Multimodal Learning in Health Sciences and Medicine: Merging Technologies to Enhance Student Learning and Communication

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Abstract Advances in consumer-level educational technologies show great promise for enhancing the learning experiences of students in health and medicine. There are particular benefits towards using combinations of devices and technologies when demonstrating challenging concepts. These include using augmented reality-enabled devices enriched with accompanying 3D printed models, or virtual reality sessions coupled with online quizzes or revision activities alongside. Tablet applications can also be integrated while students concurrently engage in desktop-based online learning. This mixing and merging of different technologies can allow educators to focus on the strengths of each device, while mitigating limitations arising from a single mode's stand-alone use. This chapter describes a series of options to integrate multiple digital modes when educating health and medical students using technology. It also presents the case for health profession program graduates to be trained in teaching using technology, as their future will careers can be enhanced by an ability to educate effectively, as well as the potentials when incorporating serious games into a health curriculum. With the dynamic and ever-changing nature of health and medical education, educators can find great benefits when introducing multi-model digital learning into their respective courses.

Keywords: multimodal education, mixed-mode learning, augmented reality, educational technology, 3D printing, medical education, serious games.

Multimodal learning in higher education

Technology is being introduced in universities at ever-increasing rates. New students are arriving at tertiary institutions from schools where combining two or more modes was common in daily curriculum (Mills 2010), and as such, would expect this same interactivity in a modern university course. Making e-books, videos, animations, blogs, web pages, and digital games are the new ways of demonstrating literacy that involve clever combinations of these modes. In digital platforms, text is most often accompanied illustrations, interactivity, pop-ups, hyperlinks, and audio files to create meaning that extends beyond the possibilities of solely-written works such as essays (Unsworth 2001). This is increasingly becoming a core component of school education, where more than 200 learning outcomes in the Australian School Curriculum address this type of literacy, right from foundation (prep) to year 12. Nearly half (44%) of current jobs are at high risk of being digitally disrupted in the next 20 years (Moro and Mills 2019), and as such, incorporating technology into university curriculum is not only beneficial to learning, but can also be vital to students ability to work effectively in their future careers. The incorporation of technology into teaching practices at universities has also resulted in academics moving away from the traditional didactic-style lecture and into more digitally-enhanced group-based (Moro and McLean 2017), self-directed (Murad et al. 2010) or online modes of learning (Clark and Mayer 2016). However, the next step is to integrate multiple forms of technology in learning. This can involve mixing 3D printing with cadaveric labs, or textbooks with smartphone or tablet applications. The merging of multiple devices allows educators to engage using the strength of various modes, which can be particularly beneficial in disciplines such as anatomy or general health care education (Estai and Bunt 2016).

Mobile devices, such as smartphones and tablets, have the potential to aid teaching in health sciences and medicine. These devices can not only be used for communication and entertainment purposes but also aid in providing easy access to a wide variety of electronic resources to support learning, such as interactive 3D models. Pimmer et al. (2016) review of past studies utilising mobile devices in higher education revealed that health and medicine were the dominant areas in which mobile learning was used. Furthermore, the authors showed that the multimodal representation of study material helped facilitate personalised and more frequent study practice and aid in improved learning outcomes. These conclusions were also supported in Klímová (2018) review of 10 randomised controlled trials of the use of mobile learning in healthcare professional and medicine education, where the authors determined mobile learning as a beneficial tool in the acquisition of new knowledge and skills that were perceived by the students as an appropriate supplement to traditional learning tools.

There are several other interactive technologies capable of displaying high-quality 3D models that can be incorporated into modern health sciences and medicine curricula. For example, when using virtual

reality (VR) devices (Figure 1, *left*), 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 head-mounted displays, stereo headphones and motion-tracking systems (Kuehn 2018; Moro et al. 2017a; Moro et al. 2017b). This technology has a multitude of applications and has previously been used to enhance learning and skill acquisition across different disciplines in education (Jensen and Konradsen 2018), aid patient rehabilitation with cognitive impairment (De Luca et al. 2018) and assist in anxiety reduction (Camara and Hicks 2019). A more accessible technology to the general consumer is augmented reality (AR) which utilises a camera and screen (i.e. smartphone or tablet) to display 3D models superimposed into the real-world. The user is then able to interact with both the real and virtual elements of their surrounding environment (Birt et al. 2018). Due to its easy accessibility, this technology has been widely used to assist in STEM education (Ibáñez and Delgado-Kloos 2018), online retailing (Bonetti et al. 2018), gaming experience (Hamari et al. 2019) and tourism (tom Dieck and Jung 2018) to name a few. Lastly, mixed reality (MR) is a merging of AR and VR environments, with real and virtual words superimposed through head-mounted displays allowing for life-like renders of anatomy and physiology in real-time using devices like Microsoft HoloLens 2 (Figure 1, *right*). This mixed reality technology is still in development stages and not yet widely available and affordable for the general consumer.

Figure 1: *Left:* An educator assists a student utilising a Samsung Gear VR device for 3D visualisations. *Right:* A Biomedical Science student utilising the Microsoft HoloLens to augment available 3D skeleton models by adding muscle layers over the top.

Merging printed text and hand-held interactive 3D visualisation devices

Using traditional methods of learning, such as attending didactic lectures and using printed resources, has caused an over-reliance on simple memorisation as the predominant study tactic (Cai et al. 2018), which is classified as the lowest order of learning by Bloom's taxonomy (Krathwohl 2002). Comprehensive understanding of a concept is considered as the highest order of learning in Bloom's taxonomy, which extends beyond simply recognising a structure and remembering its clinical

significance. Science and medical students often experience difficulty obtaining spatial understanding of three-dimensional (3D) structures from two-dimensional (2D) illustrations, such as those in found in science textbooks (Berney et al. 2015). By using these traditional methods of learning, students are required to mentally manipulate and rotate static, two-dimensional illustrations. While textbook learning resources provide invaluable factual knowledge about different scientific concepts, students who have difficulties to mentally perceiving and rotating three-dimensional models consequently perform worse in tests evaluating spatial knowledge. However, the interactive 3D applications alone do not provide the depth necessary to fully grasp the concepts surrounding the structure in question. Using printed text in conjunction with digital 3D visualisation methods may help learners acquire information and build mental representations of anatomical or physiological structures. Moreover, it will also provide an opportunity to adapt the education tools to the different types of learning styles. The use of this integrated teaching method in comparison to traditional methods of solely using 2D illustrations has previously been explored to some extent in the literature, mostly in teaching anatomy. Features can be visualised in 3D through a range of devices. This includes both Mixed and Virtual Reality, such as through the Microsoft HoloLens or the various Virtual Reality Devices (Figure 1).

Indeed, based on findings from a systematic review comparing various digital 3D visualisation methods to traditional teaching methods such as textbook learning concluded that not only medical students preferred to use 3D models over 2D images to learn anatomy, they also reported a higher knowledge gain and better results in knowledge-recall tests (Triepels et al. 2019). In an original research study, Nicholson et al. (2006) reconstructed a fully interactive 3D model of the middle and inner ear from a magnetic resonance imaging scan. In their study, medical students (n = 28) completed a tutorial on ear anatomy with an interactive 3D model, while the control group (n = 29) completed the tutorial without the exposure to the model. Based on knowledge quiz results, the 3D model group achieved a significantly higher mean score of 83% compared to 65% in the control group. In a more recent Ng et al. (2015) study, graduating medical students (n = 72) were randomised into two groups to study the anatomy of the middle ear: (1) 3D model and printed reading materials on the epitympanum anatomy and (2) printed reading materials with 2D illustrations of the epitympanum anatomy. The researchers found that using 3D models was not only the student preferred learning tool, but also 3D group fared significantly better in the anatomy quiz, achieving a mean score of 65.1% compared to 32.4% in the 2D group. Fields such as oncology or pharmacology are also becoming increasingly difficult to comprehend, with increasing numbers of medications and receptors discovered each year. As research into areas such as these continue to uncover additional actions of pharmaceuticals or receptor targets (Moro et al. 2016; Stromberga et al. 2019), the use of 3D devices can greatly assist the student when identifying the complex interactions. Thereby, combining the advantages of using printed materials together with interactive 3D visualisations presents as a promising approach to enhancing the learner's experience in health and medical education.

3D printing in health and medicine education

In recent years, 3D printed specimens have become an alternative teaching tool in health sciences and medical education (Drake and Pawlina 2014). Prior to implementing this technology in teaching, it has been typically been used for preoperative assessment and presurgical planning in an industry setting (Faur et al. 2013). Before implementing this technology in teaching, it has typically been used for preoperative assessment and presurgical planning in an industry setting (Faur et al. 2013). These 3D printed models have been recognised as a great alternative to teaching involving cadavers, as the printed models are similar to cadaveric specimens and highly accurate when compared to the original specimen (McMenamin et al. 2014). Additionally, 3D printed models are more durable, are easy to reproduce in large quantities and are also more cost-effective than cadavers (Smith and Jones 2018). Using MRI and CT scans obtained from different patients and using 3D printing technology to reproduce these models can also help show anatomical variation that the students would not typically be exposed to if they solely used textbooks, anatomical atlases (either printed or 3D) or cadaveric specimens (Figure 2). While there are numerous advantages of incorporating this technology in teaching, it is also important to consider limitations. For example, these models are unable to accurately reflect the dynamic spatial relationships and movements between the anatomical structures, which are important in order for the students to understand functional anatomy. This limitation was addressed in Cai et al. (2018) study where the authors had 3D printed a dynamic knee joint simulator. The authors compared the traditional didactic lecture learning in medical students to using the knee joint simulator and found that students in the simulator group obtained significantly better results in a knowledge-based quiz when compared to the traditional learning group.

Figure 2: *Left:* Educators working with 3D printed models alongside cadaveric material to describe physiological concepts within a medical anatomical laboratory. Right: Students utilising 3D Printing

to incorporate hearts, lungs and other anatomical structures into the traditional laboratory-based skeletons.

Serious games and gamification in higher education

The development in computer technology over the last two decades has given and the accessibility of the internet has given a rise in the use of games in a higher education setting. Serious games are interactive and entertaining digital software that serve an educational purpose. In health science and medicine, there is potential benefit to introducing gamified learning approaches, as long as they are supplementary in nature, and do not attempt to replace traditional medical teaching tools (Gorbanev et al. 2018). The number of serious games in health sciences and medicine is growing rapidly, and it the educators implementation strategies are vital to the success of these applications to learning. (Wang et al. 2016). Some games may also assist with surgical skills training, and other hands-on applied technical (Chon et al. 2019; Graafland et al. 2012). One appealing aspect of educators creating their own games, is the possibility of linking multiple modes into the one device. Text-based tablet applications, websites, visual stimulus, hyperlinks and interactive components can all be packaged in a way that can assist learning. This is evident in serious games for health science and medical anatomy and physiology education, such as the tertiary-level game, *The King's Request: Anatomy and Physiology Revision Game* (Figure 3). These types of completely free games, accessible to all students, are able to engage and excite student learning in traditionally dry or difficult subjects. These multimodal applications also bring the class content in-line with student's self-learning, where the majority of students consistently report using a variety of e-learning tools alongside the textbook (Wynter et al. 2019). There is also the additional benefit of training students up with games, which may in the future form part of the health careers. For example, serious games can be effectively utilised in the clinical environment for activities such as motor rehabilitation (Taut et al. 2017).
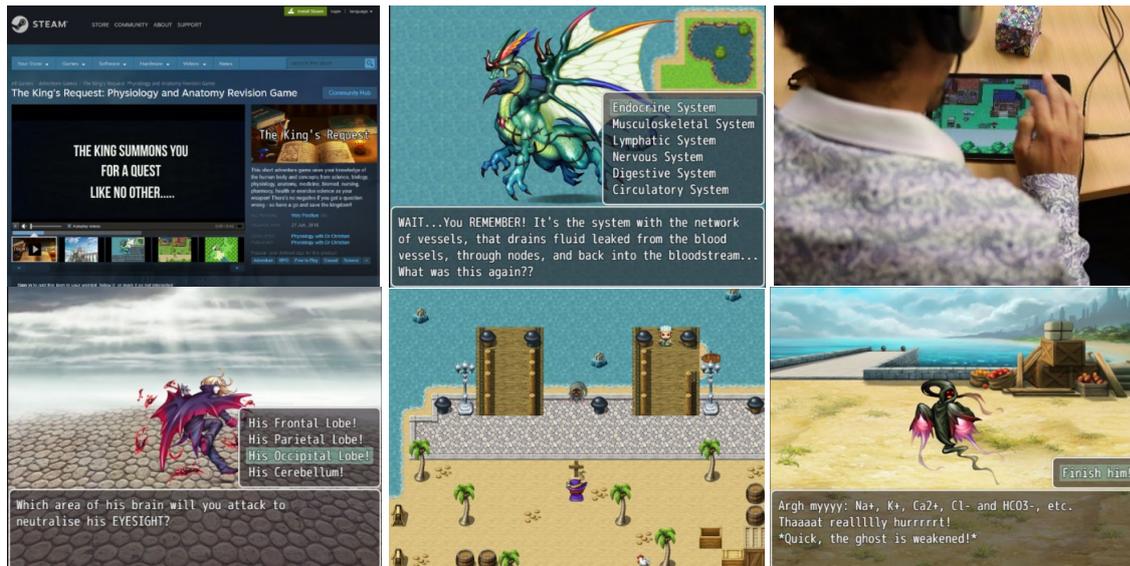
Figure 3: The King's Request: Anatomy and Physiology Revision Game. One of the available free games to engage students while revising health science content.

Health communication: teaching health sciences and medical students to use technology in patient education

One role of students graduating from health sciences and medicine will be educating their patients, clients and members of the community about their health. Most pursuits of the health system, whether it be physiotherapy, pharmacy, nursing, medicine or others involve the clinician explaining health concepts. As such, educating health science or medical students how to teach can be a great benefit to their future careers. This is particularly important when communicating with the community, where many people have difficulties with health literacy, or their ability to comprehend health information. Education in health is outlined as an essential constituent in the prevention of disease and promotion of health maintenance (Nutbeam 2000), where health professionals can increase patient health literacy through both formal and informal modes of education. Furthermore, epidemiological studies in the U.S. have revealed a link between health, socioeconomic status and educational attainment, where populations with lower educational achievement are more likely to have higher rates of morbidity and mortality as a result of chronic disease (Pamuk et al. 1998). Thus, by integrating training in how to educate others, and improve community health literacy into a tertiary health science curriculum, tertiary institutions can support students in their future careers.

Some challenges faced by modern graduates in health involve improving the health literacy of their patients and clients, many of whom may have irregular interactions with the health system, as well as greater responsibility for their treatment and care (Boice 1998). This type of additional expectation often leads medical students with concerns that they are not prepared for practice, and have not fully obtained all the required skills to be workplace-ready (Moro et al. 2019). Many teens with chronic

illnesses, such as diabetes mellitus, use the internet to gather information relating to the management of their illness. As such, healthcare professionals need to be aware of what content is available online and expect this prior knowledge into their consultations. Young adults, in particular, can be difficult to educate, and this age group often feels as though they cannot comprehend information related to the maintenance of their health (Lindau et al. 2002). As such, universities need to anticipate these clinical difficulties and assist with promoting tertiary students' knowledge of health literacy (Ivanitskaya et al. 2006), the variability between population's education (van der Heide et al. 2013) and the quality of deliverance (Baker et al. 2000; Furnham et al. 2011). This further raises the question as to how health literacy can be improved, consistently and effectively, for young adults attending tertiary institutions. Many studies are now looking into the feasibility of augmented reality as an interactive educational intervention as there has been a recent shift from passive, teacher-centred learning towards active, student-centred learning (Moro et al. 2017a; Moro et al. 2017b).

Conclusion

The modern health science and medical educator is no longer restrained to one singular mode of teaching. Instead, multiple devices, modes, formats and technologies can be utilised simultaneously to enhance student engagement and learning as well as achieving a greater level of interactivity. Using multiple modes of content delivery allows the educator to maximise the strengths of each device, whilst minimising the limitations exhibited from relying on a single mode for learning.

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