above explanations of the animation process, it marked the completion of character design as well as the pre-production phase.

Figure 5
Particles in Animating the Human Heart



After completing the pre-production phase, the 3D video production continued with the post-production phase. This phase entails combining the character design with text elements through the use of subtitles in the video. In addition, narrative audio was also included to aid comprehension of how the human heart works. Therefore, the users can watch the video with subtitles and listen to the narration simultaneously. The use of narrative audio and on-text screen such as subtitles are intended to reduce users' extraneous processing in grasping the content information (Mayer, 2017). To ensure the accuracy of pronunciations, the narrative audio was completed using the Text to Speech web application. This web application facilitates converting the written script of the video into spoken words. The size of the text was chosen based on its suitability for inclusion in the video. Hence, this marked the end of the post-production phase as well as the 3D video production process.

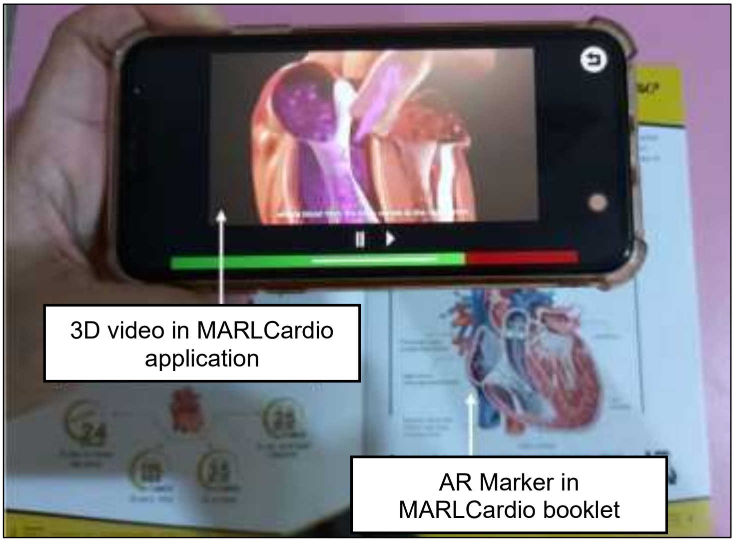
Embedding data

The contents in the form of 3D videos were embedded in the database management system by using Unity 3D software. After completing the process, the embedded database was then ready for the publishing process in mobile devices platform, namely the MARLCardio application. MARLCardio application has been published in Android and iOS mobile device platforms to expedite users accessing the application.

How MARLCardio work

Basically, the MARLCardio application is not a stand-alone AR object. It comes with another physical AR object namely the MARLCardio booklet. Both MARLCardio booklet and MARLCardio application should be used simultaneously in experiencing augmented reality. An augmented reality marker is provided in the MARLCardio booklet to trigger the display of virtual information, which is the 3D video. The virtual information will be displayed immediately when the AR marker was detected on the mobile device screen. Fig. 6 shows an AR installation of MARLCardio for better understanding.

Figure 6
MARLCardio Installation



CONCLUSION

Overall, this present study demonstrated the development of 3D video in the MARLCardio application to expand the MAR resources. The development of MAR is specifically designed for pre-service teachers to convey general knowledge regarding cardiovascular as well as expand the use of MAR. Using the AREM model as a theoretical grounding of the study can systematically facilitate the development process. In addition, the use of 3D video workflow may help to accelerate the development process of the 3D video. The 3D video can reduce pre-service teachers' cognitive load in understanding complex processes in learning content. For example, this study presented how the human heart works through 3D videos. It is impossible to simulate such interaction with an actual human heart for pre-service teachers in class hence the 3D model serves as a simulation. The model can be viewed and observed from different angles so that each of the human components can be studied by interacting with the simulation. Such a learning style would encourage engagement and attention in the learning process, especially for kinaesthetic learners who enjoy learning through movement. Allowing exploration and interaction with objects that are not feasible in the real environment is the main attraction of AR, which enables the expansion of animation through 3D model development.

The accuracy of the 3D model is essential to stimulate the learning process. However, it requires plenty of time to complete the whole process. This can be one of the factors hindering MAR developers or educators from allocating their time and thus reducing the use of 3D videos in the development of MAR, especially for those who lack related software skills. Therefore, this study suggests authorities or academic leaders invite professionals in the MAR scope of research to conduct a workshop on how to design and develop MAR technology. Pre-service teachers need to expand their software skills to maximise the utilisation of MAR in the learning process. It was expected that pre-service teachers should be able to think of possible tasks to implement the skills and develop their MAR technology for learning purposes. In addition, although this present study highlights the development process of 3D video, there are a lot of other media components such as 3D models, visuals and interactivity components that can be considered to enhance the attraction in MAR. Currently, the AR tracking in this MAR relies on image recognition, and the virtual AR object will only appear superimposed in the real environment if the image recognition is detected. Instead of using an image-based system, motion tracking could be used to improve AR tracking. It is in the hope that the outcome of this study could facilitate future researchers to explore the development of MAR technology continuously.

CONTRIBUTIONS OF AUTHORS

The authors confirm the equal contribution in each part of this work. All authors reviewed and approved the final version of this work.

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CONFLICT OF INTERESTS

All authors declare that they have no conflicts of interest.

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