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Developing and evaluating virtual anatomy resources for teaching allied health disciplines

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Allied health professionals require an understanding of anatomy for purposes such as planning radiotherapy, or treating muscle imbalance. In practice, they will rarely see the structure they are treating, but seeing it during their education is invaluable. To reveal deep structures in the human body, neighbouring structures are unavoidably removed as a donated human body is dissected. Academic and clinical staff approached the challenge for students' understanding of the male reproductive and urinary system, which is indeed disrupted by dissection. An existing radiotherapy planning instrument Virtual Environment for Radiotherapy Training was used to create videos of real patients' internal structures. Structures difficult to see in dissection, models and images were transformed from magnetic resonance and computerised tomography scans into videos that appeared three-dimensional, for use by students learning anatomy. Qualitative evaluation of these anatomy videos suggested that they can be accessed at students' convenience and can be customised with captions, pauses or quizzes. Quantitative evaluation suggested that offering assessment-related incentives may not result in all students choosing to access the videos, but that those who did performed better on both labelling and short answer explanations of related content on immediate and short-term testing.

Keywords: digital anatomy; tertiary, virtual environment for radiotherapy training; learning object review instrument

Introduction

Students in the School of Health Sciences at the University of South Australia study anatomy in preparation for future professions in occupational therapy, physiotherapy, medical radiations, podiatry, human movement and exercise physiology. Although they are unlikely to see the muscle they are guiding or the organ to which they are applying radiotherapy, visualising the structure during their education will enable them to understand its size, shape, position, function and relationships with other structures. Students who see a structure are more successful in understanding and remembering it than those asked to imagine it (Silén *et al.* 2008), so they are offered numerous ways to learn through lectures, viewing human bodies that have been dissected (prosections), performing animal dissection, watching educational, licensed videos, taking quizzes, group exercises, receiving peer tutoring and discussing basic case examples.

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Offering the opportunity of examining human body specimens and the structures within them has been a successful strategy for these students to learn anatomy in the true three-dimensional sense; however, dissection of some structures, to see others, can damage or change the relationships between them. Furthermore, embalmed human body structures are more rigid than live structures, and they are difficult to move while intact, to see structures behind or below them (Collins 2008). Students find it difficult, for example, to see relationships between the male prostate gland, and adjacent structures and organs in dissected human bodies, as exposing the gland involves removing adjacent structures. Models and images of the male pelvis show the structures; however, a large part of the prostate has to be removed to see the urethra that lies within it.

In 2015, an audit was made of students' performance in their final examination, and 44% of 747 first-year students in the school of health sciences could not label, or explain the relationship of the prostate with the bladder after studying introductory anatomy. The use of images and high-quality anatomical models in learning had not adequately fostered students' recognition or understanding of a gland that has the potential to impact the continence and reproductive functions of half of our population. The same examination yielded a poor result (85% were only partially accurate) in understanding the relationship of the pelvic floor to continence.

Several anatomical learning technologies claim to be three-dimensional and appeal to the learner, who can use them in their own time, place and at their own speed. Some of these resources offer text explanations, labelling and quizzing features. A systematic review (Tam *et al.* 2009) evaluating online resources for teaching anatomy to medical students found that students were positive towards the resources, but their learning efficacy was not clear. Furthermore, no resource was found, however, that explained and demonstrated the aforementioned structures, to fit the learning needs of first-year allied health students.

Seeking advice from allied health academic colleagues led to the consideration of the Virtual Environment for Radiotherapy Training (VERT) system (created by Vertual Ltd.), which was in use for displaying anatomical structures to radiotherapy students, who could then plan the radiation treatment of cancers in particular structures. VERT enables radiotherapy students to see their target structure (which has cancer) and the structures close to it. The premise of using radiographic images for anatomy education is not new, as it enables images to be rotated, and allows structures to be removed or made transparent so that structures of interest can be seen without any damage to them (Collins 2008). VERT displays revolveable images that are constructed from real patients' computerised tomography (CT) scans. A specialised software takes the CT scan and constructs images that appear three-dimensional and transparent, to allow neighbouring structures to be seen (Bridge *et al.* 2007). With the use of VERT, no dissection of one structure is needed to view another within or behind it, as shown in Figure 1. The question was then posed: could VERT be repurposed to teach the anatomy of structures that are frequently altered by dissection, or are difficult to appreciate in two-dimensional images?

Use of Virtual Environment for Radiotherapy Training

VERT literature describes anatomy visualisation as a software advantage (Bridge *et al.* 2017; Duxbury 2016; Montgomerie *et al.* 2016; Phillips *et al.* 2008); however, no published studies specific to anatomy teaching and learning were identified. A recent international

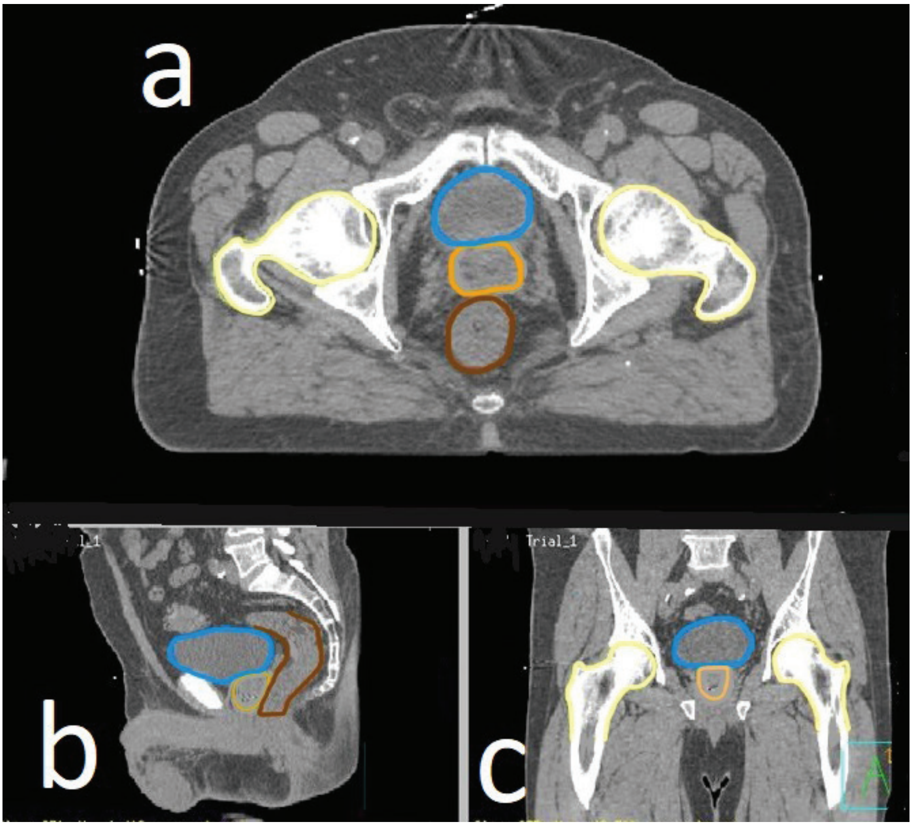

Figure 1. Computed tomography images (a, b and c) are a male pelvis, showing how structures are outlined in preparation for conversion into a video. Blue = bladder, beige = prostate, brown = bowel, yellow = femur bones.

audit of VERT training (Bridge *et al*. 2017) reported that the majority of respondents find VERT useful for understanding anatomy, as have radiation therapy students (Stewart-Lord 2016). A national VERT project report from the United Kingdom (Appleyard and Coleman 2010) reported that some tertiary institutions were developing three-dimensional anatomy applications for various students in healthcare. One conference presentation abstract was found (Carter *et al*. 2013) where VERT anatomy visualisation was compared with PowerPoint visualisation; however, upon student feedback, VERT offered no advantage. This brief report was not considered conclusive regarding the efficacy of VERT for use in different anatomical regions and teaching situations. The developers of VERT have indicated a desire to expand the anatomy feature and its application to disciplines other than radiation therapy (Duxbury 2016). The aim of this study was to evaluate the impact of educational videos on first-year allied health student engagement and understanding of the reproductive and urinary systems and their relationship with the pelvic floor.

Method

This study received ethical approval from the University of South Australia Human Research Ethics Committee. While consent was not required for auditing academic results, it was obtained from students who participated in focus groups.

Project conception and design

Student difficulty in imagining complex anatomical relationships brought radiation therapy and anatomy academics together, and a joint digital teaching and learning development grant was obtained to employ a project officer with VERT expertise. The project team included anatomists and a radiation therapist. A separate reference group with educational and radiology expertise was formed for guidance with process, evaluation and dissemination.

The prospect of making VERT anatomy videos led to consulting academics who educate health and allied health students, asking where their students had most conceptual difficulties. The initial body region identified (pelvis) was based on poor examination results across a mixture of disciplines, as demonstrated in Figure 2. The team then consulted the programme directors of nursing and physiotherapy about areas where a three-dimensional analogue of whole structures may be of use in their professions. Based on their suggestions, a further body region was prioritised (brain), as they were unable to be seen in entirety in a prosection or model, but could be clearly seen through CT and/or magnetic resonance imaging (MRI). In regions such as the pelvis and brain, the relationship between adjacent structures must be understood by clinicians, as abnormality in one area will alter the function in neighbouring structures.

Procedure for creating anatomy video resources

De-indentified CT data of a healthy patient, free of disease, were acquired ethically for teaching purposes from a local tertiary hospital. The data were imported into a software called Pinnacle (Phillips *et al.*, 2008) which allows structures to be digitally outlined on a CT image, and then multiple consecutive CT slices are used to create structures with a three-dimensional appearance. The anatomy team identified and traced an outline around individual anatomical structures on dozens of consecutive CT slices in Pinnacle before transferring to VERT. Figure 1a

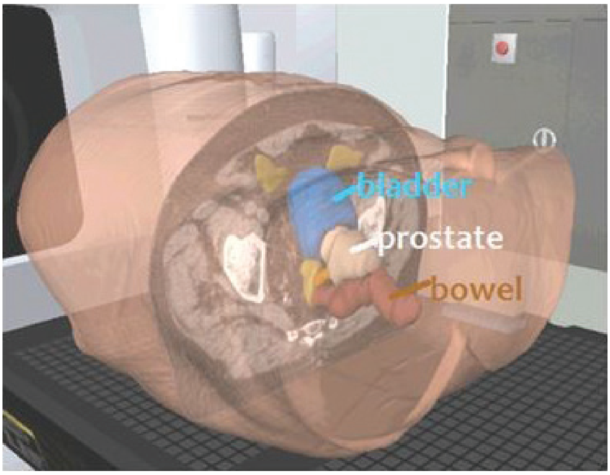

Figure 2. Computerised tomography scans of a male pelvis showed structures that have been converted into a moveable video that appears three-dimensional, through transparent skin. Blue = bladder, beige = prostate, brown = bowel.

is an example of one CT slice where structures such as the rectum (brown) and hip bones (yellow) have been outlined.

The team mapped video content to learning objectives and wrote a script for the audio commentary for the 12-min video, which first showed the bones of the pelvis, and then added the pelvic floor muscles and organs that sit on top of them. Male structures were chosen for this video, in response to the greatest learning difficulties seen in students' examinations.

Dissemination and evaluation of videos

The video resources were evaluated using the Learning Object Review Instrument (Leacock and Nesbit 2007), which advocates the following nine dimensions:

1. content quality
2. learning goal alignment
3. feedback and adaptation
4. motivation
5. presentation design
6. interaction usability
7. accessibility
8. reusability
9. standards compliance.

The first eight dimensions were evaluated; however, the issue of standards compliance was not relevant to this video – it is not intended for searchability over different databases.

Results

The video resources were disseminated and evaluated in several ways over 3 years and five deliveries of the introductory human anatomy course. The first single video was transformed into three shorter videos. They were introduced to students in class and advertised in lectures, and to watch the videos incentive was offered; students were advised that examination questions would directly relate to video content. Student access to the videos was recorded through the University of South Australia learning platform, called Moodle. Evaluation results are reported within each dimension of the Leacock and Nesbit framework (2007).

Content quality

The visual content of the video was assured to be accurate and lifelike as it was created from real anatomical images, and each was identified by a combination of radiologist, radiation therapist, physician and anatomist. Fifteen anatomy, pathology and physiology teaching academics positively evaluated the content of the initial video in a focus group. There was disagreement over the level of content and detail to be included in the musculature of the pelvic floor, but when the first-year allied health context was repeated, academics suggested that there be an advanced version of the video and a first-year introductory version. The groups were also asked for their opinion of the content, script, visual properties and the length of the video, and then were asked if it could be improved, and how so, during a tape-recorded discussion.

Learning goal alignment

The script and the identification of anatomical structures were made based upon first-year learning objectives for the reproductive and urinary systems. The team ensured that important terminology and identification of structures were first mentioned and then repeated at least once with relation to function of the structures.

When evaluating the learning efficacy of the videos, each course delivery was viewed separately because the related examination questions were different. Learning efficacy was also evaluated in the immediate sense and 4 months following introduction of the videos, some of which are described in Table 1. Over six deliveries of the course, the videos were offered to 2725 students. Examination and test results are reported for a sample of these courses, but questions varied between examinations so could not be directly compared. In one recent delivery of the course (2018), immediate and delayed retention of the video content was assessed and a conceptual question about incontinence was asked. As Table 1 shows, the students who watched the videos answered more strongly, but both groups of students failed this question.

Feedback and adaptation

Students offered feedback through focus groups and an online survey. The student focus group included seven past anatomy students, including international, mature-aged, a post-graduate and undergraduate students, who watched the video; then were asked for their opinion of the content, script, visual properties and the length of the video; and then were

Table 1. Evaluation of learning effects from videos, by examination (4 months post-video) and test (immediately following video).

Content	Pelvis, urinary and reproductive		
Method	Written examination	Written examination	Written quiz
Time delay	Delayed testing (first use of video)	Delayed testing (third time use of video)	Post video (second use of video) Immediate testing
Students	*N* = 109 entire cohort	*N* = 793 entire cohort anatomy undergraduate students	*N* = 151 randomly selected anatomy undergraduate students
Delivery	Video available online (optional)	Video available online (optional)	Video shown in class
Test	Written examination (4 months after content delivery)	Written examination (4 months after content delivery)	Quiz post-video
Result	58 watched, 49 (84%) answered related questions correctly, 51 did not to watch, 30 (59%) answered related questions correctly	565 watched, average mark = 77%, conceptual question = 43%, 228 did not to watch; average mark = 35%, conceptual question = 28%	151 answered related questions: 140 passed and 11 failed (no control group)

asked if it could be improved, and how so, during a tape-recorded discussion. Student transcripts were made from group recordings, which the students checked for accuracy.

Students were also invited to evaluate the videos online, anonymously. Their comments echoed those of the focus group as they were asked the same questions. Summarising evaluation feedback, students suggested that videos should be shorter and include captions and recounts of information. Some students complained that the script sounded monotonous and should be more animated. Of 843 students, 100 completed the survey; a few of the responders suggested several requests for a shorter video with quizzes embedded.

In response to the student focus group and survey, the video was divided into three short (5–7 min each) sections, a new voiceover was recorded, captions were added and a quiz was linked to the videos but not embedded as it would lengthen the time of each.

Motivation

Students reported positively about the video, with comments mostly about the ease of seeing and knowing each structure. Many commented that they appreciated the ability to control the video, pause it, replay it and have it accessible; one said, ‘I think this sort of thing helps you to engage. You have to have something interactive’ (second-year medical radiations student in focus group).

Educational literature supports the relationship of assessment to content (McDowell 1995), and so anatomy teaching staff subsequently told students that three test and examination questions were directly answered by the video content. The grade incentive resulted in approximately 66%–76% of the students watching the videos, over five deliveries of the introductory anatomy course.

Presentation design

Student feedback from focus groups confirmed their appreciation of viewing intact structures, ‘I like the visualisation of how organs sit on top of each other that was really easy to see’ from a student in a focus group who added, ‘and being able to see it from different angles, not just one view’ (VERT images can be revolved). Finally, as VERT images show the patient lying on a table, and even if the image is revolved, the patient’s back lies on the table, one student said, ‘the table gives you a reference point’.

Student evaluation revealed one suggestion that could not be changed – increasing the clarity of the VERT display. This was not possible with the available software; the outline of each organ appears slightly rough rather than smooth; and this issue was conveyed to Vertual, the producers of VERT.

Interaction usability

The video resource was initially offered to students through a link in the University of South Australia learning platform. It was easily accessible and no software programmes were required to play it. Loading time was less than the recommended maximum of 10 s (Leacock and Nesbit 2007). Over two most recent deliveries of the anatomy course, the students were given a YouTube link for watching the videos, as YouTube offers detailed analysis of video access. The records showed that each student opened the videos for an average of 4 min each; the videos were 5–7 min each in length.

Accessibility

YouTube provides the creator of videos with information about how many viewers have opened their video and for how long the video has been used. Viewers remain anonymous, where 565 students of 743 accessed the videos, suggests value in students having access to the pelvis videos at all times.

Reusability

The videos use widely accepted terminology, no abbreviations or reference to date, instructors or course, and have therefore been used over five deliveries of the introductory anatomy course and other related courses. It was calculated that approximate feedback from students, who have English as a second language, revealed no difficulties in understanding the voice-over or the captions, according to focus group and survey feedback.

Discussion

The majority of current tertiary students have engaged with digital technology throughout their education, and they approach information differently from previous generations (Collins 2008; Prensky 2001; Kantham and Senger 2011). Digital, interactive anatomy resources fit this generation of learners, and this paper described the process of creating a video resource for students to see deep anatomical structures. Multiple steps were taken to evaluate the resource, finding that students' utility of the videos was good and their ability to identify structures improved significantly.

Examination and test results suggested that the videos are an effective component of short- and medium-term learning. Testing students on the video content, both immediately after watching the videos and after a 4-month delay, showed that labelling questions that required memory of names, as well as short answer questions that required understanding of concepts, were positively affected. Some of the reasons for their improved performance may be explained in students' comments above, where they described seeing spatial relationships between reproductive and urinary organs. The first-year students who watched the pelvis video performed better on relevant questions in their examination, which occurred several months after the video was introduced, than those who did not watch. It was proposed that the students who elected to watch the video were those who studied more, perhaps accessed more study resources, and achieved higher grades; however, the large number of student viewers did not only include students with the highest grades. Detailed viewing analytics may suggest that some students gained more from the videos than other students; however, for the first 3 times the videos were used, the only information available was that students had opened the video link. Details of the amount of video watched, and if it was paused, was not captured. It was discovered during the dissemination phase of the project that delivery of videos through YouTube allowed for detailed analysis of video use. The videos were transferred to YouTube, for two course deliveries, to gather viewing analysis; however, each individual student was not identifiable and therefore could not be compared with their results.

Educational literature supports the relationship of assessment to content (McDowell 1995), and so the team included associated grade incentives to increase engagement. This did not result in all students watching the videos however, and given our study did not employ any other strategies to increase video usage, this is an area for potential future investigation. The authors acknowledge that a resource with known educational value requires effective dissemination to make any contribution to student learning outcomes.

Similarly, qualitative evaluation from peer anatomy academics from different institutions gave another perspective to the content included and displayed. This collegial activity encourages observation and critical reflection that can lead to transformation of shared practices (Bell 2001). Looking broadly at the evaluation data, the project team have gained an appreciation of student online access, resource features and limitations, and peer feedback.

Test and examination results suggest that the video resources aided students in learning names and functions of the structures and it improved their ability to apply this into a clinical concept such as incontinence. Even though students who watched the video explained incontinence more clearly than those who did not watch, the majority of students still failed the incontinence question. This has since been addressed by including an item into the oral examination, where students are asked to show where the pelvic floor sits, using a human skeleton, then explaining the function of the pelvic floor. This assessment encourages students to form and practice a verbal and visual description of the pelvic floor, and to practice their description in practical classes with tutors, peer tutors and peers.

Limitations of the study

The sequence of developments and improvements that were made to the videos prevented exact comparison between the large cohorts of students who were studied. This study employed a verbal and then a grade-related motivation strategy when the videos were introduced to students. The first offering of the video offered one long video and subsequent offerings were of three shorter videos. The access platform for the videos changed from the university platform that identified users and merely told the number of times they opened the videos, and later, the YouTube platform reported what user opened the video, but could not identify the detailed data it gave about how long each user watched each video. Furthermore, as part of each course when the videos were offered, examination questions differed slightly.

Conclusion

This paper describes the use of an educational resource designed for students to learn radiotherapy principles, to one that allowed students from multiple disciplines, to see internal structures that are difficult to access without harm or alteration, through dissection of donated human bodies. A team approach was described that supported the creation of learning videos of deep anatomical structures with relationships to neighbouring structures. The paper describes how the videos were evaluated by students and academics, for usability and learning effect in the short and medium term. The videos were acceptable, practical and easily accessed online.

There is scope to develop further resources for other anatomical sites, supported by findings and limitations of this project:

1. Video quality will benefit from current efforts by Vertual to improve the clarity of structures.
2. Planning access and usage analytics of the resource should include detailed utility evaluation of viewing time and identification of user.

3. Identifying the best strategies to increase usage of any resource is central to successful uptake of the resources and dissemination of the resource should be part of the evaluation plan.
4. Long-term learning has not been evaluated over periods greater than 4 months and questions remain as to the long-term value of the videos.

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