Teaching with Disruptive Technology: The Use of Augmented, Virtual, and Mixed Reality (HoloLens) for Disease Education

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Teaching with disruptive technology: The use of augmented, virtual, and mixed reality (HoloLens) for disease education.

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Abstract

Modern technologies are often utilised in schools or universities with a variety of educational goals in mind. Of particular interest is the enhanced interactivity and engagement offered by mixed reality devices such as the HoloLens, as well as the ability to explore anatomical models of disease using augmented and virtual reality. As the students are required to learn an ever-increasing number of diseases within a university health science or medicine degree, it is crucial to consider which technologies provide value to educators and students. This chapter explores the opportunities for using modern disruptive technologies to teach a curriculum surrounding disease. For relevant examples, a focus will be placed on asthma as a respiratory disease which is increasing in prevalence, and stroke as a neurological and cardiovascular disease. The complexities for creating effective educational curricula around these diseases will be explored, along with the benefits of using augmented reality and mixed reality as viable teaching technologies in a range of use-cases.

Keywords: Virtual reality, augmented reality, mixed reality, asthma, stroke, medical education.

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Medical knowledge is expanding, and the complexity arising from this growth must be supported by effective teaching applications and resources (Densen, 2011). Students within health, medical or biomedical sciences degrees are required to learn about a wide range of diseases and disorders as part of their curriculum. Most of these students will matriculate into primary or allied health professional programs and pursue careers in these fields (Panaretos et al., 2019). As a result, a clear knowledge of a broad range of diseases is essential (Richards, 2003). For many, the sheer content to learn regarding the various diseases and disorders taught within a health science or medical program can be challenging (Stegers-Jager et al., 2017). This increasing number of information identifies a need to investigate effective methods to educate students in a way that enhances their understanding and comprehension of specific diseases.

An undergraduate university degree in health sciences is a relatively generalist degree, as it provides knowledge and skills applicable for a wide range of professions and ensures graduates with multiple postgraduate career options. In the majority of cases, students emerging from undergraduate health science degrees intend to undertake further study in the fields of medicine or within allied health. In a recent study by Panaretos et al. (2019), it was found that within a cohort of 559 students studying a bachelor of science, 69% had an intended graduate destination of medicine, 34% of research, 14% science industry and 8% allied health. As a result, Australian medical schools have seen an increasing number of students graduating in the last decade, with a 53% increase from 2008 to 2018 (Medical Deans, 2019). The large proportion of primary health professionals that will emerge from these degrees will be the first point of call for many patients and, as such, must be equipped with the knowledge and skills required to perform investigations effectively in practice (Moro and McLean, 2017, Moro et al., 2019b).

Modern-day Teaching Environment

Modern-day tertiary education is shifting from traditional methods of teaching in lectures and tutorials to more self-directed, visual methods of learning. Furthermore, advances in technology have provided educators with tools to enhance their ability to deliver content in an ever-progressing environment. Incorporating technology into health science and medical

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education is essential for knowledge acquisition in these disciplines where learning is predominantly experimental, active and self-directed (Moro et al., 2020). By using modern visualisation tools, it is possible to combine three-dimensional (3D) models of relevant human structures with other information sources, such as text and audio. It also gives rise to interactive tools capable of meeting the demands fosathr increased knowledge in health sciences and medicine curricula that students currently face.

Recent studies have investigated the effectiveness of incorporating modern technology into the training of forthcoming health professionals to enhance knowledge acquisition and understanding (Birt et al., 2018). The technological resources that are being developed to improve current education practices are already readily available for the general public. These include computers, tablets, and smartphones. These tools also enable the use of interactive educational games, as well as virtual reality and augmented reality applications. Furthermore, enhanced visual information in combination with audio and on-screen text may facilitate learning at a higher level when compared to simple text-based resources (Mayer, 2014, Moro et al., 2016b), such as textbooks and anatomical atlases.

The incorporation of computers and advanced technology in student learning has brought about significant institutional change for educators. Currently, modern-day educational institutions encourage a constructivist learning environment, where the teacher has been traditionally established as a facilitator of knowledge (Stenhouse, 1975). As technology continues to evolve rapidly, the demand for engaging student-centred learning increases and challenges modern-day educators to facilitate this demand. This paradigm shift into student-centred learning has further emphasized learner autonomy, where the traditional role of the teacher is becoming increasingly dependent on advanced multimodal technology.

A study by Kim et al. (2017) compared the effectiveness of a smartphone-based application and a traditional lecture to educate nurses about infant airway obstruction. Enhanced knowledge, skills and confidence scores were reported in the performance of nurses following intervention with the education-based application. Although knowledge retention was not assessed and the number of times participants accessed the application was not recorded, it was reported that the use of familiar technology and consistent access to resources are some of the advantages of 3D digital models.

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More recent studies have investigated the effectiveness of mixed reality multimedia applications delivered through augmented reality (AR) and virtual reality (VR) as novel technologies for enhancing the educational environment and offering interactive, student-centred learning. The advancement of technology has made it possible to transform passive learning with textbooks and plastic models to engaging interactions with 3D objects (Hoffman, 2016). In Birt et al. (2018) study, the use of mobile devices in visualising 3D models in higher education health science and medicine classrooms was evaluated. The authors noted that the new learning tools were well received and associated with enhanced learning outcomes. Although significant improvements were not observed in student knowledge test scores, this could be attributed to the "novelty effect" that occurs as a result of using innovative technology. It could have also occurred as a result of the user not being familiar with the technology and spending more time familiarizing themselves with it rather than engaging with the study materials.

It has been suggested that frequent practice with AR and VR in the learning environment will improve student engagement and comprehension of health science content. While there are reports of holographic devices, such as Microsoft's HoloLens, being efficient, precise and hands-free tools in medical training (Brun et al., 2019), there remains limited research on the effectiveness of the HoloLens as a learning tool to enhance knowledge acquisition in tertiary education.

Choice of Technology for Teaching Anatomy and Physiology

The anatomy of the human body is often taught alongside the clinical relevance, forming relationships between the physiology and anatomy of structures in three-dimensional (3D) space. The current pedagogical methods to provide the 3D representations of anatomical structures in health science and medicine courses are through cadavers or silicon models. These resources are typically used in conjunction with textbooks to form links between the structures and functions of the human body (Codd and Choudhury, 2011). Both learning approaches have their advantages. Cadavers support the learning process by exposing students to anatomical variations or pathological conditions during dissection, whereas students can use textbooks in their own time for additional learning. However, these methods also have substantial limitations. Cadaver use in anatomical teaching is constrained by

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financial and ethical considerations, as well as the availability of supervisors (Turney, 2007). However, their use is often justified for active learning, as visual information in textbooks does not provide realistic detail in its presentation on a two-dimensional plane (Birt et al., 2018). Alternatively, the use of silicon models combines the advantages of both cadavers and textbooks, although a quality selection of these models can also become expensive and unavailable for student use outside of the teaching classroom or laboratory (Codd and Choudhury, 2011). More recently, the development of technology and 3D visualisation devices have provided new possibilities to enhance current pedagogical practices. Specifically, the introduction of virtual reality, augmented reality, and mixed reality devices as a supplementary tool to the currently used cadavers and silicon models to provide additional modes of learning.

The ability to mentally manipulate objects and achieve spatial understanding in 3D is essential to medical practice. In particular, professionals undertaking medical procedures rely on spatial mental models of anatomical structures when internal structures of the body are not directly visible (Erolin, 2019). Knowledge attainment and understanding in medical studies is reported to be highly associated with a students' spatial ability, particularly in surgical training and clinical education (Hegarty et al., 2009, Anastakis et al., 2000, Lufler et al., 2012). Moreover, Lufler et al. (2012) claim that visual-spatial ability may be used as an indicator of success in anatomical training. This study suggested that medical educators should implement a Mental Rotations Test (MRT) at the beginning of an anatomy courses to identify students that find it challenging to mentally rotate 3D structures. This would help the educators to identify students that require additional help and help them tailor specific pedagogical approaches to enhance their understanding of spatial structures.

The human body consists of many complex anatomical structures and would benefit from being represented in 3D as it is often difficult to achieve a spatial understanding from viewing 2D images. A randomised controlled study was carried out on a cohort of 63 medical students where both groups attended two identical seminars on congenital heart defects, but only the intervention group received 3D-printed heart models to enhance the lesson. Higher knowledge acquisition and structural conceptualisation scores were reported in the intervention group (Su et al., 2018). This improvement can be attributed to 3D models allowing for spatial and structural visualisation that traditional learning methods lack. Although general 3D heart models were used, the results are promising for the potential for

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3D technology being at the forefront of effective medical education. As this type of visualisation technology gets implemented more widely within tertiary institutions across the world, the availability of 3D models representing not only structures in health but also in disease will become accessible. Once created, these resources can be shared freely and not constrained by geographic location.

Defining modern disruptive technologies

As described, disease education is primarily taught using 2D-based illustrations and text-focused resources. Developments in learning modes have now disrupted this process, and the educator has a range of technologies to draw upon for the provision of content (Moro et al., 2020). In most cases, virtual reality, augmented reality and mixed reality applications have shown to be effective in enhancing the learning experience in some form or another. The definitions used throughout this document are adapted from (Moro et al., 2017c).

- <u>Virtual reality</u>: The user's senses (sight, hearing and motion) are fully immersed in a synthetic environment that mimics the properties of the real world through high resolution, high refresh rate (constantly-updating) head-mounted displays, stereo headphones and motion-tracking systems.
- <u>Augmented reality</u>: Using a camera and screen (i.e. smartphone or tablet) digital models are superimposed into the real-world. The user is then able to interact with both the real and virtual elements of their surrounding environment.
- <u>Mixed reality</u>: While augmented reality overlays digital information onto real-world elements, mixed reality allows for an additional layer of interactivity. Virtual objects placed within a mixed reality environment can be interacted with and respond to as if they were real objects. The user's hand and feet, as well as other people, become part of the environment, in which all objects, real and virtual, are fully interactable.

Depending on the use-case, there remains some overlap between the technologies. For example, a mixed reality headset such as the Microsoft HoloLens can be set up in a way that only enables viewing of virtual reality, with limited visibility of the real world and object interaction solely through digital means. This technology allows educators a full degree of freedom when determining the best use-case for their preferred device, without being

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restricted to any particular level of the ‘virtuality continuum’. In addition, mixing the modes of learning, such as augmented reality alongside tablet-applications, can provide multimodal benefits for users, where the strengths of each device are used to its full potential (Moro et al., 2019a).

Virtual reality

The term ‘virtual reality’ dates back to 1960s when a mechanical device, Sensorama simulator (Heilig, 1962), was created to provide a multi-sensory experience of riding a motorcycle. This experience included a three-dimensional colour film accompanied by sound, smell, the feeling of motion and even the sensation of wind on the user’s face. However, the technology was not yet advanced enough and affordable to provide immersive experiences for general masses. Before the release of the first consumer-grade head-mounted virtual reality display in 2013 by Oculus Rift, VR technology was expensive and only available for educational purposes to a very select group of people to provide training simulators for medical doctors, military fighter pilots (Drummond et al., 2014), as well as training for NASA astronauts (Vince, 1995). Since then, virtual reality technology has evolved rapidly to provide highly immersive virtual environments capable of mimicking the real world. Since the initial release of Oculus Rift from Oculus VR and Facebook, there have been several competitor companies creating their own VR head-mounted displays, such as HTC Vive from HTC and Valve Corporation, PlayStation VR from Sony Corporations, and Samsung Gear VR from Samsung Electronics, making this technology available for the wider public, education and research. The new generation head-mounted displays (HMDs) that are used to immerse the user in a virtual environment have a high pixel density that aids to create a realistic virtual environment and a high refresh rate that helps reduce latency, which has previously been associated with causing motion sickness.

The use and effectiveness of modern virtual reality devices in medicine and health science education have been well documented since the release of immersive virtual reality devices with HMDs. In medical education, realistic training experiences in laparoscopy surgery (Huber et al., 2018), emergency medicine (McGrath et al., 2018), endoscopy investigations (Mahmood et al., 2018), urological surgery (Schulz et al., 2019), orthopaedic surgery (Logishetty et al., 2019), medical imaging (Gunn et al., 2018) and study of anatomical

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structures (Ekstrand et al., 2018) provides a safe environment for students to practice their skills. Surgical training using VR has shown to be beneficial for increasing perceived self-confidence levels when compared to students in the control group, especially in novice students (Pulijala et al., 2018).

Augmented reality

Augmented reality (AR) is defined as a technology that allows individuals to interact with virtual models of anatomy or other complex processes using a smart device, such as a mobile phone or smart tablet (Moro et al., 2017a) through the merging of physical and digital realities (British Computer Society, 2014). Several research studies have investigated the feasibility of AR as an interactive educational tool capable of shifting teacher-centred learning towards active, student-centred learning (Moro et al., 2017b). AR's contribution to education mostly relates to the new dimensions offered in teaching and learning where it has the potential to encourage students to learn independently and discover abstract theories, phenomena, processes, and behaviours as well as features that would typically not be accessible or safe to use (Akçayır and Akçayır, 2016). AR offers the most affordable and accessible option to facilitate learning, as it can be run on a user's smartphone, tablet, laptop or other camera-enabled devices, while still providing similar benefits to those seen in other modes (Moro et al., 2017e, Kuehn, 2018, Moro and Gregory, 2019). The applications of AR can be further extended into clinical education and the teaching of human anatomy and pathophysiology, where multiple studies indicate success in improving student engagement and lesson enjoyability compared to traditional modes of teaching in both medical and non-medical related fields (Akçayır and Akçayır, 2016). These studies indicate that AR may become increasingly feasible as an educational tool, not only for students and young adults but also in educating the wider community.

Many educational intervention-based studies suggest that AR improves student learning outcomes. Chang et al. (2015) investigated the application of AR as a teaching tool for 87 tertiary students studying historical buildings in an outdoor setting. The study adopted a quasi-experimental design to assess the feasibility of AR as an educational intervention, finding that students in the AR intervention group had higher learning outcomes, in areas

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such as knowledge score, satisfaction and motivation comparative to the control group. Furthermore, this study found that interactions between students as well as physical interactions with the historical site became limited as students were much more engaged with the AR application, suggesting the potential for the technology itself to be disruptive to collaborative learning efforts (Chang et al., 2015). Another study conducted by Silva et al. (2017), using 21 students from three tertiary institutions in the state of Ceará (Brazil), sought to identify AR's role in the de-stigmatisation of schizophrenia. Results from a questionnaire revealed that the simulation was instrumental in educating schizophrenia symptoms as well as increasing empathy for medical students towards individuals with schizophrenia. These findings are also concurrent with a study conducted by Ferrer-Torregrosa et al. (2015) where AR was found to enhance learning outcomes, particularly in teaching anatomical models, in addition to enhancing participant's motivation and positivity towards their learning.

One of the essential conditions for developing new educational interventions is the student's satisfaction and confidence while using these tools. In research studies evaluating the effectiveness of an educational intervention, it is most often examined using Likert scales. Studies have shown that the use of AR enhances student motivation, competency and satisfaction while using these tools in their education (Akçayır and Akçayır, 2016). In a study by Rosenbaum et al. (2007), where an outbreak of influenza was stimulated via the use of AR, found that participants reported increased curiosity towards this educational intervention. Some of the concepts covered in this learning tool included how viruses affect an individual's health, treatment options and prevention of virus spreading in the community. Despite these positive findings, the results could be explained by the novelty effect of using this technology (Lu and Liu, 2015) which may potentially diminish over time as students become familiar with using this technology as part of their routine education.

This technology also supports a collaborative, team-based learning approach to accomplish a task. This approach was investigated in Barmaki et al. (2019) study, where students used AR tools to study the musculoskeletal system. In comparison to the control condition, the AR group that used interactive system scored significantly higher in knowledge retention and reported a higher level of engagement. The effects of mobile AR application for examining different types of gunshot wounds as part of forensic medicine course was investigated in Albrecht et al. (2013) study. Similarly, students worked in pairs by placing AR markers on each other's skins to better visualise gunshot wounds. Even though the control group

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students, who used a textbook to learn about gunshot wounds, were allowed to interact freely with other students of the group, no interactions were observed during the study. In contrast, as the AR group shared a mobile device and markers between the two individuals, it supported social interaction. The authors noted that the group that received AR intervention also performed significantly better in the knowledge test administered at the conclusion of the activity. As such, these two examples out of many demonstrated that AR works exceptionally well both as an individual learning tool and also a method for collaborative learning.

Though AR has the potential to change the current landscape of how information is delivered to students, it is not without its limitations. Potential difficulties relating to AR may include the virtually rendered image or animation itself and feelings of frustration should the application not work correctly. Another limitation may be the disruption of the interaction between other people, which counteracts the purpose of collaborative learning. Otherwise, AR is designed for specific knowledge fields where teachers, at all levels of education, may not have the means to develop learning content for students applying for their respective assessments. Further developments should be made to AR so that teachers can create their personalised content. Despite these limitations, there is evidence that supports the effectiveness of AR in educational settings, learning outcomes, student engagement and motivation towards learning (Bacca et al., 2014).

Figure 1: Example of a Biomedical Sciences student using augmented reality to investigate the brain. This technology allows for the full utilisation of 3D representations of the brain, enabling a higher-level of instruction in diseases such as stroke, compared to 2D illustrations. The rightmost image also shows the potential for users to remove layers and regions of the brain as part of an augmented reality lesson. Image: C. Moro.

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Mixed reality and holograms

Similar to virtual and augmented reality, mixed reality is one of the most recently developed three-dimensional visualisation tools that are now available to the general consumer. The visual displays within mixed reality devices are presented as holographic renderings of images that merge these virtual images into the real world. The most supported holographic technology is HoloLens 2 by Microsoft, which was made available to the public in late November of 2019. The HoloLens utilises a head-mounted computer that enables its users to see and hear the augmented world, without interfering their physical reality (Hoffman, 2016). This collaboration of the real and virtual environment addresses the shortcomings of augmented and virtual reality devices, where adverse health effects are experienced, such as cybersickness, blurred vision and disorientation (Moro et al., 2017d). These symptoms occur in VR environments due to a mismatch of the visual information of moving, while the vestibular systems tells the body it is stationary (Howarth and Costello, 1997). As the individual is able to perceive both the real world and the digital world, these adverse effects are no longer experienced.

The high-precision holographic images presented within the HoloLens allow this technology to be integrated into educational institutions of all levels. In particular, incorporating mixed reality holograms within the health sciences curriculum in tertiary education will allow students to visualise human anatomical structures from all perspectives, providing further depth to their learning (Moro and Gregory, 2019). Anatomical models displayed in the HoloLens can be placed in a surgical plane so that the user can explore and virtually dissect structures via hand gestures, providing a more realistic and clinically relevant surgical experience compared to textbooks (Maniam et al., 2020). The integration of mixed reality technology into anatomical learning will enable students to readily access content, which addresses the constraints of cadaver use (Incekara et al., 2018). Additional advantages of the HoloLens include the ability for this device to detect precise shapes or objects in real space and accurately align the hologram with these structures, which has been used in surgical training procedures (Mitsuno et al., 2019). Moreover, this tool would be beneficial in anatomical education due to the hands-free nature of the device for students to take notes while learning (Incekara et al., 2018).

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Holograms demonstrate the potential to significantly improve knowledge scores and spatial awareness compared to traditional teaching methods, particularly for anatomical learning (Hackett and Proctor, 2018). The benefits of 3D holographic visualisations compared with printed images, were recently investigated in a study population of 179 nursing students during a cardiac anatomy course. Hackett and Proctor (2018) reported significant improvement in anatomical knowledge in the hologram intervention compared with printed images. It has been suggested that this improvement in knowledge scores could be attributed to the cognitive efficiency of holograms, shown by a reported decrease in the cognitive load of students using holograms compared to the mental capacity required to manipulate 2D images visually. However, this study is lacking follow-up of knowledge retention to assess the long-term gains of holographic technology.

Figure 2: Students studying health and medicine investigate physiology and anatomy using the Microsoft HoloLens mixed reality device. Image: C Moro.

Future studies should investigate knowledge retention scores from novel technologies, particularly the holograms, as results may be influenced by increased interest in new learning methods. The short- and long-term learning outcomes of mixed reality interventions in anatomical education were recently investigated in a 2020 randomised controlled trial. Second-year medical students were randomised into three groups utilising three learning tools, including textbook-style learning, laptop-based learning and a Microsoft HoloLens application. The study reported that although the HoloLens group scored lower on the short-term knowledge acquisition test compared to the other groups, their knowledge retention scores after one month were superior. It was suggested that the lack of short-term knowledge acquisition with the HoloLens was due to a lack of time and orientation with the mixed reality device, as indicated by participant responses. These findings highlight the potential for mixed reality tools to support and enhance the student learning experience in anatomy education; however, they must be accompanied by an orientation to the new learning tool to maximise learning outcomes (Wang et al., 2020).

The mixed reality platform has also demonstrated success as a tool to assist health professional training. Thirty-six congenital heart disease (CHD) professionals tested a HoloLens application displaying segmented cardiac computed tomography angiogram (CTA) images (Brun et al., 2019). Participants were able to share and manipulate the holographic visualisations of the heart in a surgical conference. It was reported that this method has the potential for using the HoloLens as a diagnostic and planning tool to assist surgeons in preoperative training. The study group, consisting of CHD professionals with varying ages and experience levels, rated the holographic experience highly positively, suggesting the potential for this tool to be used across a more generalised population.

Reports have also suggested the clinical feasibility of hologram technology for surgical procedures. This approach was seen in the accurate alignment of holograms with the actual surgical field in the case of a post-traumatic foreign body in the tibia (Mitsuno et al., 2019). While the holograms are not yet technically advanced to use as a strict means of navigation in surgery, the accuracy is sufficient to apply to intraoperative simulation for assistance with objective judgement. Further contributing to the clinical usefulness of this tool was a study using 3D hologram reconstructions of brain tumours in 25 patients to assess its efficiency in preoperative neurosurgery (Incekara et al., 2018). While the average planning time was longer when compared to standard systems, holograms were successfully created in all of the patients. Suggestions for further improvement of this method to enhance the surgeon's interpretation and focus of the structures include overlaying patient data directly on the field of view within the hologram.

Using Modern Technology to Teach Disease

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Learning tools for students in the health science or medicine fields need to be readily available, three-dimensional and interactive for optimal engagement. Most diseases and disorders studied in health science and medicine exist in three dimensions and are often not best represented using standard two-dimensional screens. An additional benefit of using modern visualisation technology for disease education is that it can be updated to provide rapid updates to accommodate new information. For example, new research has suggested the potential for lower urinary tract diseases such as overactive bladder and interstitial cystitis to have involvement from the urothelium, the bladder's inner lining (Stromberga et al., 2019, Stromberga et al., 2020, Moro et al., 2016a, Moro and Chess-Williams, 2012). As novel research of this kind is replicated and validated, these facts can be introduced quickly and seamlessly into virtual lessons, something not possible with traditional print-based textbooks and resources. Living with chronic disease places a significant burden on the patient, as well as their family and carers. In particular, two such diseases are stroke and asthma. These conditions present themselves at different stages of life, and thus future healthcare professionals must be educated appropriately to ensure proper management and care.

The complexities around stroke education

The heart is a complex anatomical structure, in which the relationships of its components can vastly alter its function in both health and disease states. The challenge for university students is to understand those relationships and predict their impact on physiology. Those attempting to comprehend these complex relationships are often forced to use two-dimension images presented in atlases and medical textbooks. Modern visualisation technology presents a novel and potentially effective digital tools capable of benefitting students exploring the various cardiac pathologies. One such cardiac pathology that would greatly benefit from the integration of novel education tools is stroke.

Stroke is defined as a syndrome relating to deficits in the vascularisation of the brain (Tyrrel, 2008). Ischaemic stroke and haemorrhagic stroke constitute the two major classifications of stroke. Stroke is one of the leading causes of death and disability in Australia, accounting for 6.8% of all deaths in 2015 (Australian Bureau of Statistics, 2017). In 2011, stroke accounted for 3.0% of the total burden of disease in Australia and was the eighth-leading specific cause of disease burden. Stroke is ranked the third highest disease burden for those aged eighty-five

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and over, accounting for approximately 7.0% of the total burden of disease in men and approximately 9.0% of the total burden in women. Moreover, as the prevalence of stroke generally increases with age (Australian Bureau of Statistics, 2017), and with an ageing population there is expected to be a growing strain on health care teams; thus placing importance on developing quality and effective educational resources for future healthcare professionals tasked to care for these patients.

There may be a particular benefit in using AR to educate the community in cardiovascular health and disease management, where cardiovascular diseases accounted for 27.0% of all Australian deaths in 2017 (Australian Bureau of Statistics, 2018). Furthermore, cerebrovascular diseases, which includes stroke, accounted for 6.3% of all Australian deaths in 2017 (Australian Bureau of Statistics, 2018). Educating an individual in health and disease management, and thus improving their health literacy, is noted to be of benefit to overall recovery, with relationship observed between health literacy, health behaviours and subsequent health outcomes (Pamuk et al., 1998). Health professionals also hold a crucial role in educating patients, ensuring that they receive quality information regarding their disease is essential. It further reinforces the importance of enhancing stroke education in the tertiary system, as it enables higher-order learning for students studying health profession degrees. In this area, the integration of technologies such as augmented and mixed reality can affect students, all the way up to patients, families and carers.

Stroke management through education

The complexities surrounding the education of any curricula for diseases, such as stroke, do not solely rest on the anatomy and physiology. Knowledge of common treatments, patient recovery regimens, and even dietary alterations and patient-focused educational interventions can also help a student comprehend the disease and associated health impacts on patients. This is particularly holds true in stroke, where its management and treatment are dependent on the underlying aetiology. For example, distinguishing stroke into either of its major classifications helps determine the most suitable pharmacological interventions. Irrespective of stroke classification and pharmacological interventions, there is evidence to suggest that patients suffering from acute stroke have better health outcomes when admitted to a hospital unit that is specialised for the care of patients with all types of acute stroke, such as ischaemic stroke, intracerebral haemorrhagic stroke and subarachnoid haemorrhagic stroke (Candelise

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et al., 2007, Di Carlo et al., 2011, Govan et al., 2007, Langhorne et al., 2018, Meretoja et al., 2010). A specialised stroke care unit can take on some of this care. This unit is generally defined as one that includes dedicated telemetry beds continuously staffed by a multi-disciplinary team of physicians, nurses and other medical professionals who specialise in stroke care or expertise in vascular neurology and neurosurgery (Alberts et al., 2005, Alberts et al., 2011). Furthermore, where there is the management of fever, hyperglycaemia, and swallowing dysfunction, the implementation of stroke protocols and disease-performance measures have been shown to improve health outcomes alongside decreasing the risk of stroke-related complications, especially post-discharge from stroke units (Middleton et al., 2011). As such, the content best suited for student learning around stroke involves not just the presentation, but may include potential interventions, the treatment teams and even explore the ideal patient journey through the health system as they progress after presenting.

The complexities around asthma education

Asthma is a disorder that is commonly integrated within the health sciences and medicine curricula. Asthma is a chronic, non-communicable disease of the airways that affects people of all ages. It is characterised by reversible, episodic attacks of wheezing, shortness of breath, chest tightness, and coughing (Papi et al., 2018). An asthma attack is typically triggered by factors such as environmental allergens, occupational exposure, exercise, stress or viral respiratory tract infections. It remains one of the most common chronic diseases globally, affecting over 11% of Australians, and up to 10% of the worldwide population (Australian Institute of Health and Welfare, 2019, Morris and Pearson, 2019). The Global Asthma Network Report estimated that a total of 334 million people worldwide are affected by asthma, which is an increase of 3.6% since the previous report in 2006 (Global Asthma Network, 2018). Annually, a quarter of a million asthma deaths are reported worldwide, and 15 million disability-adjusted life-years are lost (World Health Organisation, 2019). Physicians are the primary point of contact for asthma education and control. However, it is often reported that physicians lack the time, skills, motivation and resources to provide formal asthma education in primary care settings (Canonica et al., 2007). Given their level of involvement in asthma management, physicians hold a key role in improving patient education and communication. Additionally, there has recently been a shift in healthcare towards person-centred care, achieved by educating patients about disease and treatment

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processes (Vijn et al., 2017). As a result, medical education has had to increase their focus on patient care in their professional roles to improve quality of care. In light of this, proper education and training must be provided to current health science and medicine students who will emerge into primary health professional roles.

There is a clear need for improved education that will lead to increased knowledge and awareness of this disease (Coelho et al., 2016). The need for effective education is highlighted by reports stating a paucity of asthma understanding in school environments, primary care settings, emergency departments and households (Canonica et al., 2007, Coelho et al., 2016). Mixed reality holograms (via the HoloLens) have the potential to be a useful educational tool to visualise diseases in 3D, such as asthma, due to the interactive, self-directed nature of this technology.

Need for improved asthma education

Overdiagnosis of asthma commonly occurs as a result of diagnosis being solely based on the presence of respiratory symptoms, without objective measurements of variable airflow obstruction and bronchial hyperresponsiveness (Wu and Greenberger, 2018). The overdiagnosis occurs more frequently in children because pulmonary function tests cannot be undertaken in children under five years (Johnson and Theurer, 2014). In 2016, all required asthma diagnostic tests were undertaken on a study population of 652 asthma-diagnosed children between the ages of 6-18. The results showed that 53.5% of children were overdiagnosed while only 16.1% of children actually had an asthma diagnosis that was confirmed by spirometry (Looijmans-van den Akker et al., 2016). Overdiagnosis has also been confirmed in an adult population. In a cohort study of 613 physician-diagnosed asthmatic patients diagnosed within the last five years, 33.1% of participants did not have asthma (Aaron et al., 2017). In Aaron et al. (2008) study, it was also determined that obesity was not a contributing factor of asthma overdiagnosis (Aaron et al., 2008). This data should be interpreted with caution as it did not include participants with a recent diagnosis of asthma and had a lack of long-term follow-up to exclude possible remission or reoccurrence of asthma symptoms. These alarming results of asthma being commonly over-diagnosed can have significant impacts on the overall wellbeing of patients and can financially burden the healthcare system. Therefore, there is a clear need for improved education on asthma.

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Asthma education programs

Living with chronic disease places a significant burden on the patient, as well as their family and carers. Asthma has been seen to deteriorate a patient's quality of life, due to poor asthma control and self-management, increased school and work absenteeism, social isolation and decreased productivity (Lucas et al., 2020). While poor patient adherence to asthma self-management is a factor contributing to this burden, patient education is at the forefront of asthma control. Many patients lack the knowledge and awareness of asthma and its severity due to lack of information among patients, families, health professionals, as well as school staff (Divecha et al., 2020, Coelho et al., 2016). Asthma patients rely solely on their physicians as the most important source of information on asthma, due to lack of awareness or time to attend asthma education programs or general feelings of discomfort (Atmann et al., 2019, Canonica et al., 2007). As such, it is essential that the future health professionals are trained not only in the disease management and treatment, but also possess the ability to break down complex scientific concepts and effectively educate their patients.

Along with the overall improvement of the health status of the population, the primary outcomes for health education activities include providing access to information, increasing knowledge and acquiring new behaviours. Knowledge and awareness of asthma have been found to improve as a result of education intervention programs, particularly in the school-based environment (Coelho et al., 2016). Asthma intervention programs implemented in schools have increasingly improved the knowledge of asthma and confidence in the management of acute asthma among patients, families and teachers (Soo et al., 2013). Buckner et al. (2018) studied the effectiveness of a school-based asthma self-management education (ASME) program on 18 middle-school students with moderate to severe asthma. The ASME program was presented by an interprofessional team of nurses, respiratory therapy students and medical residents and implemented over five sessions. The authors reported a significant improvement in asthma knowledge and skills pre- and post-intervention, with scores for the correct use of a metered-dose inhaler increasing from 17% to 83%, respectively. The study also found improvements in the control of asthma symptoms and higher confidence levels in self-management. It has also been reported that asthma

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education programs are effective in increasing school staff knowledge. A recent study with a more extensive study size developed an asthma workshop based on the National Heart, Lung and Blood Institute (NHLBI) asthma management guidelines for 64 teachers in New York (Reznik et al., 2019). The aim was to enhance teacher knowledge, ability and confidence to manage asthma in students. Significant improvement in eight out of twelve self-efficacy and confidence items post-intervention were noted, and 95.3% of teachers agreed that asthma education programs should be implemented annually in schools. Further study should investigate the efficacy of the NHLBI workshop in a more generalised population to enhance asthma education in the school environment.

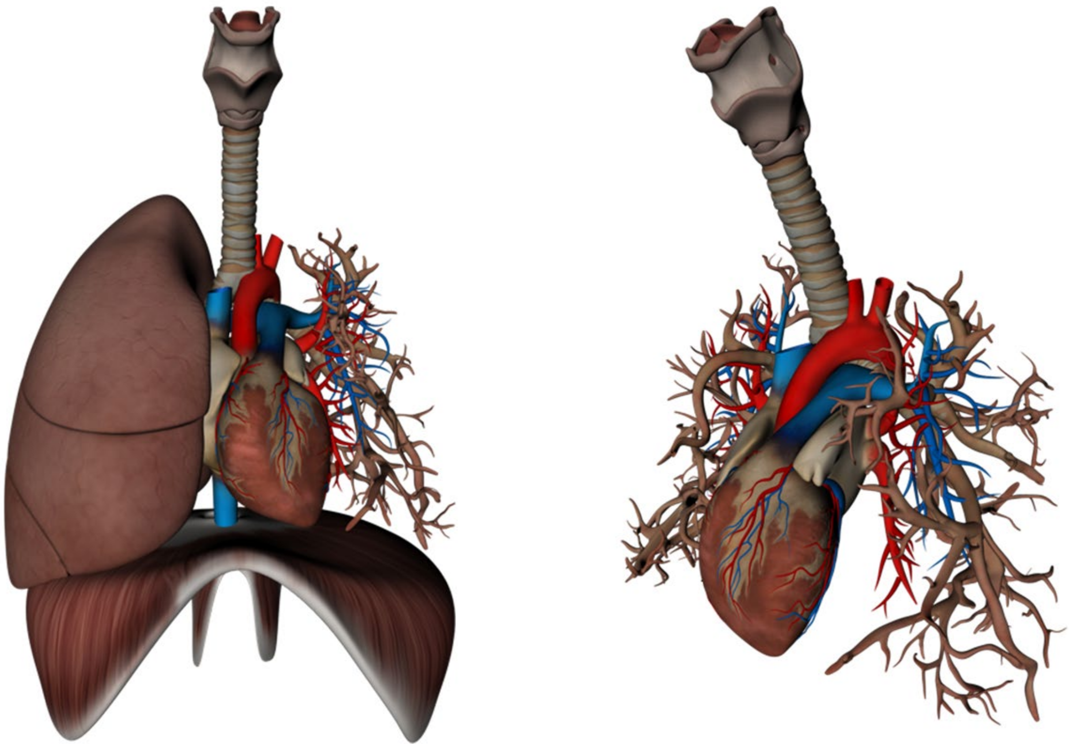

Figure 3: Examples of the potential for high-quality 3D renderings of the cardiovascular and respiratory systems to be used in asthma education. This provides the user with a stereoscopic, rotatable model where they can clearly see the interactions between components while learning about specific aspects of the disease. Image: C Moro.

Concluding remarks on novel technologies in education

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There is a clear need for improvements to be made in the training of forthcoming health professionals, due to the complexities associated with learning complex neurological, cardiovascular and respiratory diseases, such as stroke and asthma. The current two-dimensional teaching methods for anatomical education, along with the constraints of cadaver use, are not sufficient to optimise student learning. Therefore, to best represent the diseases and disorders that exist in three dimensions, mixed reality technological devices that are readily available, three-dimensional and interactive, should be incorporated into education settings for optimal engagement. Augmented reality, virtual reality and mixed reality demonstrate the potential to enhance scientific understanding and education by transforming passive learning with textbooks and plastic models to engaging interactions with 3D objects (Hoffman, 2016). Students can actively learn content presented in their studies with the aid of these devices, which increases spatial understanding and overall engagement with the study material. Asthma and stroke education is essential in rural and remote areas, outside of universities and schools, where resources and professional training are limited (Carpenter et al., 2017). Therefore, these devices can become powerful tools that enable the transferability of educational materials and training programs to future health professionals, tertiary institutions and families to provide support (Coelho et al., 2016, Pratt et al., 2018, Birt et al., 2018).

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