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Finding the Hidden Bones: VR or AR? Virtual Reality & Augmented Reality Medical Smart App V-Learning in China

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Abstract

Applying virtual reality (VR) and augmented reality (AR) application in the intelligent medical classroom to present students an interactive, conceived virtual world has been developing. The traditional method of two dimensional and body specimen anatomy teaching was complicated; since describing or locating precisely the hidden sphenoid bone and ethmoid bone in the human skull was very difficult. However, this can be done simply if the human skull can be split and refined by modern VR and AR technology, which can identify the multi-dimensions of the hidden bones. In the meanwhile, determining the impaction of visualization on VR and AR medical teaching. This study was conducted by comparing virtual reality and augmented reality in terms of precision of Anatomy, image quality, and students learning improvement. The results illustrated the advantage of comprehending VR and AR technology in achieving anatomical alignment, which resolves the traditional difficulties, also enhanced students' understanding and memorization. The purpose of this study aimed to popularize and recommend future VR and AR medical applications on the teaching of anatomy.

Keywords*: Virtual Reality, Augmented Reality; Medical Education; Mobile Applications; V-Learning.*

I. INTRODUCTION

Mortara and Chiara [1] said that 'three dimensional (3D) technology could be a valid support to cultural heritage not only for visual presentation and documentation but also for communication and educational purposes.'

The medical applications based on virtual reality (VR) and augmented reality (AR) technology has become popular in medical education [2]. VR and AR are immersive, conceptual, interactive, virtual and real-time interaction, which stimulate interactive learning process between students and help them enhance their enthusiasm towards learning [3].

However, in the first year of introductory courses in most medical schools, students have been taught in the traditional two dimensional (2D) way of anatomy [4]. As Gorgich, Sarbishegi, Barfroshan, and Abedi [5] stated that the conventional way of anatomy teaching was quite confusing in terms of finding the right articulation of various organs, bones, muscles, blood vessels, and nerves, and was very complicated to imagine the position in the brain even using corpses in the study.

While in a Virtual Learning Environment (VLE), virtual technology can show the accurate position and spatial structure of various organs in the human body [6]. Through the medical applications on mobile devices, the virtual image not only fully display the human brain tissue and structure, but also particularize on the human skull and the articulated parts in full vision [4]. Students can begin their introductory courses with a genuine understanding of the structures of the skull, the ability to manipulate and locate them and comprehend the form association of their anatomical morphology [7].

Thus, this research was conducted through VR and AR mobile application to test the understanding of the human skull structure to see which ones provide a more precise and better understanding of the spatial location of the skull. In this study, the position of the sphenoid bone and ethmoid bone was studied as they are two of the most challenging bones hidden in the neurocranium [8].

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II. LITERATURE REVIEW

A. Traditional and Skull Specimens Teaching

The difficulty of 2D skull image teaching was that students were not able to imagine hidden inner positions, nor to be able to visualize the internal correspondence [9]. As shown in Figure 1, the involvement of using body specimens can partially improve students understanding, but the lack of intuitively feel the neural, vascular correspondence still cannot be clearly illustrated [10].

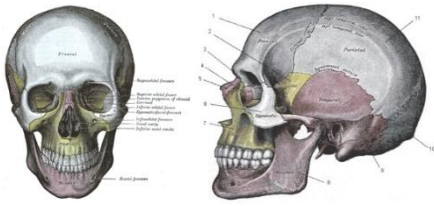

Fig. 1. Illusion of Skull of Gray's Anatomy (Gray's Anatomy)

B. Virtual Reality Teaching

The application of virtual reality in medical education and instruction has been developed very early. The advantages of presenting students to 3D animations and simulations were proven by various researchers [10]. In the most medical education department, anatomy was still taught traditionally, at least in their introductory courses [3]. It was confusing for students to accurately locate themselves nearby various organs, bones, muscles, vessels, and nerves as they might have the opportunities to work on human cadavers later in their studies [11].

Using VR technology to establish anatomical virtual teaching environment, let students visually obtain a feeling immersed in the virtual environment, by showing the 3D spatial structure of the human body in all aspects; therefore, to improve the students' theoretical and operational level [12]. Based on Asano, Okada, and Inaba, combining VR technology with anatomy teaching can achieve the most convenient and vivid simulation of some hard-understanding structures and physiological processes that were difficult to describe orally, which was of great help to the image understanding of these structures and dynamic physiological processes, saving teachers and students' time and energy [13].

C. Augmented Reality Teaching

In AR teaching platform, students can get a full 3D visual experience; can see a precise demonstration of body's organs, bones, blood vessels, and other internal subtle anatomy and their spatial positions [14]. Meanwhile, students can be interactively operated to its arbitrary axis 360 degrees rotation, easy to form a 3D concept in mind and make up for the defects of 2D resources in traditional teaching [15]. In the end, many teaching difficulties in conventional teaching can be solved [16].

By focusing on AR teaching methods, students were placed at the center of learning, improving their critical thinking, group work, and collaboration [6]. Besides, by leveraging problem-based solutions, they help students develop practical and transferable abilities [17]. Then learning becomes a delightful experience, and individual students will be satisfied and worth learning [18].

On the other hand, Kamphuis, Barsom, Schijven, and Christoph [19] noted that while AR learning environments may provide meaningful learning experiences, they have concluded that AR teaching can lead to enhanced learning shifts to conceptual understanding of complex causality.

D. Understanding sphenoid bone and Ethmoid bone

Sphenoid bone: Based on the definition provided in Gray's anatomy handbook 'The sphenoid bone is an unpaired bone of the neurocranium. It is situated in the middle of the skull towards the front, in front of the temporal bone and the basilar part of the occipital bone. It is the site of attachment for most of the muscles of mastication. Many foramina and fissures were located in the sphenoid that carries nerves and blood vessels of the head and neck...' [8].

The structure of sphenoid bone is also stated in Gray's anatomy 'It is divided into the following parts: a median portion, known as the body of the sphenoid bone, containing the sella turcica, which houses the pituitary gland as well as the paired paranasal sinuses, the sphenoidal sinuses. Two greater wings on the lateral side of the body and two lesser wings from the anterior side.' [8].

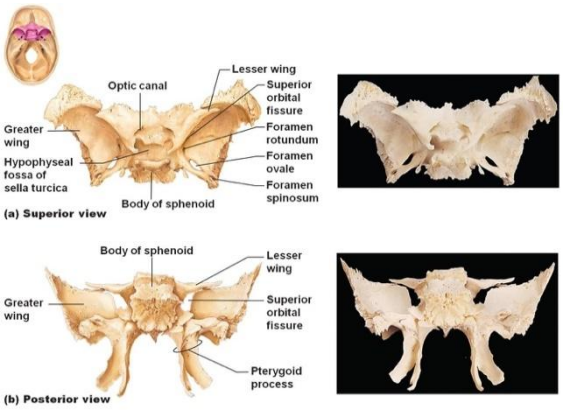

Fig. 2. Illustration of sphenoid bone (The Skeleton, Human Anatomy and Physiology)

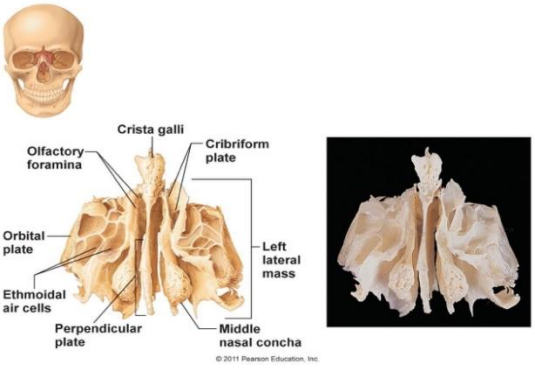

Fig. 3. Illustration of ethmoid bone (The Skeleton, Human Anatomy and Physiology)

Ethmoid bone: Based on the definition provided in Gray's

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anatomy handbook 'The ethmoid bone is an unpaired bone in the skull that separates the nasal cavity from the brain. It is located at the roof of the nose, between the two orbits. The ethmoid bone is an anterior cranial bone located between the eyes. It contributes to the medial wall of the orbit, the nasal cavity, and the nasal septum.' [8].

The structure of Ethmoid bone is also stated in Gray's anatomy 'The ethmoid has three parts: cribriform plate, ethmoidal labyrinth, and perpendicular plate.' [8].

III. METHODOLOGY

A. Research methods

This research involved the utilizing of two mobile medical applications, Essential Skeleton 4 by 3D4Medical.com, LLC for virtual reality technology and The Brain AR App by Harmony Studios Limited for augmented reality technology. The method of medical teaching in anatomy was illustration instruction. A projector was used so that the virtual model can be projected on the monitor. Students can virtualize the procedures and results

These two mobile applications were particularly chosen due to the facts that they were widely used in over 250 universities and 95 countries around the world, as well as the fact that the cost of these medical mobile applications were negligible. Student can get access with no limitation of time and venue besides the classroom. In addition, as head-mounted display hardware generate high expenses, portable and spatial projection systems can be preferred as monitors. Both of the mobile applications used in the research were an immersive desktop application, which means that the head-mounted display hardware was not required.

B. Research Instruments

1) Essential Skeleton 4 by 3D4Medical.com, LLC: (https://3d4medical.com/apps/essential-anatomy-3)

Essential Skeleton 4 is self-contained medical mobile application with full functions, that including the essential anatomy of the human skeleton. 3D4Medical has developed a cutting-edge 3D graphics engine. Fade mode allows fading multiple bones.

2) The Brain AR by Harmony Studios Limited: (https://www.harmony.co.uk/project/the-brain-in-3d/)

The Brain AR App includes mono-object models. It allows studying a human head, scoping from the skin, muscles, and skull to the inner regions of the brain. The program has an intuitive interface, but its use involves explaining from the teacher. The student remains an observer. A fantastic insight into the position, structure, and articulation were provided from any mobile devices.

C. Research experimental procedures

1) Essential Skeleton 4: The position of the sphenoid bone and ethmoid bone can be accurately located from different dimensions through four stages in Essential Skeleton 4. The first stage was to create a skeleton model. Then the skull can be isolated by fading all the other bone structures. From there, the sphenoid bone and ethmoid bone can be highlighted in the color green by correct locating and fading all the other bones in the skull. An illustration of procedures can be observed in figure 4.

Fig. 4. Procedures for locating sphenoid bone and ethmoid bone by Essential Skeleton 4

2) The Brain AR App: The position of the sphenoid bone and ethmoid bone can be accurately located from different dimensions through four stages in The Brain AR App. The first procedure was to establish a skull model. Then skin, muscles, respiratory, and circulatory need to be removed correspondently in order to expose the skull. Followed by the removal of the brain to isolate the skull to make sure that the skull can be split without any disturbance. After the skull was split, sphenoid bone and ethmoid bone will be exposed and can be observed. An illustration of procedures can be observed in figure 5.

Fig. 5. Procedures for locating sphenoid bone and ethmoid bone by The Brain AR App

IV. FINDINGS

A. Anatomy Precision Evaluation Analysis for Sphenoid bone

The sphenoid bone can be seen from six dimensions that were anterior, posterior, left lateral, right lateral, superior, and inferior aspect, respectively, from both medical applications.

The images collected were analyzed based on two considerations, the modality of vision and visibility of detail in each aspect individually against the real model.

1) Anterior Aspect: The images shown in figure 6 was the anterior aspect which indicated that from the Essential Skeleton 4, the sphenoid bone showed a precise shape and visible structure details, whereas in The Brain AR the sphenoid bone cannot be displayed because of the full obstructions by the left and right maxilla.

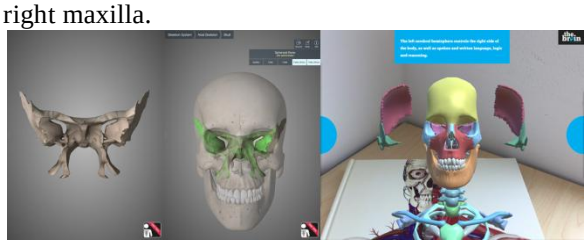

Fig. 6. An illustration of the sphenoid bone in anterior aspect

2) Posterior: The results shown in figure 7 were the posterior aspect, which illustrated that from both Essential Skeleton 4 and The Brain AR, the sphenoid bone indicated a precise shape and visible structure details.

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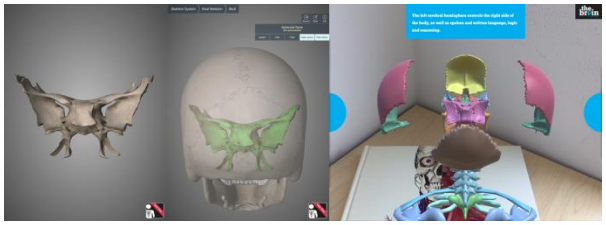

Fig. 7. An illustration of the sphenoid bone in posterior aspect

3) Left Lateral Aspect: The illustrations shown in figure 8 was the left lateral aspect, which recommended that from both Essential Skeleton 4 and The Brain AR, the sphenoid bone revealed a precise shape and visible structure details.

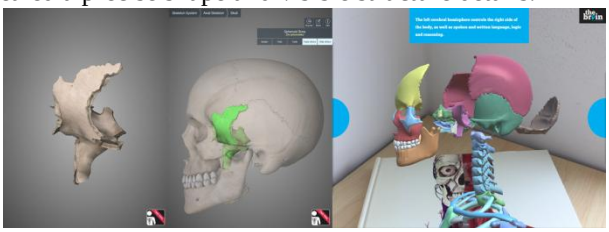

Fig. 8. An illustration of the sphenoid bone in left lateral aspect

4) Right Lateral Aspect: The images shown in figure 9 was the right lateral aspect, which suggested that from both Essential Skeleton 4 and The Brain AR, the sphenoid bone showed a precise shape and visible structure details.

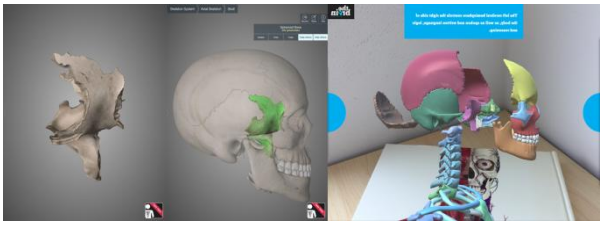

Fig. 9. An illustration of the sphenoid bone in right lateral aspect

5) Superior Aspect: The output shown in figure 10 was the superior aspect, which suggested that from both Essential Skeleton 4 and The Brain AR, the sphenoid bone indicated a precise shape and visible structure details.

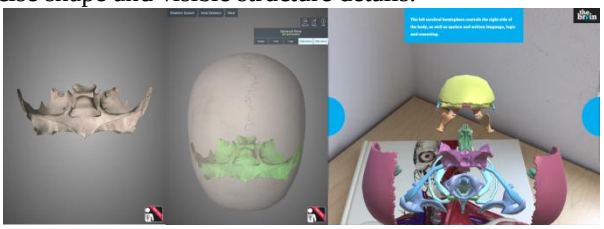

Fig. 10. An illustration of the sphenoid bone in superior aspect

6) Inferior Aspect: The results shown in figure 11 was the superior aspect, which suggested that from both Essential Skeleton 4 and The Brain AR, the sphenoid bone revealed a precise shape and visible structure details.

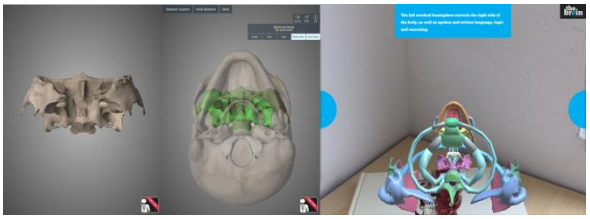

Fig. 11. An illustration of the sphenoid bone in inferior aspect

B. Anatomy Precision Evaluation Analysis for Ethmoid bone

The ethmoid bone can be seen from six dimensions that were anterior, posterior, left lateral, right lateral, superior, and inferior aspect, respectively, from both medical applications.
The images collected were analyzed based on two considerations, the modality of vision and visibility of detail in each aspect individually against the real model.
1) Anterior Aspect: The images indicated in figure 12 was the anterior aspect which showed that from the Essential Skeleton 4, the ethmoid bone displayed a precise shape and visible structure details, whereas in The Brain AR the ethmoid bone cannot be displayed because of the full obstructions by the left and right maxilla.

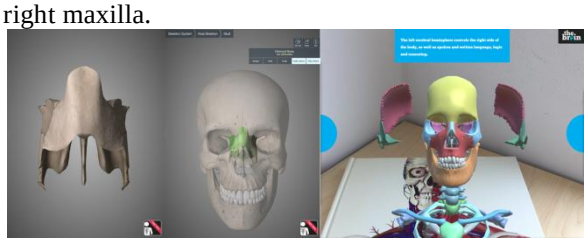

Fig. 12. An illustration of the ethmoid bone in anterior aspect

2) Posterior: The images shown in figure 13 was the posterior aspect, which indicated that from the Essential Skeleton 4, the ethmoid bone showed a precise shape and visible structure details, whereas in the Brain AR the ethmoid bone cannot be shown because of the fully obstructions by the occipital bone.

Fig. 13. An illustration of the ethmoid bone in posterior aspect

3) Left Lateral Aspect: The results shown in figure 14 was the left lateral aspect, which suggested that from both Essential Skeleton 4 and The Brain AR, the ethmoid bone illustrated a precise shape and visible structure details.

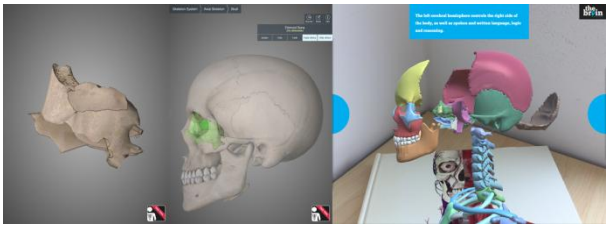

Fig. 14. An illustration of the ethmoid bone in left lateral aspect

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4) Right Lateral Aspect: The images shown in figure 15 was the right lateral aspect, which suggested that from both Essential Skeleton 4 and The Brain AR, the ethmoid bone showed a precise shape and visible structure details.

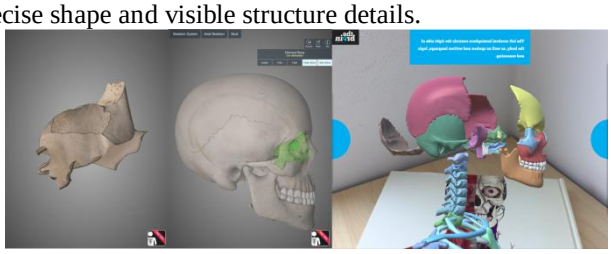

Fig. 15. An illustration of the ethmoid bone in right lateral aspect

5) Superior Aspect: The result displayed in figure 16 was the superior aspect, which suggested that from both Essential Skeleton 4 and The Brain AR, the ethmoid bone showed a precise shape and visible structure details.

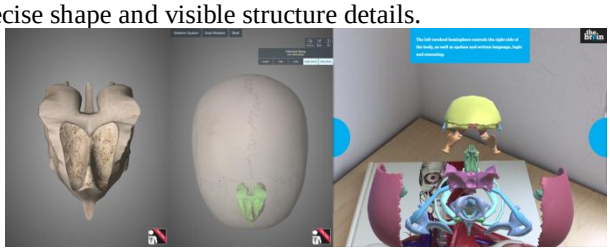

Fig. 16. An illustration of the ethmoid bone in superior aspect

6) Inferior Aspect: The images shown in figure 17 was the superior aspect, which suggested that from both Essential Skeleton 4 and The Brain AR, the ethmoid bone showed a precise shape and visible structure details.

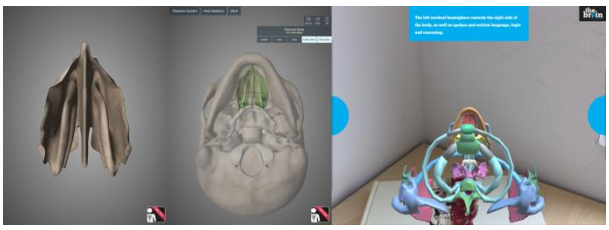

Fig. 16. An illustration of the ethmoid bone in superior aspect

6) Inferior Aspect: The images shown in figure 17 was the superior aspect, which suggested that from both Essential Skeleton 4 and The Brain AR, the ethmoid bone showed a precise shape and visible structure details.

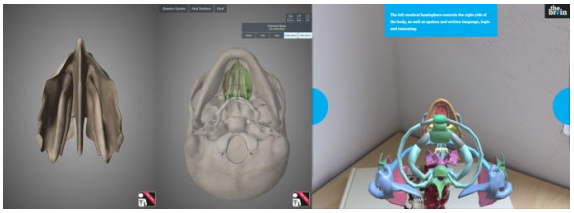

Fig. 17. An illustration of the ethmoid bone in inferior aspect

C. Image Quality Analysis

The quality of image output for both mobile applications needs to be analyzed as they contributed to the learning effect on students as a tool. The comparative results were shown in table 1.

VR Essential Skeleton 4 provided realistic images with precise details and very sharpened edges. The selected skull structure was highlighted in the color of green, whereas the background and other skull parts remained in the shade of gray, the contrasting colors formed un-confused images to help student with a better understanding of the precise position for different learning objectives. The texture details on the bone structure surface were detected and observed with no noise point in the image itself nor the background. However, VR Essential Skeleton 4 required tedious procedures and pre-known knowledge to locate a particular bone.

On the other hands, AR the Brain AR App provided distorted images with unprecise details and unsharpened edges. Human skull structures were illustrated in different colors; however, the background color was depended on the actual environment. The unobvious contrast may cause a confused image; as a result, the student loses intentions quickly. The texture details on the bone structure surface were unable to be detected and observed. However, The Brain AR App required non-tedious procedures to locate a specific bone; first-year students with no previous experiences or knowledge can be able to identify and visualize easily.

D. Image Quality and Student Learning Effect Analysis

The analysis of image quality and student learning effect was concluded in table 1.

Table 1: Image quality and learning effect evaluation criteria

Learning Effect Criteria		VR	AR
Image	Image sharpness	•Realistic and precise details; •Sharpened edges	•Distorted and unprecise details; •Unsharpened edges
	Precision of 3D images	•Visible texture details; •Clear instruction of shadowing	•Invisible texture details; •Unclear instruction of shadowing
	The visibility of the 3-Dimensional images	•Un-confused image contrast against background; •Highlighted green color on chosen parts; •No Noise in background	•Confused image contrast against background; •Different colors in parts; •Noise in background
	Object manipulation	•Tedious procedures	•Non-tedious procedures
Learner	Learning improvement	•Better discovering perspective position;	•Better discovering perspective position;

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		• More precised on position identification; • Permanent learning; • Increased attention; • Enhanced remembrance through quiz; • Fluoroscopy vision	• More precised on position identification; • Permanent learning; • Increased attention; • Euthyphoria vision
	Enhancement of understanding	• Self-learning; • Enhancing problem solving skill; • Virtualizing hidden bones with details; • Increased spatial ability; • Remembrance effectiveness on fluoroscopy	• Self-learning; • Enhancing problem solving skill; • Virtualizing hidden bones with details; • Increasing spatial ability; • Developed imagination; • Remembrance effectiveness on euthyphoria
	Terminology memorization	• Achieved learning objectives; • Stronger self-centered learning concept; • Manipulating application in real time; • Enhanced remembrance through quiz;	• More realistic virtual human model; • Distinguished color on closed parts; • More attractive on colorful scheme • Audio explication on medical terminology
Educator	Stimulating interest and motivating learning	• Fun, attractive and effective learning; • Increased engagement; • Providing a sense of reality; • Visualizing complex articulation • Saving time and space	• Fun, attractive and effective learning; • Increased engagement • Providing a sense of reality • Visualizing complex articulation • Increasing student participation • Providing flexibility

V. DISCUSSION

The teaching method of involving VR and AR technology provides a two-way interactive teaching form. The innovative learning experience enhances students' knowledge and expertise in a productive multi-modal learning environment by integrating virtual objects with real-world situation, bring higher learning satisfaction to students throughout their powerful interactive performance, also offer students with an innovative learning tool and learning experience, so that students can make mobile learning in a pleasant environment, self-learning. At the same time, enhance student's understanding and remembrance the placements, indentations, and textures of the human skull.

Also, the function was still not perfect; the user experience needs to be strengthened; the research of VR and AR technology in education system was still at the primary stage.

As markerless applications provide a more elevated sense of authenticity, the usage of these medical applications in education can be elongated. Attention should be associated with choosing the appropriate application and providing technological infrastructure while formulating educational applications with VR and AR technologies.

Selection of applications, while generating content with AR technologies, influenced the quality of the application. AR applications had a negative impact on physical factors, for example, light, image quality, and camera features. As a consequence, precaution should be applied to optimize the effect of certain elements.

VI. CONCLUSIONS & RECOMMENDATIONS

VR and AR presented students a virtual world that can collaborate and interact in classrooms, which can satisfy students' experience impression and curiosity, but also impart awareness in innovative ways, which can significantly improve the teaching effect of teachers, stimulate students' interest in learning and improve their learning efficiency.

This research demonstrated that VR and AR technology can be used to enhance student understanding and improve learning outcomes. However, in the use of VR and AR technology courseware to avoid too much rendering, which quickly interferes with the focus and difficulty of teaching, and even distracts students' attention.

Virtual communication has the function of bridging the gap between medicine teaching and learning. Future research can focus on how to optimize AR image technology, and how to use multimedia creation tools to produce AR works still need to make graphic colors automatically and adapt to different template plates and foregrounds color matching principles.

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