

Developing A Mobile Immersive Reality Framework For Enhanced Simulation Training: MESH360

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This paper reports on the second iteration prototype design stage of an immersive reality (XR) enhanced simulation project in critical healthcare higher education. While there is no doubt of the positive impact on the development of a variety of clinical skills through the use of XR in health education, a literature review indicates that the level of engagement with learning theory and the wider literature to inform the design of these learning environments is limited. The authors propose that XR can be employed within the learning environment to introduce critical elements of patient and practitioner risk and stress through environmental and socio-cultural influences without putting either students, educators, practitioners or patients at real risk, but create a safe learning environment that more authentically simulates these risk elements. The MESH360 project involves a collaborative transdisciplinary team of educational researchers, designers, practitioners, and working professionals in the design of mobile XR to enhance student and professional paramedic training to prepare practitioners for the environmental stressors and critical care decisions involved in high risk situations. Using Design Based Research (DBR), the project explores the impact of mobile XR enhanced simulation for novice and professional paramedics.

Keywords: Immersive Reality, Biometrics, Design-Based-Research, Critical Care Health Education.

Introduction

Critical healthcare first responders deal with the everyday carnage of the road toll, as well as unforeseen events ranging from natural disasters to mass murders. Higher education providers need to critically explore how to best prepare first responder professionals for these high risk, unforeseen events that require critical awareness, diagnostic and problem solving capabilities beyond their training and expertise in controlled medical treatment procedures. Simulation is a widely adopted and proven technique for clinical training and critical care response education (Kaufman, 2010). However, there is little evidence of engagement with newer pedagogies or learning theories that can inform the development of student critical thinking and critical diagnostic capabilities within health disciplines, beyond on the job experience such as clinical placements (Stretton, Cochrane, & Narayan, 2018). Zepke et al., (2010) identified “enabling students to work autonomously, enjoy learning relationships with others, and feel they are competent to achieve their own objectives” (2010, p. 3) as ways to enhance student engagement in tertiary education in general. Within the context of healthcare higher education, scenario-based analysis and critique are widely used, but can be made more authentic through the integration of well-designed immersive reality (XR) learning experiences. Recent critiques of the literature surrounding XR in healthcare higher education indicates that XR is predominantly utilised in healthcare education for clinical simulation exercises, with a focus upon skill development rather than higher level diagnosis or higher order clinical reasoning (Stretton et al., 2018). Consequently, there is little evidence of engagement with learning theory in the design of XR for higher health education, and a subsequent reliance upon behavioural learning design (Cochrane, Smart, & Narayan, 2018). While there is no doubt of the positive impact on the development of a variety of clinical skills through the use of XR in health education, the level of engagement with learning theory and the wider literature to inform the design of these learning environments is limited (Stretton et al., 2018). Authentic learning experiences in health education add elements of patient and practitioner risk and stress through environmental and socio-cultural influences. This is where XR can be employed within the learning environment to introduce these critical elements without putting either students, educators, practitioners or patients at real risk, but create a safe learning environment that more authentically simulates these risk elements.

There is much recent hype and rhetoric surrounding how virtual reality is transforming education, however the literature evidences that it is predominantly being used to deliver interactive content – effectively enhanced textbooks - rather than enable student determined learning that explicitly develop problem solving and navigation of the unknown or focus upon critical threshold concepts (Peter & Harlow, 2014). Ideally, the integration of technology into education environments should be driven first and foremost by sound pedagogical design principles based upon the key graduate profile capabilities that are critical to a specific professional context. To make this pedagogy-first approach explicit explorations of technology enhanced learning environments can be embedded within a Design-Based Research (DBR) methodology (Cochrane et al., 2017; McKenney & Reeves, 2012) informed by the scholarship of technology enhanced learning (SOTEL) (Cochrane & Farley, 2017; Haynes, 2016). Several contexts have been identified as being highly relevant to immersive learning environments, including; clinical and critical care health, automation, high-risk environments, environments that are prohibitively costly to reproduce, and educational environments that utilise simulation. These can be directly mapped to mixed or immersive reality learning environments.

The MESH360 project builds upon these key findings applied to the context of critical care health practice in high risk learning environments, simulated via the design of immersive reality learning environments, utilising the principles of heutagogy (student-determined learning) as a guide for the design of the learning environment (Blaschke & Hase, 2015). Building upon an initial 2017 prototype that explored critical scene awareness (Cochrane, Cook, et al., 2018), the project uses mixed methods to triangulate qualitative data and quantitative data over several iterative prototype designs. Specifically the project utilises biometric triangulation of subjective qualitative participant responses and feedback. The 2018 iteration of the MESH360 Paramedicine project explored the following research questions:

- How effective is immersive reality for authentically preparing tertiary paramedic students and upskilling workplace paramedic professionals to develop the critical decision making capabilities they need to best respond to unfamiliar high risk critical care incidents?
- What are the key elements of an implementation framework that can guide the scalable development of accessible immersive reality learning environments that enhance critical care simulation training for authentic real world high risk first responder scenarios?

Methodology

To advance the potential impact of XR in critical care health education curriculum design can be more explicitly informed by the Scholarship Of Technology Enhanced Learning (SOTEL) (Cochrane & Farley, 2017). The academic advisors bring this critical lens to the project team, and act as mentors to the paramedic lecturers in the team as they critically explore their teaching practice through the lens of SOTEL. SOTEL explores critical practitioner reflection on the design and implementation of technology enhanced learning environments founded upon learning theory. The MESH360 project uses a DBR methodology. DBR and SOTEL are particularly relevant to move technology enhanced health education beyond the predominant mode of individual comparative trial-based case studies, towards transferable design principles that can be applied to a variety of health education contexts for wider impact (Cochrane & Farley, 2017). DBR provides a structured, four-phase iterative framework (McKenney & Reeves, 2012) for designing XR learning environments for health education (Cochrane et al., 2017). The four phases of our project are:

Phase 1: Analysis and exploration - Identification of the critical pedagogical issues surrounding the design of XR learning environments and exploration of supporting literature to identify initial design principles to address these issues (Cochrane et al., 2017).

Phase 2: Design and construction - Prototyping of the design of an XR learning environment and pedagogical intervention informed by the identified design principles (Cochrane, Cook, et al., 2018).

Phase 3: Evaluation and reflection - Evaluation of the prototype XR learning environment design through user feedback, and refinement of the design principles (Initial prototype evaluation 2018).

Phase 2-3 Loop: Iterative redesign and re-evaluation of the prototype XR learning environment (2018-2019).

Phase 4: Theory building - Development of transferable design principles and dissemination of findings (2019).

The 2018 iteration of the MESH360 project focused upon Phase 3 and the first Phase2-3 loop leading to the development of a second higher fidelity enhanced simulation environment and an implementation framework. The MESH360 project partnership participants (outlined in the project team details Table 1) comprise a collaborative transdisciplinary team of researchers, development team leaders, practitioners, students and professionals. The team members have collaborated on the initial conceptual and prototyping development of the MESH360 project over the past 2-3 years (Aguayo et al., 2018; Cochrane, Cook, et al., 2018; Cochrane et al., 2017; Cochrane, Cook, Aiello, Harrison, & Aguayo, 2016). Simulation participants included AUT paramedic students and professional paramedic ambulance crew members.

Table 1. Transdisciplinary Design-Based Research project team

Team Members	Role in project
Academic Advisors	Principal investigator and educational technologist
App development team	Co-Principal Investigator and immersive reality application development team
Paramedicine Lecturers	Paramedic lecturers and core members of the MESH360 enhanced simulation project development, development of simulation environment
Embodied Reports, Santiago, Chile	Biometric data researchers and tracking software development
Paramedic students and practitioners	Simulation participants: 30 student volunteers from year1-3, 5 invited professional paramedics

The 2018 Phase 2-3 loop was informed by the evaluation of the 2017 prototype that recommended: redesign of the embodied biometric instruments; redesign of the enhanced simulation environment through a). development of multiple authentic scenarios that are linked through the VR experience, b). addition of new forms of user interaction, c). exploring higher definition Head Mounted Displays (HMD). We attempted to address these issues in the design of the 2018 VR scenario that moved from a static 360 scenario viewed via a Google Cardboard compatible HMD to the development of a virtual ambulance callout via an Oculus Go HMD.

Data collection and analysis methods:

The project uses mixed methods to triangulate qualitative data and quantitative data over several iterative prototype designs, initially across two years of iterations of the project. Building upon prototype XR learning environment design (Cochrane, Cook, et al., 2018), we use biometric triangulation of subjective qualitative participant responses and feedback (Pre and post participant surveys, and post focus group for each iteration of prototyping and implementation of the immersive simulation) (Aguayo et al., 2018). Participants wear a smart watch during the XR simulation that measures participant stress by recording heart rate (HR) and skin conductivity data (Galvanic Skin Resistance or GSR) facilitated by the development of a custom application. The first prototype trial in 2017 indicated the alignment between cognitive and emotional impact of the XR learning experiences on learner outcomes within an enhanced simulation (Cochrane, Cook, et al., 2018). In 2018 we wanted to correlate the difference of the impact of enhanced simulation from novice students to professional practitioners. Post enhanced simulation participant interviews were conducted and recorded to explore the subjective impact of the enhanced simulation upon participant learning, comparing their analysis of an enhanced critical care scenario simulation. Data collected from both novice (trainee students) Paramedics and expert Paramedic practitioners provided comparative impact of the project at different user experience levels. The analysis of the alignment between the subjective participant feedback with the immersive environment hot spot and participant eye mapping, triangulated by time-aligned biometric participant data provides a rich basis for answering the research question regarding the impact upon participant learning, and the subsequent 2019 iterative redesign of the project will enable the development of transferable design principles. A summary of the implementation framework for the MESH360 project is provided in Table 2.

Table 2. Mobile XR enhanced critical care simulation implementation framework

Data Collection Activities	Implications for enhancing critical care clinical simulation
Recruitment of volunteer participants	Participants invited via Facebook, Instagram and announcement on the LMS to respond via email to a project email account. Respondents were then emailed a simulation booking, instructions, consent form, information sheet – in accordance with the MESH360 ethics approval from the university ethics committee
Pre survey to gather participant demographic and prior experience data	Anonymously coding participants to map the impact of the VR enhanced Simulation
Biometric Sensors worn on wrist by participants	Measure participant stress levels via GSR and HR
Pre-VR experience - HMD	Define baseline levels of stress
VR experience – HMD with eye tracking, hot spot activation, user navigation of scenario, wirelessly mirrored to monitor for observation	Creating an authentic simulation within a real context that approximates real world stress and risk elements and participant diagnostic skills via multi-sensory VR experience
Post VR initial diagnosis	Participant initial diagnosis based upon VR simulation
Traditional clinical simulation treatment of high fidelity mannequin	Participant treatment of mannequin based upon VR scenario
Post clinical simulation diagnosis	Participant final diagnosis of VR + clinical simulation
Post simulation participant interview - videoed	Brief subjective participant feedback on the impact of the VR experience
Post simulation participant survey	Purposive sampling of subjective participant feedback on the impact of the VR experience

The 2018 VR experience consisted of a 4 minutes long '[Ambulance Ride](#)' VR experience, which was divided as follows:

- a). Presentation of 'calm' scenario, a nature scene, to smoothly introduce participants to the VR experience (15 seconds),
- b). Transition to static 360 Panorama of the back of the ambulance (45 seconds) to gain baseline data,
- c). Transition to 360 video of the back of the ambulance ride including ambient sound (1 minute),
- d). Presentation of job description by radio call first, then by text box providing more details, followed by a job update increasing complexity of job (radio first, then text box),
- e). [Arrival at accident scene](#) in a garage with patient for participants to explore,
- f). Close up scene of patient with emergency care equipment laid out exactly as in the physical high fidelity mannequin simulation suite.

The participant VR experience was wirelessly mirrored to a monitor for the research team to follow their progress and exploration of the VR scenario. Following the VR simulation experience participants were asked to provide a preliminary diagnosis of the patient, and were then ushered into the adjacent physical simulation suite with a high fidelity mannequin and equipment to demonstrate treatment procedures while observed through a one-way window.

Summary of results

Space limits detailed analysis of the project results, hence we present a brief summary of results, and a full analysis will be the subject of a following journal article.

- Participant post simulation survey: Very positive feedback, with suggestions on improving fidelity.
- Participant post simulation feedback video playlist: all participants agreed that the VR experience enhanced the traditional simulation and helped inform their patient diagnosis.
- VR environment eye-tracking [heatmap](#): participants spent significant time exploring the 360 scene with the virtual patient discovering clues for diagnosis and treatment procedures.
- Biometric triangulation: Stress levels were highest in first year students, and all student stress levels significantly increased when the job call came through in the VR scenario. Conversely practicing paramedic stress levels were highest pre simulation, and their stress levels decreased as the VR scenario progressed.

Initial thematic analysis revealed that the most positive participant feedback was from the second year students and the professional paramedics – both groups were the most enthusiastic about the value added by the VR enhanced simulation to their learning. This indicated that there was a ‘sweet spot’ for the impact of the VR enhanced simulation between non-experienced novices and third year students who are highly experienced with traditional clinical simulation techniques. Practicing paramedics believed the VR provided a more authentic training experience than their prior educational experiences. Next Stages: The 2019 iteration of the project aims to better integrate the flow of the learning experience between the VR pre simulation and the actual clinical mannequin-based simulation. The third iteration the MESH360 project in 2019 will refine the design principles established in the first two iterations of the DBR project.

Conclusions

This paper outlines the research methodology design and second iteration prototyping of the DBR project that explores the development of an immersive reality framework for enhancing critical care simulations for educating first responders for the real world stressors involved in critically analysing environmental factors and patient diagnosis and treatment in authentic learning environments. We identified significant differences in the impact of the immersive environment between novice and expert practitioners. The next stages of the research will iteratively evaluate and refine prototype immersive reality learning environments, comparing the impact upon both novice and expert paramedics. This will inform the development of transferable design principles.

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