Immersive Learning for Medicine using Augmented Reality with iPads

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Abstract

The COVID-19 pandemic crisis has resulted in educational institutions across the world being pressured to revamp their teaching and learning practices, as well as to utilize the available technological tools to create content for remote learning. Medical education, on the other hand, requires a learning approach that is more appropriate with the program structure and technological advancements. In the medical domain, approaches as Augmented Reality (AR) could revolutionize the way to teach and train medical students. AR can be used in training for complex physiological systems to provide the medical students experience much closer to real-life, developing adaptive expertise and acquiring collaborative skills. AR technology could help physicians and surgeons-to-be learn about the latest methods and tools in their areas, as well as refining and encouraging their knowledge retention. In this capacity, AR is more than just a learning approach. Learning in the medical domain is usually situated in a real-life context. In other words, training in this real-life context is not always possible. AR learning environments potentially offer a meaningful situated learning experience that may enable the transfer of learning into the professional context. Previous studies were performed primarily into the development, usability, and initial implementation of AR learning environments. As such, this study was aimed to develop and evaluate an immersive learning environment for medical students using AR. The study applied the design and development research approach that involved three stages: (i) analysis; (ii) design and development; (iii) implementation and evaluation. This study described how AR enhanced the experiences of medical students, by improving understanding and knowledge, as well as practical and social skills. These elements were discussed within the context of AR in immersive medical education, which were action, performance, competency, and knowledge. Moreover, these elements were used to develop the final immersive learning environment for medical education using AR. Finally, this study also discussed the challenges of AR in teaching and learning, and proposed future directions for the use of this technology in revolutionizing medical education.

Keywords: Augmented Reality, Digital Learning, Immersive Learning, Learning Environment, Medical Education

Introduction

As we move towards the fourth industrial revolution (4IR), the way we approach education changes. As technologies get smarter, educational affordances will grow in ways we have never imagined. There is an urgent need to align current educational practices with the new educational affordance that 4IR offers in terms of physical, digital, and biological interconnectivity (World Economic Forum, 2016; Schwab, 2017). Augmented Reality (AR) for instance, is where digital objects are overlaid onto the real-world surroundings, facilitated by mobile devices, or other related tools (Holley & Hobbs, 2019). AR can be used to create a better learning experience. AR is being applied across disciplines in higher education, including history, biology, physics, chemistry, and geography. Imagine history teachers using AR to walk students around the Hanging Gardens in the ancient city of Babylon, biology teachers walk students around the human anatomy, physics teachers walk students around the solar system, and chemistry teachers walk students around the laboratory to conduct thermite reaction experiment.

There are different types of AR, which can be utilized in various ways to meet learning needs as: (1) Marker-based AR relies on a trigger object, for instance, a QR code, logo, or barcode to generate an augmented element. (2) Marker-less AR does not use a trigger object, in which the augmented element is activated when other criteria are met, for instance, GPS tracking data associated with mobile devices. (3) Projection-based AR needs a flat surface as a trigger object, simply move the device at a table, floor or wall, and the augmented element appears immediately. (4) Superimposition AR uses image recognition to augment parts of the real-world.

Higher education is in a state of constant evolution due to technological advancements. There are a lot of reasons for medical education programs to utilize AR. Since medical students need more situational experiences in medical care, especially for the sake of patient safety, there is a clear need to conduct a study about the use of AR in medical education. AR provides rich contextual learning for medical students to achieve core competencies, such as effective teamwork and decision making. AR provides opportunities for more authentic

learning and appeals to multiple learning styles, providing students more personalized and explorative learning experience. The patients' safety is safeguarded if mistakes are made during skills training with AR. AR is useful because it helps the medical students to understand concepts and spatial relationships, to strengthen cognitive-psychomotor abilities, to acquire knowledge and skills, and to prolong learning retention and shorten their learning curve. Students are also provided with authentic simulated experiences that lead to increase subjective attractiveness as well as other conveniences, including, time and cost.

According to Brunzini et al. (2020), Chung and Chung (2019), Hemanth et al. (2020), Herron (2016), and Kamphuis et al. (2014), there were several reasons why AR should be incorporated within medical education. AR is a powerful tool because it makes the learning experience and information access as easy, fast, and hassle-free as possible. Instead of searching content libraries, browsing the internet, or finding an expert, students can simply move their devices at the surface, image, or object to learn and relevant information will instantaneously display on the screen. Interestingly, AR does not need wearable technology, for instance, smart glasses, expensive headset, or smartwatch. Students can use their mobile devices to preview the learning composition in an AR session. AR offers visual and interactive experience than text-based tutorials or video-based lectures. The immersion leads to a more efficient and engaging learning experience. Students can scan a surface or an image of an object to activate learning. Students learn best when they have the opportunity to practice the hands-on activities. AR allows students to involve in various learning activities, even high-risk tasks by interacting with a virtual model, providing students with new a learning experience.

Studies by Brunzini et al. (2020), Maniam (2020), and Wang et al. (2017) found that AR increased the learning speed and made the learning process easier. When AR is used in training, it decreased the amount of time needed for practice, providing trainers an opportunity for assessment, and increased success rates. Herron (2016) believed that making AR technology available for student use can help to revolutionize medical education. Students can apply AR to construct new understanding based on the interaction with virtual objects, brings underlying information to life. In anatomy courses, AR technology allows students to observe 3D models that can be easily explored for training purposes. Instead of assisting medical students, AR can also impact patient care through its ability to enhance medical training. In other words, AR complements the real-world with virtual 3D objects, providing contextual, powerful, and situated learning experiences, as well as to help the exploration of the complex interconnections of information in the real life (Herron, 2016).

Immersive Learning Experience with Augmented Reality

Multimodal learning environments is defined as learning environments that use two different modes to represent the content knowledge: which are verbal and non-verbal. In the age of technology, the use of multimedia in conjunction with hypermedia have been successfully applied to many online learning environments in order to both enhance these environments and to cater for a wider variety of student learning styles. Multimodal learning environments allow instructional elements to be presented in more than one sensory mode which are visual, aural and written. In turn, materials that are presented in a variety of presentation modes may lead learners to perceive that it is easier to learn and improve attention, thus leading to improved learning performance (Moreno & Mayer, 2007).

The Cognitive Theory of Multimedia Learning Principle by Mayer (2005) states that words and graphics are more conducive to learning, rather than just text or graphics alone. In AR, understanding of message and lesson could be enhanced from a multimedia based simulated environment. The multimedia principle states that people learn more deeply from words and pictures than from words alone (Moreno & Mayor, 2007). However, simply adding words to pictures is not an effective way to ensure effective content delivery in educational videos. It is imperative to understand how human mind works keeping in mind the three assumptions of Dual Channel, Limited Capacity and Active Processing. This cognitive theory of multimedia learning principle proposes three main assumptions when it comes to learning with multimedia: (i) Dual Channel – There are two separate channels (auditory and visual) for processing information; (ii) Limited Capacity - Each channel has a limited (finite) capacity; and (iii) Active Processing - Learning is an active process of filtering, selecting, organizing, and integrating information based upon prior knowledge.

The design and developmental research approach (Richey & Klein, 2014) was applied in the study as follows:

1. Analysis phase: In this phase, needs analysis was conducted and aimed in capturing learning requirements of undergraduate medical students enrolled in Anatomy courses. The activity is conducted in Faculty of Medicine at a public research university in Malaysia.

2. Design and development phase: The findings from the analysis phase were used to elicit the factors as well as design and develop the output for the project. The factors related to this field were elicited via fuzzy Delphi by Chang et al. (2015). A consensus on the factors is gained from a panel of experts comprised of subject-matter experts, pedagogical experts, technical experts, medical experts, and also surgeons. The conceptual framework used for this study was based on Zhu et al. (2015). By using Reality Composer on iPad, the AR anatomy course was designed and developed, focusing on four learning modules: (i) external features of the heart, (ii) blood supply of coronary arteries, (iii) chambers of the heart, and (iv) great vessels of the heart.

3. Implementation and evaluation phase: The outputs were then assessed using qualitative approach and analysis, which included clinical analysis. It was conducted with undergraduate medical students in Faculty of Medicine at a public research university in Malaysia, in collaboration with the Department of Anatomy. This produced the final immersive learning environment for medical students.

Overall, the objectives of this study were:
1. To identify learning requirements of medical students with regards to an immersive learning environment using AR
2. To develop an immersive learning environment for medical students using AR
3. To evaluate the developed immersive learning environment for medical students using AR
4. To make recommendations based on the developed immersive learning environment for medical students using AR

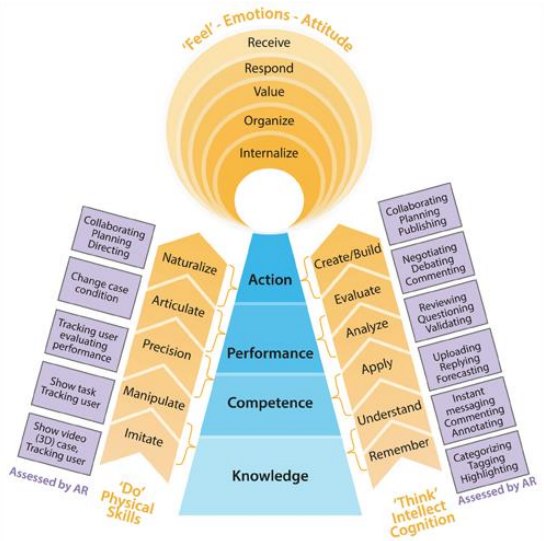

Figure 1: Conceptual framework (Zhu et al., 2015)

Learning Outcomes with an AR-based Anatomy Course

AR is a technology that enables medical students to seamlessly apply the learned knowledge and skills, preparing them for the real world of medical training and practice. By addressing specific professional skills and providing a safe educational environment, an AR course for learning in medicine were employed to enhance medical students' experiences as can be seen in Figure 2. In the AR anatomy learning module, a 3D heart shows external features, allowing a medical student to interact with the organ. Here, the student can explore blood supply of coronary arteries, chambers and great vessels of the heart by using an iPad or other mobile devices.

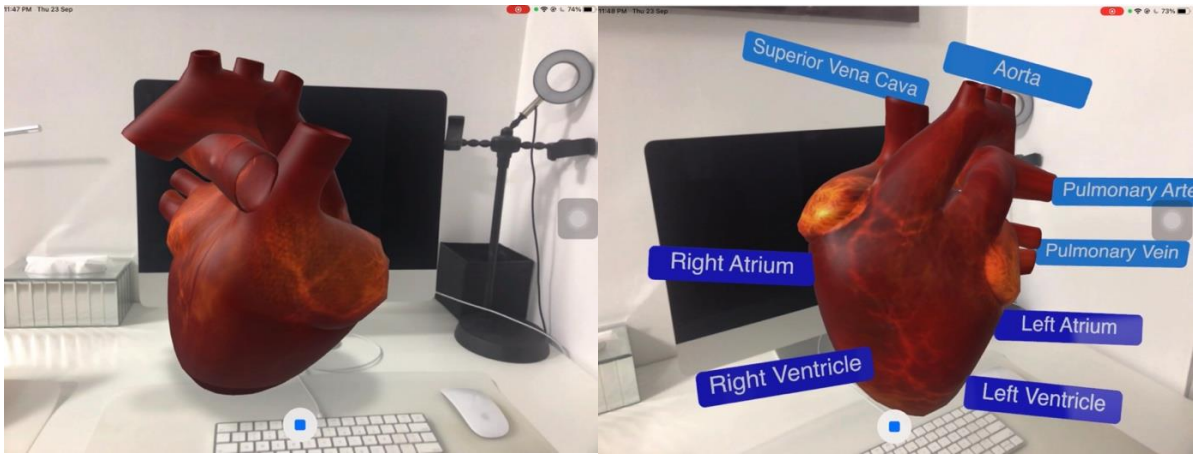

Figure 2: AR-based Anatomy Course

Apart from fun and stimulating, learning with AR is typically related to more positive personal experiences. AR could improve online learning delivery, application of sensory systems and presentation, which are the essential elements of Mayer's cognitive theory of multimedia learning. University students are often associated with higher levels of digital literacy. The use of iPads, tablets and smartphones among higher education students are generally high. Thus, in this study, medical students reported that they feel confident with adopting AR alternatives to conventional learning approaches, for instance, lecture notes or textbook. AR allows the use of personal digital devices that enables self-paced learning. In this study, medical students could ran anatomy modules such as external features of the heart, blood supply of coronary arteries, chambers of the heart and great vessels of the heart on an iPad. Virtual Reality (VR) on the other hand, requires special interface devices to achieve similar learning outcomes as AR. Furthermore, AR is likely to be less prone to adverse effects of using special interface devices, such as VR headsets that could cause dizziness, headache, nausea, as well as blurred vision.

Undoubtedly, the ability of AR in medical education could support students' experiences, which in turn leads to enhanced learning outcomes. Other than that, medical students who successfully completed AR anatomy activities were likely to accomplish both practical skills and theoretical knowledge. Overall, this study focused on the effect of AR on students' experience and learning outcomes in terms of the following elements: action, performance, competency, and knowledge. Future medical professionals are expected to perform their responsibilities within a broad spectrum of health care settings, thus medical education involves extensive learning on human behavior and social interactions. AR provides an opportunity to train medical students for complex social conditions in a save and controlled environment. Besides, AR enables development of specific competencies that are critical for medical professionals. Although AR in medical education has been viewed as a means to enhance practical skills and knowledge, it also offers different conditions to support social skills in healthcare settings.

To conclude, the expected findings and knowledge from this study were as follows:

1. An immersive learning environment for medical students using AR
2. Factors of successful immersive learning environments for medical students using AR
3. Transfer of learning results acquired with the AR technology to the professional context

Discussions

The year of 2020 is significant to the people around the world with the outbreak of COVID-19 that has been declared a pandemic by the World Health Organization (WHO) which involves many countries in the world. Due to the pandemic, Prime Minister of Malaysia had announced to have a nationwide Movement Control Order (MCO) from 2020 until 2021 that is intended to mitigate the spread of Covid-19 through social distancing. All of the sectors which included schools, colleges, and higher learning institutions are forced to close until further announcements. Students from all levels need to continue learning and studying from home through online learning. Therefore, it is important to introduce AR technology as part of the online learning to help the medical students during the pandemic.

Students have to fully access technology and online learning during the pandemic as the institutions and

universities are not allowed to open. Hence, the students need to be motivated and engaged in their own learning and it has become an important part of the research in the field. Oliveira et. al. (2019) pointed out that due to the advancement of technological innovation in recent years, there is a dire need for more educational research that can foster better understanding on how learning can be supported by emerging technologies such as AR.

Since the application of AR in orthopedics, the adoption of AR in medical education has increased significantly (Wu et al., 2013). However, the cost of designing and developing these AR platforms is the most significant challenge faced by the university. This issue is related to the lack of resources to fulfil the needs of medical students that hinders the application of AR in this field. Accessibility is another major concern regarding this technology, whether all students are able to access an equivalent user experience. AR can be manipulated on iPads, tablets or smartphones, which all these mobile devices usually contain a GPS, processor, display screen, camera, and microphone – all the hardware required for AR. What will happen to poor students who cannot afford to own those smart devices?

AR provides opportunities for educators in medical education to design an immersive learning experience. This new technology however have enabled educators to push the boundaries of conventional pedagogies to create an engaging, student-centered, and enriching learning experience for the medical students. Apart from learning, AR allows students to experience the material and learning contents. The COVID-19 pandemic crisis has resulted in educational institutions across the world being pressured to revamp their teaching and learning practices, highlighting the significance of advanced technologies, including AR to ensure student learning is not hindered. AR can be used in training for complex physiological systems to provide the medical students experience much closer to real-life, developing adaptive expertise and acquiring collaborative skills.

With all the change and technology advancement, making AR technologies affordable will be the main agenda. Collaborations between universities, industries and increased funding for this effort will pave way for latest AR platforms in medical education. The purpose for this collaboration is to bring experts and social scientists from the industry together, designing and developing the platforms for AR in medical education and training. AR anatomy textbook, for instance could allow students to immerse themselves in the learning experience. The ability to visualize human anatomy topics will support deeper understanding and retention of the physiology of the human body. AR textbook could provide an interactive contents for both students and educators if compared to the traditional textbook that are text-based and stagnant. Thus, considering the ability of AR to enable multiple users to collaborate in the same platform could assist in solving the isolation problem that AR may create for students.

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