ORIGINAL RESEARCH ARTICLE

Authentic interprofessional health education scenarios using mobile VR

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This paper explores the use of mobile virtual reality (mVR) to create authentic learning environments for health education, initially in three contexts, followed by the development of collaborative health team scenarios that mirror professional practice. The use of mVR mitigates the dispersion of the university's seven health departments across three geographical campuses. We argue that the use of mVR provides an immersive and authentic student experience of real-world medical team scenarios. Building upon our experiences we critique the development of design principles for the integration of mVR within the curriculum and the establishment of a socio-cultural ethos of collaboration across the seven health disciplines at the institution. The unique contribution of our methodology is the focus upon a low-cost rapid user-generated development model explicitly founded upon design-based research, supported by a transdisciplinary team, modelling interprofessional practice.

Keywords: design-based research; scholarship of technology enhanced learning; collaboration; cooperation; mixed reality; mobile learning

Introduction

Simulation is an established educational methodology utilised in healthcare higher education (Kaufman 2010; Laschinger *et al.* 2008). However, there are three main limitations – authenticity, access and cost. The authenticity of simulated practice is weighed against the risk to real patients during training exercises. Simulation is usually conducted in dedicated clinical training spaces, requiring remote students and professionals updating their registration to spend time on-site during intensive block course training. However, dedicated training facilities and high-fidelity mannequins are high-cost items. Online simulation technologies are one way to mitigate these limitations of traditional approaches to simulation training (Kushniruk 2011). Mobile virtual reality (mVR) provides a potential practical and cost-effective solution to design innovative and authentic training environments (Barr and Foster 2017; Birt, Moore and Cowling 2017; Plahouras *et al.* 2018). In this paper we explore the design of low-cost mVR scenarios in

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several health education professional contexts and outline a transferable design methodology for integrating these technologies into the curriculum.

Literature review

The importance of collaboration in health professional teams

Health professional practice involves the collaboration of teams of professionals with a variety of expertise in specific areas of patient care and treatment. Research shows that patient survival is dramatically increased when patient information is correctly transferred between the health teams, and this process is termed 'patient handover' (Shah, Alinier and Pillay 2016). However, universities tend to fragment the health professions across distinct departments or schools that seldom interact or provide authentic opportunities for students to collaborate across these artificial boundaries. Despite this siloing of the professions in health education there are common approaches utilised in all of the disciplines that can be leveraged as points of overlap between departments and student interaction, such as the use of simulation.

Technology-enhanced simulation in health education

Simulation is a well-established educational strategy in health education (Greenblat 1977). Traditional forms of simulation in health education have included written simulations, simulated patients, audio-visual simulations, computer simulations and mannequins (Kaufman 2010). The predominant mode of healthcare simulation has become the use of high fidelity mannequins for practising clinical techniques.

> The Nursing and Midwifery Council recognizes the use of simulated practice and has enabled higher education pre-registration nurse programme providers to incorporate a maximum of 300 hours of simulated practice as part of the 2300-hour practice hours component. However, not all students respond positively to simulated activity, which should be used to augment clinical practice and not replace it. It is important to ensure the quality of the simulation enables the educational experience to be positive for students. (Valler-Jones, Meechan and Jones 2011)

In a systematic review and meta-analysis Cook *et al*. (2011) concluded, 'In comparison with no intervention, technology-enhanced simulation training in health professions education is consistently associated with large effects for outcomes of knowledge, skills, and behaviours and moderate effects for patient-related outcomes' (Cook *et al*. 2011). More recently there have been many efforts to utilise technology-enhanced simulation techniques in health education. In a 2018 systematic review Plahouras *et al*. (2018) conclude that VR simulation training can effectively supplement conventional health professional training. We argue that to be effective in leading to positive learning outcomes the integration of VR simulation requires significant curriculum redesign involving new pedagogical strategies.

Curriculum redesign for student-determined learning

The goal of simulation exercises is usually to develop student competency for a specific task, and therefore they utilise teacher-directed pedagogical strategies. However, we are interested in developing student capacity to analyse and navigate the unknown – to enable students to develop the capacity to deal with new and varied situations in which they will find themselves as medical professionals after graduation. We therefore chose heutagogy

as a pedagogical framework around which to design educational simulation scenarios. 'Heutagogy' is defined by Hase and Kenyon (2001, 2007) as student-determined learning, involving the development of student capabilities such as creativity, problem-solving and negotiation of learning outcomes. However, while Hase and Kenyon argue that heutagogy can be applied in virtually any learning context and at any learning level, others (Blaschke 2012; Garnett 2010; Luckin *et al.* 2010) argue that a move from teacher-directed pedagogy towards student-determined heutagogy requires a scaffolded process and appropriate support structures, not only for the students but also for teachers to reconceptualise their role. Luckin *et al.* (2010) coined the term 'the pedagogy–andragogy–heutagogy (PAH) continuum' to describe a scaffolded approach towards heutagogy in the curriculum. Cormier (2008) argues that the role of the teacher moves from content deliverer to becoming a designer of triggering events to stimulate student creativity and facilitate collaboration. These triggering events are supported through the negotiated selection of an ecology of resources (Luckin 2008) that support learners in the development of core capabilities such as creativity, rather than the delivery of a body of content. Through various curriculum design projects we have identified that redesigning the curriculum for student-determined learning thus requires a staged and scaffolded design approach that may involve several redesign iterations over time (Cochrane and Antonczak 2015a, 2015b; Cochrane and Keegan 2012; Cochrane *et al.* 2017a). This guided the design of the introduction of mVR into the health education curriculum.

mVR in health education

The use of mVR to enhance clinical simulation educational environments is relatively new (Birt, Moore and Cowling 2017; Hussein and Natterdal 2015) but growing rapidly with the ubiquity of mobile device ownership (International Telecommunication Union 2016). Mobile virtual reality presents an affordable platform (Amer and Peralez 2014) for developing and sharing authentic learning environments (Burden and Kearney 2016). Mobile mixed reality (MMR) encompasses the technological spectrum from real-world experience to augmented and virtual reality (Milgram and Kishino 1994). MMR requires relatively low technical expertise for development (Dolan and Parets 2016) and has wide user experience because of the popularity of mobile AR and VR platforms such as Pokémon Go, Google Streetview and Google Expeditions. However, Barr and Foster (2017) note, 'Although the benefits of simulation in medical and health education have been well researched, there is a paucity of research into how to deliver simulation using immersive media (IM) due to its recency as a strategy in paramedicine' (Barr and Foster 2017, p. 121). Foster (2017) summarises three key affordances of mVR in health (paramedic) education that facilitate authentic connections between higher education and professional practice:

- By creating explicit, tangible links to professional paramedic practice that extend beyond the usual didactic university environment.
- By constructing learning in such a way that enriches graduate skills such as information literacy, critic thinking, communication and reflection.
- By exposing the students to unique and complex learning and teaching environments to simulate reflection and metacognition. (Foster 2017)

The design of mVR within the health education curriculum requires a structured approach that leverages these key affordances, and we argue that design-based research provides such a structured methodology.

Design-based research

Laurillard argues that curriculum design should be approached as a design science and involve collaborative teams to provide the variety of expertise required (Laurillard 2012; Laurillard *et al.* 2013). Mor, Craft and Hernández-Leo (2013) argue for the relevance of design-based research (DBR) as a framework for learning design. Amiel and Reeves (Amiel and Reeves 2008; Reeves 2015) argue for DBR as a framework for reflective practice research. Building upon this argument Mor *et al.* (2014) and Bannan, Cook and Pachler (2015) argue that DBR provides a robust framework for designing authentic mobile learning environments. Design based research is a four-stage iterative process (McKenney and Reeves 2012; Reeves Herrington and Oliver 2005). According to the McKenney and Reeves model, the main stages of DBR include: analysis and exploration, design and construction, evaluation and reflection, redesign and dissemination. McKenney and Reeves argue that the goal of DBR is the development of transferable design principles.

mVR design principles

In a previous paper we identified key design principles (DP) from the literature for designing authentic mobile learning and scaffolding innovative pedagogies (Cochrane *et al*. 2017a), summarised here as five design principles:

- DP1: Basing the project within a design-based research methodology (Bannan, Cook and Pachler 2015; Cook and Santos 2016).
- DP2: Supporting the project through the establishment of a community of practice (Cochrane 2014; Cochrane and Narayan 2016).
- DP3: Using heutagogy (student-determined learning) as a guiding pedagogical framework (Blaschke and Hase 2015; Hase 2014).
- DP4: Designing around the authentic use of mobile devices and VR (Burden and Kearney 2016; Cochrane and Narayan 2017; Kearney *et al.* 2012).
- DP5: Integrate collaboration and teamwork into the project activities (Kearney *et al.* 2012; OECD 2015).

These five DP informed the iterative design and development of five projects in healthcare education disciplines at the university, explored in the following section.

A design-based research methodology for implementing mVR

We used McKenney and Reeves's four-stage model of DBR (Figure 1) as a common methodology for each project, mapped to our identified design principles (DP1–DP5), with the implementation of each stage discussed below.

Stage 1. Analysis and exploration

Each project involves a collaboration of researchers and practitioners and is informed by a search of the existing literature leading to the identification and analysis of a specific pedagogical intervention driven by the graduate outcomes of the programme.
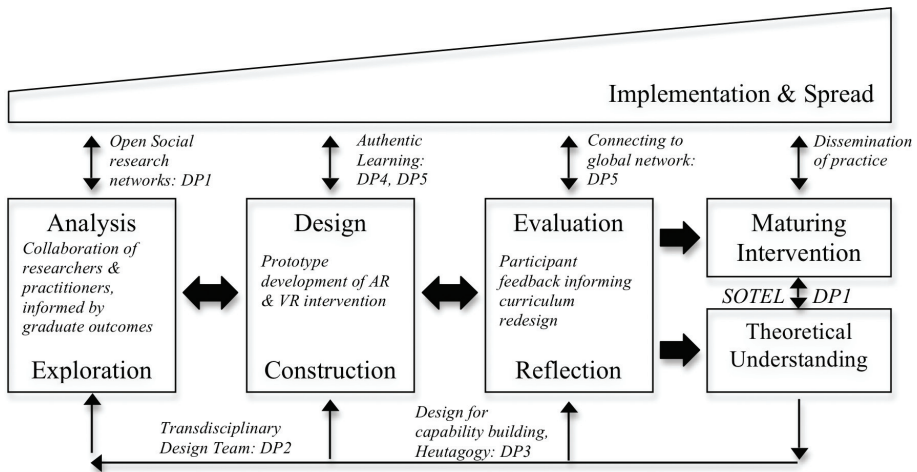
Figure 1.   McKenny and Reeves's design-based research stages.

Stage 2. Prototype development and intervention

We used a rapid prototyping model based upon low-cost user-generated mVR content designed to enable the identified pedagogical innovation. A transdisciplinary team designed a common ecology of resources to support the technological as well as socio-cultural elements of each curriculum redesign project.

Stage 3. Evaluation and redesign

The goal of each project was the development of student self-determined learning capabilities (heutagogy). Participant feedback informed the iterative redesign of each project along the PAH continuum. While heutagogy is the learning design goal, it is a work in progress across the projects, with each being at a different stage of the PAH continuum.

Stage 4. Dissemination of practice

We explicitly integrate peer-reviewed reflective practice research into each project through the embedding of the scholarship of technology-enhanced learning (SoTEL) within each project's implementation. According to Haynes (2016), SoTEL 'seeks to create dialogue between the findings of educational research and actual teaching in technology-enhanced learning contexts' (p1). Thus the focus of each project is upon exploring how technology can authentically enhance learning, rather than driven by technology, and each project is disseminated through the publication of peer-reviewed conference proceedings and journal articles. This also facilitates critical reflection and feedback on each project.

A transferable methodology

The DBR methodology was enabled by the development of a transdisciplinary project support team, comprised of a collaboration between researchers, practitioners and educational technology developers, as outlined in Table 1.

Table 1.   Transdisciplinary mobile VR development team

DBR collaborators	Transdisciplinary mobile VR project design team				
	Paramedic lecturers	*Physio lecturers*	*Nursing lecturers*	*MMR team*	*Academic advisors*
Key responsibility	Discipline context experts	Discipline context experts	Discipline context experts	MMR production advice	Educational technology foundations

DBR, design-based research; MMR, mobile mixed reality.

Table 2.   Applying a mobile VR framework in healthcare higher education

Design principles	Design of learning experiences	
	Ecology of resources	Triggering events
DP1: Embed a DBR methodology	Support lecturer culture of exploration, and iterative design and evaluation via participation within communities such as ResearchGate, and CMALT.	Collaboration between lecturers and academic researchers, participation in professional development cMOOCs.
DP2: Establishment of COP	Collaboration tools for project planning: e.g. Google Plus Community, Google Docs.	Formation of SoTEL research cluster groups. Design new curriculum. Gather feedback through peer-reviewed publication of projects.
DP3: Heutagogy	Negotiated ecology of resources enabling sharing of user-generated content.	Assessment activities designed as a series of triggering events to stimulate student graduate capabilities and develop a professional global network with healthcare professionals. Students form project teams and negotiate team roles.
DP4: Authentic learning: situated content	Shared 360 video: e.g. YouTube 360 via HMD e.g. Google Cardboard.	Development of content for prototype mobile VR environments supported by DBR transdisciplinary team.
DP4: Authentic learning: situated context	360-degree immersive environment simulation using SeekBeak or similar platforms.	Authentic healthcare scenarios are embedded within an authentically simulated virtual environment.
DP5: Collaboration and teamwork	Community Hub: e.g. Google Plus, Facebook and Twitter.	Students connect with peers and experts globally via specific social media hashtags and events such as conferences and competitions.

CMALT, Certified Member of the Association for Learning Technology; cMOOCs, connectivist Massive Open Online Courses; COP, Community Of Practice; SoTEL, scholarship of technology-enhanced learning; HMD, Head Mounted Display.

Implementing the framework design principles

The application of the mVR framework to healthcare higher education contexts is illustrated in Table 2.

This methodology was applied initially to three health discipline contexts, with the goal of implementing the methodology across all seven health disciplines at

the university. We discuss the implementation of the methodology in the three health disciplines and an interprofessional project in the following sections.

MMR in healthcare education case studies

The project team have been involved in the application and development of MMR in several health education domains, including:

- Multiple Environment Simulation Hub 360 (MESH360) critical emergency scene analysis in paramedic education
- Differential diagnosis scenarios in physiotherapy education
- Orienting nursing students to clinical practice via MMR
- Interprofessional handover scenarios

The discipline-based teams are linked via the establishment of a research cluster (http://sotel.nz) and a common research methodology, outlined in the previous section.

Figure 2 is a concept map of the supporting ecology of resources for the MMR subprojects.
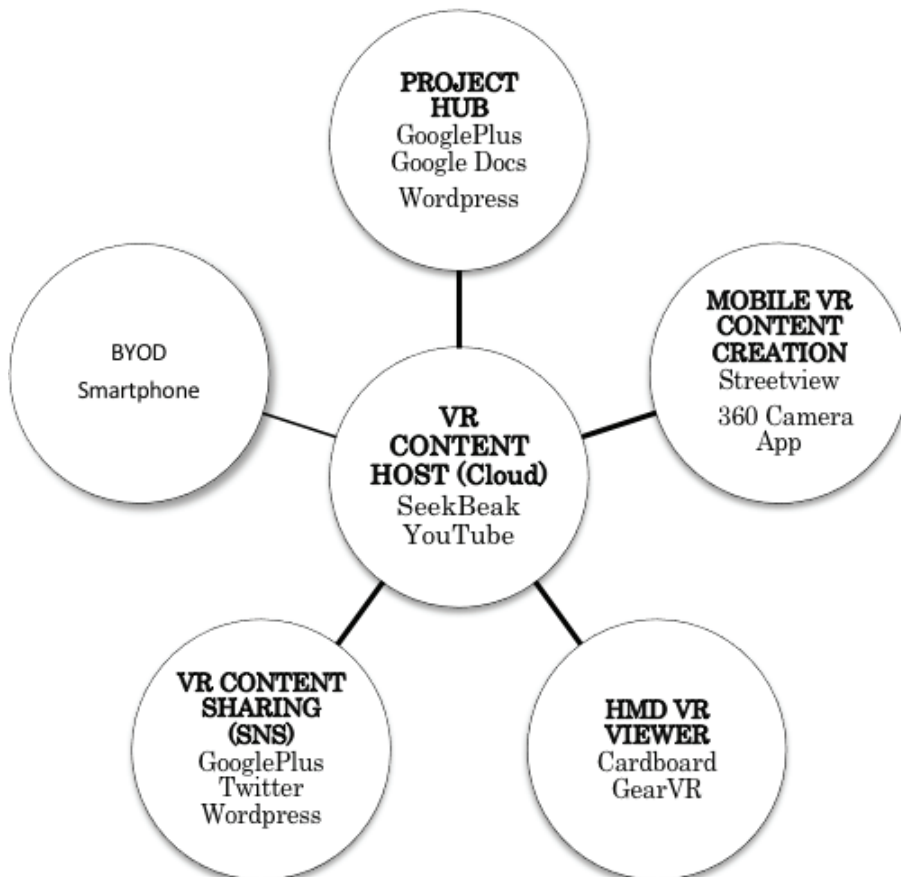

Figure 2.   An ecology of resources for mobile VR.

We outline the three disciplinary subprojects followed by a sample collaborative interprofessional team project in the following sections.

MESH360

The first case study is in the context of paramedicine education. Paramedics' scope of practice, in prehospital and out-of-hospital environments, requires a comprehensive understanding and application of a range of clinical procedures. These procedures require paramedics to work autonomously or as part of multidisciplinary teams and to take a multisystem-based approach to managing patients' conditions. In addition, they often work within multidisciplinary teams to manage patients who have sustained multiple injuries following traumatic events, such as road traffic collisions.

Research question

How can mVR and biometric sensor technology be utilised to study paramedicine students' response to analysing critical care environments?

Participants

The initial project prototype was tested with 45 undergraduate Auckland University of Technology (AUT) paramedicine students volunteering to participate in a 1 min mVR simulation in August 2017. A second redesigned prototype was tested in 2018 with 30 volunteer paramedicine students.

Intervention

The MESH360 project aimed to give paramedic students a 360° overview of a critical care scenario before entering the simulation suite, where they would then 'treat' a high fidelity mannequin. The presimulation scenario was designed to allow the student a period of time to critically evaluate the scene, therefore allowing students to gain information to make informed decisions during the simulation. Typically when doing simulations the teacher will feed information to the student verbally. Although this works, it can interfere with the student's train of thoughts and interrupt his or her learning. By engaging in 360° VR the student experiences an authentic environment from which he or she can learn from by exploration in a more authentic manner as an on-road paramedic does.

Implementing the design principles

Stage 1. Analysis and exploration

Practice simulation in acute and prehospital care settings is a growing area of interest for clinicians and health educationalists, and there is much evidence to support its use (Pike and O'Donnell 2010). It is a goal of this project to provide a facility that offers pre- and post-graduation paramedics the opportunity to experience a range of scenarios in a 'real life' but secure and safe environment. Guhde (2011) highlights that a simulated experience has its best learning when students are able to role-play, react and make decisions with little input from instructors. Critical awareness (CA) within paramedicine is an important skill that is very difficult to teach in a classroom.

As Norri-Sederholm, Kuusisto, Kurola, Saranto and Paakkonen (2014) discussed, it is critical within prehospital care for the clinician to have the right information when creating a treatment or management plan at a scene.

Stage 2. Prototype development and intervention

The project was designed to enable students to apply theory to practice in complex situations, such as managing patients injured in road traffic collisions. The goal of this project was to enable students to learn to use the environment they work in as a chance to get information and therefore help with their critical decision-making in the treatment of their patients. A community of practice of paramedic lecturers and an academic advisor was established in 2016 to explore the feasibility of the project, and we decided to use mobile technologies because of the universal ownership of these devices by our students, as well as the increasing integration of mobile devices into professional paramedic practice. The technology had to be simple to develop without high levels of technical expertise, and after advice from our development team we chose SeekBeak as a suitable cross-platform online development and dissemination tool (Cochrane *et al.* 2016). A prototype SeekBeak environment was created by the paramedic practitioners in order to understand how to use this technology to enhance paramedicine education through the development of more authentic simulation scenarios and exercises. A trial implementation with a group of volunteer students was then carried out in 2017, followed by a redesigned second trial in 2018 that introduced biometric feedback to triangulate students' subjective feedback with involuntary biometric responses to the intervention. Student feedback from both prototype iterations was captured via pre- and post-VR simulation experience surveys, and videos of student responses to three questions after the second iteration (Cochrane *et al.* 2018b).

Stage 3. Evaluation and redesign

The positive response to the prototype project from students encouraged the project team to be more ambitious with the second iteration of the project. Expanding the initial community of practice formed around the project we enlisted the aid of a transdisciplinary development team that integrates mobile application development and biometric data collection and analysis experts (Table 1). The addition of biometric data to the second iteration of the project provided objective data for triangulating the subjective feedback from the participants to the mVR scenario. Initial analysis of biometric data from the second iteration of the project identified a definite correlation between students' identification of critical elements in the VR scenes and biometric responses such as increases in heart rate, blood pressure and skin conductivity. The VR scenarios were also developed in much more detail and incorporated 360 video as well as 360 panoramic imagery. We also compared the use of smartphone-based VR to use of the Oculus Go mVR dedicated headset.

Stage 4. Dissemination of practice

The project team were invited to share their experiences with the wider faculty at the university. Presentations were made at international conferences (Cochrane *et al.* 2016, 2017b, 2018b) and results published in journal articles (Cochrane *et al.* 2017a).

Prototype MMR scenario

Figure 3 shows the deployment of the prototype VR scenario in SeekBeak using a smartphone in a head mounted display and prototype biometric sensors.

The URL for the prototype is https://seekbeak.com/v/xLrqVr47qbp. In this prototype scenario, students explored a staged critical care virtual scene in order to identify and analyse potential hazards in the environment before commencing simulated treatment of the high-fidelity mannequin 'patient'. The second iteration of the project was captured in a series of multimedia tweets curated into a Twitter Moment (https://twitter.com/i/moments/1039297771692412928).

Physiotherapy scenarios

The second case study was in the context of physiotherapy education. The physiotherapy lecturer joined the MESH360 community of practice in 2017 after participating in a presentation from the original MESH360 paramedicine team.

Research question

How can mVR environments be integrated into the physiotherapy curriculum to bridge the gap between theory and experience to help increase student clinical reasoning?

Participants

The initial project involved 120 third-year students in an undergraduate physiotherapy programme in New Zealand during 2017–2018.

Figure 3.   Example of prototype deployment with students.

Intervention

Students are introduced to sports-related concussion in the sixth semester of the undergraduate physiotherapy programme. While integrating musculoskeletal and neurological assessment and treatment, students are taught current guidelines, ethics and conflict management on and off the field. Previous delivery of the content had been from a didactic paper-based case scenario, which did not result in the module level of clinical reasoning expected. An alternative approach was considered utilising capture of a virtual environment and the use of online software. This involved the development of a case scenario in a virtual environment that is available for students to interact with using BYOD mobile (and non-mobile) Internet-capable devices.

Implementing the design principles

Stage 1. Analysis and exploration

The physiotherapy lecturer joined the MESH360 project team and built upon their experiences of designing a virtual environment and the use of online surveys for student feedback. A workshop was held with representatives from three of the health disciplines in 2017 (paramedicine, physiotherapy and nursing), academic advisors, and our app development team, from which we settled upon SeekBeak as a suitable rapid development mVR platform. The project was also informed by a systematic review of the literature surrounding mobile AR and VR in health education (in review).

Stage 2. Prototype development and intervention

The physiotherapy lecturer designed a theoretical critical care scenario drawing upon real-world experiences of sports injuries and based upon a game of hockey. An image of the hockey turf was captured using a 360-degree camera (LG 360cam) after consent was provided by the local hockey club. SeekBeak was used to add interactive hotspots with information pertinent to the case scenario including symptoms of the patient; observation of injury by the umpire and players; links to assessment findings (text and image), guidelines (PDF) and assessment protocols (via Google Forms). Six small group tutorials (15–24 students) utilising blended learning were briefly introduced to the case scenario, then directed to the SeekBeak site (http://tinyurl.com/MCCECase1) to continue collecting their assessment findings by exploring the virtual environment. Direction was provided by the embedded guidelines and outcome measures as well as the lecturer at the time of the tutorial. As the scene was presented online, students were encouraged to utilise the SeekBeak scenario up until the time of assessment. The summative assessment took the form of a referral letter to a general practitioner or concussion clinic; and *viva voce* for clinical reasoning and evidence-based practice.

Stage 3. Evaluation and redesign

Although the students were novel to SeekBeak, the majority of students found exploring the virtual environment to be intuitive while some required some additional assistance by the lecturer. After the tutorials, students were asked to complete the System Usability Scale (SUS) to provide feedback for redesign of the project. The SUS includes questions regarding complexity of scene, support required, consistency, ease and confidence of use and recommendations for future use. While the response rate

was low (19%; 24/126), students identified that it was 'helpful in learning'; 'quick and easy to learn' and 'would use it again'. The use of transparent (hidden) icons meant that students needed to identify where they might look for relevant information as they would in a real-life scenario. This was a different approach compared to the more didactic presentation where all information would be provided up front.

Based upon participant feedback, future iterations of the online virtual environment will include a brief tutorial and less use of the transparent icons. Audio of demographic information will be embedded, minimising the lecturer introduction of the case, as will consideration of interprofessional input within the scenario.

Stage 4. Dissemination of practice

The use of a virtual environment prompted a workshop during an education day for the school and, subsequently, utilisation of virtual case scenarios in other programmes (https://seekbeak.com/v/QXw1LnZYjL8), as well as conference presentations (Cochrane *et al*. 2017b, 2018c; Stretton 2018) and journal articles (Cochrane *et al*. 2017b). The project was expanded to include a virtual examination room to prepare students for an upcoming assessment (https://seekbeak.com/v/AVvjMv-kRqlJ); a sample screenshot is shown in Figure 4.

Prototype MMR scenario

Nursing

The third case study involves nursing education. The nursing lecturer joined the MESH360 community of practice in 2017 after participating in a presentation from the original MESH360 paramedicine team.

Figure 4.   Screenshot of SeekBeak© concussion case scenario in physiotherapy programme (http://tinyurl.com/MCCECase1).

Research question

How can mVR be implemented into the nursing curriculum to give authentic context to scenarios and exposure to the role and responsibilities of other professions?

Participants

One hundred ninety-three first-year nursing students participated in the mVR prototype in 2018.

Intervention

The nursing component of this project aims to involve students at each year level of the nursing degree to provide authentic context to scenario-based learning. Students need familiarisation with clinical environments including a hospital ward/lab, hospital room, patient living rooms and patient bedrooms. Students also need experience of working with a variety of health profession teams; thus interprofessional teamwork is critical but seldom modelled in the university setting. The project explored the development of mVR environments to meet these two learning outcomes within the nursing curriculum.

Implementing the design principles

Stage 1. Analysis and exploration

The VR environments were designed to represent the situations that nurse practitioners typically find themselves in after graduation. First, the 360 hospital ward and simulation lab provides a platform for students to familiarise themselves with the lab environment and supplies useful information such as lab rules and expectations, ordering uniforms, and videos from the previous students, which we utilise to decrease student anxiety prior to classes in year one.

All nursing scenarios begin in the ward or simulation lab where students can choose to explore environments related to patient scenarios, for example, Daniel (a hockey player) and Mr Smith and Mrs Jones, elderly clients who usually live at home.

The prototype VR environment was designed to be integrated into a first-year nursing course that uses case and inquiry-based scenarios such as meeting patients Mr Smith and Mrs Jones to augment student CA of safety issues in the nursing environment. In addition, the interprofessional scenario (open to all students) is designed to enhance student interpretation of interventions based on information found in the 360° environment. Students can also explore other disciplines (physiotherapy and paramedicine) to gain history and insight into Daniel's needs, forming a virtual patient handover.

Stage 2. Prototype development and intervention

After joining the MESH360 project community of practice in 2017 the nursing lecturer subsequently developed the nursing 360 environment followed by a redesigned prototype in its second iteration in 2018. The prototype mVR environment was implemented in a first-year nursing paper with links to the 360 environments developed by the other participating disciplines (paramedicine and physiotherapy).

Through consultation with the supporting team, SeekBeak was chosen as a development and dissemination platform for the virtual environments. The initial design began with a scenario about Daniel (a hockey player), who had an accident on the sports field. An interprofessional scenario was also designed where students learned about other professions through handover from ambulance staff and formulate a plan based on the information that they receive.

Stage 3. Evaluation and redesign

However, we soon realised that this task would be too complex for first-year nursing students, who would predominantly participate in this research. Therefore, a scaffolded design was proposed with senior nursing students delegating to junior nursing students. This approach aligns with the requirements of the Nursing Council of New Zealand competency for delegation and supervision and provides an opportunity for our students to experience delegation to and from others.

Stage 4. Dissemination of practice

The use of mobile virtual environments has created interest throughout the School of Nursing and will lead to the development of virtual case scenarios in other courses. Conference presentations (Cochrane *et al*. 2017b, 2018a, 2018c) and journal articles outlining the nursing project in more detail have also been submitted for publication.

Prototype MMR scenario

The following screenshot (Figure 5) shows an examples of the use of SeekBeak in the development of the nursing mVR scenarios.

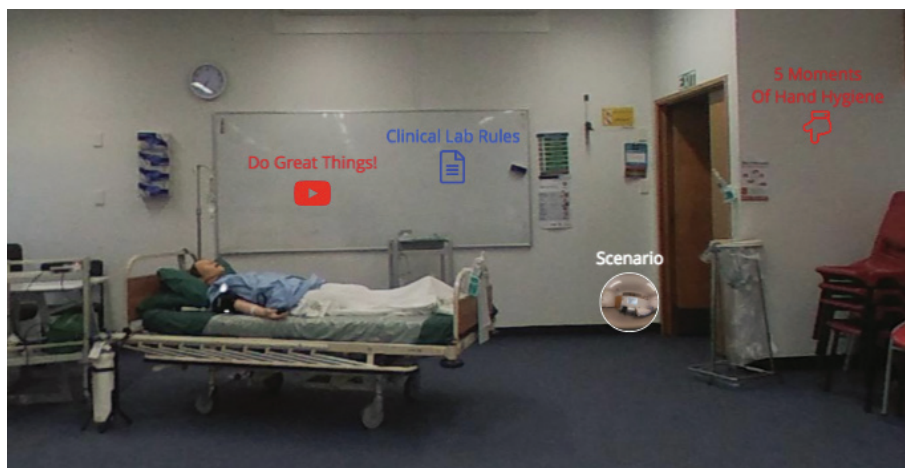The following example highlights collaborative teamwork between interprofessional health teams.

Figure 5. The 360-degree interactive hospital ward / simulation lab used to join simulation environments through scenarios (https://seekbeak.com/v/NYojXG69z8e).

Interprofessional collaborative project: Virtual patient handover

The interprofessional handover project was conceived as a virtual collaboration between the physiotherapy, paramedicine and nursing student teams, and it involved the entire MESH360 team that had developed throughout 2016–2017.

Research question

What are the key principles for creating an authentic virtual experience for healthcare students that simulates real-world health-team patient handover using mVR?

Participants

Participants were representative lecturers from paramedicine, nursing and physiotherapy at AUT and volunteer students from select courses in paramedicine, nursing and physiotherapy.

Intervention

The interprofessional mVR project involved the design of a case scenario in a virtual environment for students to interact with using mobile (and non-mobile) Internet-capable devices. Environments were developed collaboratively by a transdisciplinary team (Table 1) to enable students to explore and experience the practice of the other health disciplines to enable the development of an appreciation of interprofessional practice, which is essential in the real world of critical care health.

Implementing the design principles

Stage 1. Analysis and exploration

A key determinant in successful patient clinical treatment and outcome is efficient and reliable transfer of patient care between the various healthcare professionals (Fletcher *et al*. 2014; Shah, Alinier and Pillay 2016). This includes the verbal handover of the patient's current and relevant medical history, which may begin with the on-site physiotherapist, followed by emergency services such as paramedics to hospital services (including nursing). Common barriers to authentic handover teaching and learning include spread of location of healthcare professional schools, resulting in few opportunities for interprofessional practice (Gough, Oliver and Thomas 2012; Reeves *et al*. 2013) and variation in professional language (Thomas *et al*. 2013, Wong, Yee and Turner 2008). These barriers have been found to leave undergraduates feeling challenged and unprepared prior to their clinical placements (Reed *et al*. 2017; Thomas *et al*. 2013). Thus the team decided to design an mVR environment to provide students with an authentic experience of patient handover.

Stage 2. Prototype development and intervention

Representatives from paramedicine, nursing and physiotherapy had an initial meeting to discuss potential collaborative projects. One of the most vital areas of collaborative practice was the verbal handover between healthcare professionals. A problem-based

case scenario was developed and agreed upon using www.Storyboardthat.com. The case introduced students to assessment and management of concussion, whereby a 12-year-old is initially attended to by the physiotherapist and subsequently by the paramedic and emergency nurse.

While each scene was developed by an allocated discipline (i.e. on field – physiotherapist; ambulance – paramedicine; and hospital ward – nurse), consistency was ensured by the developed storyboard and the use of an actor for all three scenes. Feedback was sought from healthcare educators of what would assist their inclusion of MMR in their teaching and learning practices.

Stage 3. Evaluation and redesign

Once each scene was drafted, the three disciplines met again to ensure adequate scenario flow and development of interprofessional collaboration – namely understanding of discipline roles and expectations, the use of common language or terminology and a scaffolded introduction to real-world environments – especially an ambulance and hospital ward experience. It is anticipated that this case scenario will be utilised in the 2018–2019 curriculum in the undergraduate programmes of the three disciplines. The current scenario will be modelled to the first-year students of each discipline utilising a heutagogical, student-directed learning approach, with the aim that students will develop, present to peers and be assessed on their scenario(s). Potential scenarios may demonstrate interprofessional management of moving and handling of patients, falls and other sports-related injuries.

Stage 4. Dissemination of practice

The design of the prototype interprofessional mVR environment has been published in conference presentations (Cochrane *et al*. 2017b, 2018a, 2018c) and upcoming journal articles for critical peer feedback.

Prototype MMR scenario

Figure 6 shows three sections of the handover MMR environment via three SeekBeak screenshots.

Discussion

The five projects outlined in the previous section provide examples of the implementation of our MMR DBR framework. More in-depth detail regarding each individual project can be found in upcoming publications as linked in the dissemination section of each example. Here we explore the common emergent themes regarding the implementation of our DP across these projects.

Revisiting the research questions

While each project has a specific research question linked to its specific context, they are all linked by a common research goal: What are the key DP for authentically integrating MMR into the healthcare curriculum in order to enhance traditional simulation techniques?

Figure 6. Virtual patient handover scenario (https://seekbeak.com/v/eEB15vvazgV):
(A) physiotherapy – on field; (B) paramedicine – ambulance; (C) nursing – hospital ward.

Refining the design principles

In this section we briefly revisit our five identified DP for integrating MMR into the health education curriculum in light of the impact of the five projects outlined. These have informed the iterative development of the supporting design framework (Table 2) and the common ecology of resources (Figure 2).

DP1: Basing the projects within a design-based research methodology

Utilising DBR as a design and development methodology has provided a simple yet robust common structure to each project that ensures the projects are critically informed by an initial analysis and exploration stage, leading to prototype development, implementation, evaluation and redesign (Figure 1). A systematic review of the state of the art of mobile AR and VR in healthcare education (Stretton, Cochrane and Narayan 2018) revealed the unique contribution of the DBR methodology to fill the identified gaps in the literature: (1) limited engagement with learning theory in the design of mobile AR and VR in health education and (2) a focus that is limited to clinical skill development rather than student critical analysis and diagnostic capability development.

DP2: Supporting the projects through the establishment of communities of practice

Veletsianos (2015) makes a strong case for the creation of curricula that help scholars to make sense of networked identities, societies and cultures. This aligns with our

development of the transdisciplinary development team (Table 1) that was modelled upon a community of practice, as well as the formation of supporting communities of practice for each of the three health disciplines that were linked through the development of the SoTEL research cluster network (http://sotel.nz/groups). This has provided not only support for each project but also a forum for sharing and dissemination of ideas and reflective practice research.

DP3: Utilising heutagogy as a guiding pedagogical framework

This aligns with our identification of heutagogy or student-determined learning that focuses our projects on integrating elements of learner negotiation and learner-generated content and collaboration. While this is a design goal of the projects, we acknowledge that the integration of heutagogy within the curriculum of these disciplines is a work in progress, and the projects illustrate a variety of movement along the PAH continuum from teacher-directed pedagogy towards student-determined heutagogy.

DP4: Design for the authentic integration of MMR

MMR has provided a low-cost agile development platform for creating rich authentic simulation environments. Participant feedback from all of the sample projects has been very positive, with the common theme being the authenticity added to healthcare education scenarios and simulations through the integration of mVR. The addition of biometric feedback within the paramedicine project provides a triangulation of subjective participant data that correlates to the impact of student learning via the mVR environments. This will be further developed across the projects in the future.

DP5: Integrating collaboration and teamwork into the projects

The linking of all three discipline projects via the development of a collaborative interprofessional handover project and the support of a transdisciplinary design team has provided a rich collaborative framework for the projects. The collaboration across the three disciplines of paramedicine, nursing and physiotherapy has provided a model for the other four health departments to follow and has led to institutional recognition of the project team (Aiello, Cook and Cochrane 2017).

A transferable methodology

In the future, the four-stage design-based research methodology used to guide the design and implementation of the MMR projects will be applied across all seven health disciplines in the university in the next phase of the research. We also envision that the same methodology will be able to be modified and implemented in other educational contexts and faculties across the university to the extent that has been achieved in the three health disciplines so far.

Limitations and future directions

The main limitations of our MMR development methodology are reliance upon higher education practitioners who have the desire and time to explore innovation

in their practice through the integration of new technologies into their curricula. The practitioners are supported through the development of a design team that includes academic advisors and an MMR development team (Table 1). In the future we hope to expand the project into all seven health disciplines in the university, and this will require the identification and support of key practitioners in each of the remaining five disciplines. Converting interest into commitment is the main limitation of our approach, but the benefit is the sense of ownership and empowerment that practitioners gain as a result.

Conclusions

In this paper we have discussed the development of a design-based research methodology to guide the integration of MMR into the health education curriculum. The projects are founded upon a desire to create flexible learning environments that are authentic and learner-directed, enhancing traditional simulation techniques utilised in healthcare education. The methodology leverages mobile social media to facilitate user-content creation and sharing, producing an agile, low-cost and scalable model, supported by a transdisciplinary design team.

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