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Augmented reality learning environment for physiotherapy education

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Background: An understanding of how to translate anatomical knowledge and application of body mechanics to dynamic scenarios with real-life clients and movement is often a challenge for physiotherapy students.

Objective: Augmented Studio is an augmented reality system that helps facilitate this by projecting anatomical structures over moving bodies and allowing annotation of these structures.

Methods: Via a user and learner-centred design approach, augmented reality technology can assist education of physiotherapy students through augmentation and annotation.

Results: Using projection mapping Augmented Studio enables display of anatomy such as skeleton and muscles on the body in real time as it moves. With the creation of a technique to deliver hand-drawing annotation projected onto the moving body student and teacher clinical reasoning strategies can be made explicit.

Conclusion: Outcomes from a pilot usability study showed that Augmented Studio promotes the creation of an engaging teaching and learning experience and the facilitation of communication between teachers and students.

Keywords: Physiotherapy education, Augmented reality, Annotation, Projection mapping, Virtual anatomy

Introduction – clinical reasoning and anatomy in physiotherapy

Physiotherapy teaching involves multiple modalities including lectures, tutorials and practical classes. However, physiotherapy students often have difficulty in translating a textbook understanding of anatomy to more dynamic real-life scenarios.

During their course, students are expected to develop hypothetico-deductive reasoning skills as the foundation for their future clinical practice. As such anatomy needs to be understood as dynamic and evaluated in clinical contexts. Students begin to integrate multiple factors, including a strong understanding of domains, such as anatomy, in first forming then testing hypotheses through patient inquiry and examination, as part of developing clinical reasoning.1 This is defined as the sum of thinking or decision-making processes in the context of clinical practice.2 To be competent in clinical reasoning is one of the most sought-after physiotherapy skills in a new graduate.3 Teaching clinical reasoning can be intricate as students need to critically review decisions which are often ephemeral and tacit.4 Typically, the learning of these skills involves a class of students interacting with the therapist ‘expert’ consulting with a real or surrogate patient, yet may not still make the clinical decision-making of the therapist explicit to students. Identification of cues and key features and integrating key components of information to help create diagnostic hypotheses can be a significant difficulty for students as they learn to clinically reason.5 In a review of teaching approaches Eva6 outlines the need to give specific instructions and to focus on mechanisms of basic science which, in many cases are anatomical knowledge.

Multiple pedagogical elements, including virtual simulation and the traditional dissection of cadavers, form part of a modern curriculum in anatomy education.7 Although recognised as part of ‘optimal learning content’ in the context of international curriculum review,7 use of cadavers facilitates a 3D understanding of anatomy via exploration but has significant maintenance and preservation expense. This allows an opportunity to consider alternative or related delivery forms, via virtual simulation, as described below.

Alternative/related delivery forms of anatomy – augmented reality (AR) technologies

Augmented reality has been applied in many areas of medical education including real-time visualisation, anatomy and surgery.8 In physiotherapy education, there are a number of challenges for which possible application of augmented reality technologies outlined below may be useful.
**Head-mounted augmented reality**

The overlay of virtual information on real-world objects describes the interactive medium of augmented reality. The ability to alter the perception of reality makes possible application of information visualisation in medical education. Use of a form of AR though a head-mounted display (HMD) enabled bones to be overlaid on the body. This was described by the user as being similar to X-ray vision and was developed to train medical practitioners via a HMD with optical tracking system to perform surgical operations.

Further to HMD, a system of virtual reality (VR) using 3D sound and vibrotactile gloves was created that combined auditory and haptic navigation of the 3D representation of the abdominal and pelvic region. Results of a trial with expert surgeons and students pre- and post-assessment indicated that the VR system provides improved understanding of anatomical spatial relationships and users strongly preferred it over traditional teaching methods.

**Screen-based augmented reality**

Magic Mirror, is a form of AR displaying augmented information via a computer screen using body tracking. It shows internal human anatomy/ organs on the person standing in front of the screen. Acting as a mirror, the person’s movements are tracked in real time by a depth camera and displayed with virtual anatomical structures overlaid on the body. Based on the verbal feedback collected through a demonstration at the hospital open day, medical students and surgeons indicated the system was helpful for visualisation in anatomy education.

**Projection-based augmented reality**

Spatial augmented reality changes the user’s perception of the environment by use of digital projection. Augmented reality can be defined as the ability to overlay or project virtual objects onto the physical world. An example is the Spatial Augmented Reality on Person (SARP). This projects skeleton, internal organs and muscle onto the body using a single projector with Microsoft Kinect sensor for body tracking to assist anatomy education. Using a purpose built game called Augmented Anatomy where players correctly identify anatomical structures projected onto the human form, positive comments relating to increased interest and engagement were obtained from student, expert and online survey, with reduced identification errors.

AnatOnMe was designed for a clinical setting to improve communication between patient and doctor. Using a handheld projector pointed onto the patient’s body, pictures of bones or internal organs are projected to assist with education of relevant medical concepts. Results of an evaluation of patient preference for projection on body or mannequin model indicated no significant difference. Use of an expert review with therapists highlighted that a handheld form factor provided a barrier to physical contact with the client, potentially affecting a common work occurrence in physiotherapy.

Prior work on augmented reality systems for education in anatomy have been limited to identification/visualisation of anatomical structures primarily focusing on the single user which limits application to a classroom model.

**Methodology**

**Augmented Studio – design**

A pilot field study with physiotherapy students and teacher examining the question how can augmented reality technology enhance physiotherapy teaching and learning? were conducted, detailed below. Findings highlighted augmentation and annotation as the key useful features of AR for physiotherapy education. Augmentation is the core offerings of AR systems to superimpose virtual information on the real world using different types of display technology, such as HMD, mobile devices or projectors. Augmentation can provide augmented visualisation for better understanding of musculoskeletal structures applicable to a clinical context. Annotation facilitates explicit communication of teacher clinical reasoning strategies and experience to the students.

This facilitated the design of Augmented Studio. A learner-centred design approach, which focused on the learner’s needs and maximum student benefit, was applied to develop the system.

Augmented Studio uses projection mapping to display anatomical information, such as bones and muscles, on the human body in real time whilst the body is moving. The system uses a large-scale projection mapping appropriate to multiple students in a classroom model.

Development and evaluation of Augmented Studio in physiotherapy teaching and learning comprised two main aspects which are outlined below in further detail: (1) A field study; (2) A pilot usability study.

**User-centred design**

We applied a user-centred design approach for the development of Augmented Studio. A field study then piloted usability study conducted to evaluate Augmented Studio in physiotherapy learning and teaching are detailed below. The aim of the field study was to identify the opportunities for technological intervention in current teaching practice. The field study generated design guidelines to help build the Augmented Studio system. A pilot usability study was conducted to evaluate the extent to which the prototype system has satisfied the design guidelines derived from the field study.

**Field study**

Initially, a pilot field study conducted at the Department of Physiotherapy at the University of Melbourne was undertaken to elucidate pedagogical practices in physiotherapy in teaching of manual skills, which assisted design using immersive technology of a system to assist teaching.
Study design
We observed six 2 h practical classes over the first semester of first-year students of the Doctor of Physiotherapy programme at the Department of Physiotherapy at our university. The class used a method of demonstration, where the teacher performed the skills on a student volunteer who acted as a mock patient while being observed by other students. A peer-to-peer (P2P) group practice between students was carried out after the demonstration, with feedback from the teacher. Each class covers a series of skills via the same process. This teaching approach is used across multiple institutions in Australia, and has been reported internationally.

Data collection
Observations and informal conversations are the primary data collection methods. The researchers observed the teacher, students and their interactions during demonstrations and P2P practice. Informal conversations with the students were conducted with minimal disruption to the class by limiting to short questions during P2P practice.

Anatomical references
A skeleton mannequin, which was provided in the practical classroom as teaching material, was constantly referred to by the students during their P2P practice, to verify skeletal structure. The researcher noticed this especially in the class where the students were instructed to identify the cuneiform bones on the arch of the feet.

The majority of the teacher and students interactions were focused on correct anatomical identifications during the demonstration. The teacher consistently elicited verbal answers from the students to identify skeletal and/or muscular structure.

Both the teacher and students confirmed with researchers that students often struggle to translate their anatomical understanding onto the patient’s body.

Body annotation
Body painting is a useful tool for anatomy education, as a survey by McMenamin. The teachers in the study stressed the importance of on-body drawing practice in their classes. However, body painting is not easily altered or annotated.

Augmented Studio
The Augmented Studio provides a stage enabling interaction between students, teacher and student or surrogate patient in a practical class setting (see Figure 1). Models of muscles or skeletons can be directly projected onto the patient’s body, moving with the patient and enabling dynamic explanation and understanding of the anatomy.

Spatial learning environment
The Augmented Studio enables set-up for either practical room or a lecture theatre. After initial calibration to the surrogate patient or student in the ‘T’ position, the skeleton or muscle projections are highlighted on the body and move with the patient via projection mapping. Annotations can be displayed in a variety of colours as determined by participants to select joint or muscles structures or types of actions.

In a traditional practical class, the focus is often on the use of photos, figures and diagrams which do not capture the complex real-time dynamics of the human movements.

Hardware set-up
The stage area of the system is made up of four tripods connected with four cross beams, to create a 3 × 3 × 3 m

Figure 1 Augmented Studio set-up: projected skeleton model on a student volunteer
volume, called the stage (see Figure 2), which can support a group of up to 15 students, similar to traditional classes. Via two projectors and two Microsoft Kinect sensors mounted on two adjacent beams, the projected images cover the entire stage. It is possible to scale to a larger size with addition of projectors.

Model preparation, animation and annotation
While previous work reconstructed anatomical models from medical imaging, Augmented Studio adopted an off-the-shelf anatomical model which was verified by field experts to determine accuracy and suitability. A high polygon count muscular system model was used, incorporating all major deep and external muscles, which could then be scaled to match the size of the patient’s body.

In order to have realistic muscle animation for anatomical teaching a single 3D mesh model containing all the muscles, was bound to the skeleton rig to enable accurate deformation of the mesh during animation, a process called manual skinning. Multiple iterations with validation enabled achievement of maximal animation accuracy for physiotherapy lessons. The validation was completed with an expert lecturer in physiotherapy.

An annotation capability was enabled via mouse input, to draw coloured lines on the virtual model to be projected on the physical body of the students.

Pilot usability study
A pilot usability study was conducted to evaluate annotation as an original design feature of Augmented Studio. The hypothesis was that Augmented Studio enhances the teaching and learning experience for physiotherapy education, through augmentation and annotation.

Task
Entry-to-practice physiotherapy students were invited to participate in a novel manual therapy classes, which was not part of their usual curriculum, using Augmented Studio. Each class was approximately 15 min and was taught by lecturers from the physiotherapy department, who had not been involved with the development of the technology.

Students participated in a 15 min class designed to analyse hip joint motion during the action of kicking a soccer ball. The total time required for each participant was 45 min on average, including class time, questionnaire and group discussion. The participants were compensated with a $15 gift voucher.

Data collection
During class time, the researcher observed and took notes. Qualitative evaluation of the class was completed using both questionnaire and small group discussion. Following participation in the class, students completed an evaluation questionnaire which aimed to understand their perception of the value of the Augmented Studio to their learning in the class. The questionnaire was based on DeLone and McLean’s model of information system success. The model categorises questions in five aspects: overall experience, learner experience, use intention, system and content quality. Each aspect contains several statements, such as I believe that Augmented Studio is a very efficient...
educational experience, or I find the hand drawing on the virtual model useful. The questionnaire used a 5-point Likert scale to address these statements.

To further enrich the qualitative data captured in the questionnaire, the teacher and students participated in a small group discussion, where the learning experience was discussed. These were both video and audio recorded to aid in data analysis. Particular attention was given to communication between students and teachers. The researcher guided the discussion using questions regarding the system performance and limitations, as well as potential improvements. The small group discussion was facilitated by such questions as: How did the system enhance your teaching? If yes, please elaborate. Further discussion outside of the questions was also encouraged.

**Participants**

Nine entry-to-practice physiotherapy students from the University of Melbourne were recruited and consented to participation (age from 21 to 29, mean 24.7, SD 2.27). Students were from all three year levels of the course (2 first years, 3 second year and 4 final year), with 3 males and 6 females. Three teachers also participated in the evaluation. Participants were recruited via the LMS (learning management system) forums of the physiotherapy department.

**Procedure**

A $3 \times 3 \times 3$ m stage projection area was set up with two projectors and two Kinect sensors. A lab member acted as the patient and wore all white clothes to maximise the projection effect. Data were collected across three separate classes, each with an average of three students.

For the purpose of teaching, two virtual anatomy models were employed: bony skeleton and muscular. Throughout the class, the teacher was able to switch between the two models whenever desired. This was facilitated by the researcher who controlled the models via computer. The teacher traced a finger on the projection on the volunteer’s body while the researcher at the computer station would recreate the trace path on the virtual model via a mouse. There were three colour options, blue, green or red, indicated verbally to the researcher. The effect appeared as if the teacher drew the annotation directly using their finger. It is intended to develop the future capability of direct annotation for the system. Deletion of the annotation involved a similar process.

**Results**

Descriptive statistics were used to interpret the questionnaire data. Inductive coded analysis with a theoretical thematic approach was completed on observation notes and group discussion transcript.

Table 1 shows the mean, standard deviation, min and max values of the questionnaire data. It can be seen that Augmented Studio received a positive response on the majority of factors (mean >4.0). Among the highest scores were satisfaction, enjoyment, improvement with anatomical and kinesiology understanding, useful drawing and visualisation, and compelling projection technology.

The researcher also observed positive responses from students and teachers during the classes. In particular, the

<table>
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<th>Min</th>
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<td>0.52</td>
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<td>Improves communication</td>
<td>4.3</td>
<td>0.67</td>
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<td>Encouraging communication</td>
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<td>Model relevance</td>
<td>4.4</td>
<td>0.52</td>
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skeleton superimposed over the human body was found to be very impressive. The teacher also invited students to annotate, using the same method as the teacher, as a way of encouraging participation. During the group discussion, all the participants including teachers unanimously agreed that Augmented Studio enhanced their teaching and learning experience.

Discussion
Augmented Studio assists development of domain knowledge, through direct projection of anatomical information onto the body. Students are therefore given additional support to engage in activities they are looking to master via scaffolding in a learner-centred design environment. Scaffolding has been defined as the support to assist students in mindful engagement for learning, to facilitate understanding of the foundations of new concepts and processes. Learner-centred design which includes the dimensions of domain (e.g. anatomical) knowledge and strategic (e.g. clinical reasoning) knowledge, places strong emphasis on the learner’s needs.

Augmented Studio enables drawing on the projected anatomical model. Here, the teacher is able to illustrate clinical reasoning using annotations – coloured hand drawings projected onto the body. These enhance communication between student and teacher to assist scaffolding of students’ knowledge with real-life experience of the dynamic form of anatomy. By allowing the teacher to draw virtual information on the body, student clinical reasoning and teacher expert clinical reasoning can be illustrated. This annotation capability is used by the teacher as a scaffolding tool, providing additional assistance to the student’s learning.

Augmentation and annotation – design guidelines
Use of 3D display technology in anatomical education has demonstrated benefit in 74% of the applications with communication facilitated between teacher-student and doctor-patient. In using AR systems for anatomical purposes spatial interpretation and also student motivation were assisted.

The field study assisted derivation of design guidelines for a physiotherapy education support system, focusing on augmentation and annotation. These aligned with the theory of scaffolding in learner-centred design and formed the basis of the design of Augmented Studio applying spatial augmented reality with annotation capability for moving bodies.

Benefits
The Augmented Studio presents an innovative and novel pedagogical practice aiming to deliver benefits for both students and teachers. Via augmented kinesthetic information and annotated information, the system aims to enhance the learning experience of students and the teacher is assisted to support interactive observation with augmented visualisation, for better clinical understanding of musculoskeletal structures. This is hypothesised to enhance appreciation by students of dynamic change in 3D in anatomical configuration.

Augmented Studio allows the volunteer to move freely within the stage without the alignment of the virtual model being broken in comparison with previous projection-based systems.

Outcomes
Overall, the pilot usability of Augmented Studio received positive feedback from all users. Both students and teachers reported that the Augmented Studio improved student–teacher communication during the class and enhanced the learning experience. It should be noted that the name Augmented Studio is not a trademark and the authors do not have commercial interest to the system.

Enhanced experience
Dynamic movements
Participants unanimously agreed that the system enhanced their learning in multiple ways (Table 1). The students found seeing dynamic movements of anatomical structures very useful and more relevant compared with existing methods which use static models or pre-recorded animation. Augmented Studio rated highly with regard to enjoyment, enhancing understanding and visualisation of anatomical structures, adaptability, the compelling nature of the projection and quality as well as relevance of the system.

Cadaver lab
In comparison to cadaver lab, which has helped guided dissections by expert demonstrators by assisting the understanding of 3D anatomical structures, students saw that Augmented Studio had further benefits. In addition to enabling similar anatomy learning benefits, it also demonstrated the advantage of seeing the body in movement.

Annotations
Students uniformly found the annotations on the body very helpful in clarifying muscle attachments and function as part of movement, with some understanding the action of certain muscles for the first time. Even drawing annotations was sufficient for the dynamics of movements to be illustrated to some of the students.

Increased communication
The teacher encouraged the students to perform annotations. This could be done simply by tracing their finger on the volunteer’s body. In subsequent group discussion, both students and the teacher observed that this annotation capability of Augmented Studio encouraged interactions and engagement between the teacher and the students. This is illustrated in Figure 3, and enabled the teacher to
better gauge student understanding of the class material with students commenting that the annotations were very helpful, relevant and highly interactive.

Limitations
In the study there were relatively small student numbers and a high ratio of teacher to students which may have increased communication, therefore additional research with larger numbers of students is recommended.

Another limitation is the cost of the technology in terms of time, money and space, with the system currently needing a technician. It is envisaged that in future models the annotation will be automated. Ideally, the system would also have a dedicated room or component of a practical room to be housed. Thus another recommendation is for additional research with further technical development of the system.

Conclusion
The application of Augmented Studio to enhance learning and teaching in physiotherapy has successfully been presented. Connections have been drawn between physiotherapy education and augmented reality technology via the key elements of augmentation and annotation. These elements informed the design and implementation of Augmented Studio, through projection mapping to display virtual anatomical structures on the moving body. Additionally, projected hand-drawing annotations helped make explicit both students and the teacher’s expert clinical reasoning strategies. The pilot usability study highlights the potential of Augmented Studio to engage the students in understanding dynamic anatomical concepts. Additional research with further development of the system and larger numbers of students is recommended.

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Thuong N. Hoang is currently a lecturer in Virtual and Augmented Reality at Deakin University, Melbourne and an Honourary fellow at the Microsoft Research Centre for Social Natural User Interfaces, at the University of Melbourne, Australia. His research expertise is in augmented reality, wearable computer and human–computer interactions. His focus is in interaction techniques and devices, human factors, and educational technologies. He completed a PhD in Computer Science at the University of South Australia, creating innovative interaction technologies and devices for the field of augmented reality and wearable computer.

Martin Reinoso is originally from Ecuador, where he received an Electronic Engineer degree from USFQ. He was recipient of the Ecuadorian Scholarship ‘Top Universities’ to study a Master of Science at The
University of Melbourne. After completing this degree, he was awarded a scholarship in Melbourne to continue PhD, focusing on human–computer interaction for Movement Teaching. Martin is currently working in project related to developing tools to improve communication in immersive VR and AR systems as part of his work in the Interaction Design lab and the Microsoft SocialNUI lab.

Zaher Joukhadar is software engineer, and researcher. He works as a research fellow at Microsoft Research Centre for Social Natural User Interfaces at the University of Melbourne. Zaher has a bachelor degree in Informatics Engineering from the University of Aleppo, Syria, and master degree in Information Technology from the University of Melbourne. His research interests are machine learning and image processing.

Tamara Clements is the coordinator of the Doctor of Physiotherapy programme at The University of Melbourne, School of Health Sciences. She is a registered physiotherapist with extensive experience in the treatment of patients with acute neurological conditions. Tamara holds postgraduate qualifications in Neurological Physiotherapy and Clinical Education and has a strong interest in the use of technology to enhance physiotherapy student learning experiences.

Frank Vetere is a teacher and researcher in the School of Computing and Information Systems at the University of Melbourne. He is the director of the Microsoft Research Centre for Social Natural User Interfaces (Social-NUI) and leads the Interaction Design Laboratory. Frank’s expertise is in Human–Computer Interactions (HCI) and Social Computing. He has particular interests in design thinking and in technologies for ageing well. His research aims to generate knowledge about the design and use of information and communication technologies for human wellbeing and social benefit.

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**References**


