Blended reality: Issues and potentials in combining virtual worlds and face-to-face classes

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This paper describes issues and potentials related to blending virtual worlds and face-to-face environments for the purposes of learning and teaching. By streaming a live video feed of a face-to-face classroom into a virtual world space at the same time as projecting the virtual world space onto a screen in the face-to-face classroom it is possible to merge participation in the two environments. In this way students in remote locations can be offered improved access to and involvement in face-to-face classes, and face-to-face students can capitalise upon the affordances of the virtual world to extend the range of possible learning experiences. A pilot of this technique revealed several potentials for learning and teaching were evident including enhanced remote access to face-to-face classes, increased possibilities for online interaction, and the capacity to leverage the affordances of both worlds within the one learning environment depending on needs. However there were several implementation issues including latency and resolution of the video-stream into the virtual world, the quality of the audio feed, and distorted orientation between face-to-face and virtual world participants. A framework for evaluation is proposed based on an Activity Theory perspective. An invitation for participation in an Australian Learning and Teaching Council grant application is also extended.

Keywords: virtual worlds, blended reality, mixed reality, augmented reality, augmented virtuality, learning and teaching spaces, learning design, pedagogy, technology.

Introduction

We are creating a new kind of reality, one in which physical and digital environments, media, and interactions are woven together throughout our daily lives. In this world, the virtual and the physical are seamlessly integrated. Cyberspace is not a destination; rather, it is a layer tightly integrated into the world

around us. Technology enables this transformation but, as is always the case, when we invent new technologies, they in turn re-invent us. In the realm of blended reality, the technologies and tools that we are creating change a fundamental part of our existence: the lenses through which we view and interact with the world. We are literally beginning to see and feel the world through a new set of eyes and ears—things that were previously invisible become visible, and we see the familiar in a new way.

<div align="right">(Institute for the Future, 2009)</div>

Virtual worlds

Virtual worlds (also called virtual environments or synthetic worlds) are "electronic environments that visually mimic complex physical spaces, where people can interact with each other and with virtual objects, and where people are represented by animated characters" (Bainbridge, 2007). They offer opportunities for educators and learners to interact within dynamic environments, through adaptable identities, and have been successfully integrated into higher education courses as platforms for role-play (Jamaludin, Chee, & Ho, 2009) and experiential learning (Jarmon, Traphagan, Mayrath, & Trivedi, 2009).

Castronova (2005) discusses the interplay between virtual worlds and more traditional forms of activity, using the metaphor of a membrane to describe the boundary between the two spaces. As Castronova (2005) points out, the distinction between virtual and physical worlds is becoming increasing blurred, through the increasing prevalence of social practices, such as trading goods and services, which are distributed across the two worlds. In this way virtual worlds have the potential to address issues learning and teaching space issues (such as overloaded lecture theatres and inferior remote learning experiences) by providing more realistic, synchronous and interactive access to learning and teaching episodes.

Blended reality

Blended reality has been defined as "an interactive mixed-reality environment where the physical and the virtual are intimately combined in the service of interaction goals and communication environments" (Hoshi, Pesola, Waterworth, & Waterworth, 2009). There are many who believe that in the future there will be a shift from virtual reality towards the blending of physical and virtual worlds (Castronova, 2005; Moore, 2010; Swan, 2007). There has been considerable research and development into how real-world activity can directly interface with virtual world objects (Huynh, Xu, & Wang, 2006) and such research has resulted in a range of technologies and approaches that allow more natural real-world interaction with virtual worlds, for instance gaming environments such as the Nintendo Wii. This research, however, has focused on the interface between a person and virtual objects, rather than the enactment of social practice involving a group of people exchanging information and artefacts across a membrane.

Mixed reality has been defined as "a creative or social activity that takes place simultaneously in real and virtual worlds and where the interaction in each are resonant and dependent on each other", with examples including a children's television broadcast where children's collaboration in a virtual world appears to help the progression of the story or a film on a DVD with clues that allow participants to progress with other players in an online game (Hayes, 2008). Two types of mixed reality environments include augmented reality (where virtual images are overlaid upon our physical world) and augmented virtuality (where items from the physical world are integrated into a virtual world).

Figure 1 shows how augmented reality and augmented virtuality are positioned on the Physical-Virtual continuum (adapted from Milgram, Takemura, Utsumi, & Kishino, 1994). Based on this schema mixed reality encompasses any environment where physical and virtual environments are interwoven.
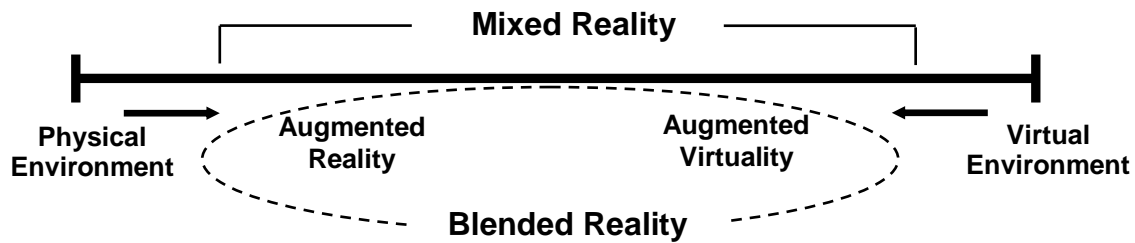
Figure 1: The Physical-Virtual continuum

In some cases it is possible to created a *blended reality* environment. For the purposes of this paper a blended reality environment is defined as an environment that synchronises both an augmented reality and augmented virtuality space. Importantly, there are participants in each of the environments, and they interact with one another between the augmented reality and augmented virtuality environments.

There has been limited work in the use of blended reality environments for learning and teaching. Master of Digital Media students from the Great Northern Way Campus have used 'green screen' technology (both in the real world and in the virtual world) to shoot videos of people in the real world seemingly interacting with avatars in Second Life (Wood, 2008). There have been cases of live video streams into virtual worlds to facilitate collaboration (Smarr & Gruber, 2008), and using augmented reality to simulate a conference meeting between remote participants (Regenbrecht, et al., 2004). Research into the use of blended reality in the health sciences has suggested that tangibility increases the level of perceived presence, but that presence and self-presence are unrelated phenomena (Hoshi, et al., 2009); yet, is difficult to find examples of mixed or blended reality approaches being applied in education.

This study investigates the use of a blended reality environment for learning and teaching in a tutorial setting. A face-to-face classroom was setup to include a projection of a virtual classroom space. A virtual classroom space was configured to include a live video stream of activity that was occurring in the face-to-face classroom. This enabled examination of issues and potentials associated with the use of blended reality classes. On this basis a framework for evaluating blended reality learning environments is proposed.

Conceptualising blended reality learning environments

In a blended environment where face-to-face participants in a physical environment interact with avatars in a virtual world, inter-world activity is necessarily facilitated by the technological tools being used. Engeström's (1987) Activity Theory provides a suitable referent for conceptualising blended learning environments because it considers how people (subjects), interact with objects via mediating tools in order to effect outcomes. This is done in the context of a community with its own set of rules and approaches to division of labour. Activity Theory is a powerful framework for the design and development of technology-enabled learning environments because its assumptions are consonant with the ideas of constructivism, situated learning, distributed cognition and everyday cognition (Jonassen & Rohrer-Murphy, 1999). The framework provides a useful lens through which to study intersubjective learning in distance educational contexts, because it focuses upon the relationships that exist among those involved in an activity and how they can be facilitated using the mediating technology (Greenhow & Belbas, 2007). Figure 2 represents the Activity Theory components in the context of this study.
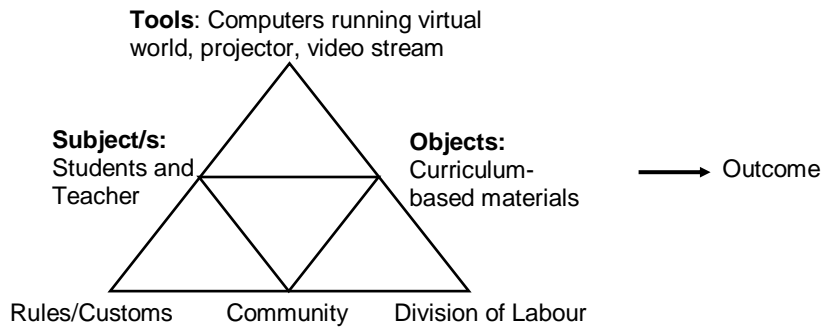
Figure 2: Engeström's (1987) Activity Theory framework as applied to this study

In terms of the blended reality learning environment being examined in this trial, the overall activity system can be considered as two parallel and interconnected activity systems running in tandem – a real world face-to-face environment and a virtual world environment – that tend towards one system as the performance of the system improves.

The tools in the face-to-face classroom include all of the standard equipment for a computer learning lab, plus tools to transmit activity to the virtual environment (computer, video camera, microphone/s) and tools to receive activity from the virtual environment (computer, projector, speakers). The tools to facilitate activity in the virtual classroom include normal equipment to participate in a virtual world experience (for instance, computer, speakers, microphone), as well as the functionality embedded within the virtual world technology (for instance, virtual object construction tools and scripting). It is assumed that computers being used in both environments have Internet access.

The subjects in the trial include the students (distributed across both the real and virtual environment) and the teacher (in this case residing in the real world). The objects are the physical or mental products being developed in either the real or virtual world, including texts, models, narratives, and so on. In the face-to-face classroom these may be physical as well as digital, however in the virtual world these manufactured outputs are always digital.

The community is the interdependent subjects who participate in the joint activity. In the case of this trial the community is fragmented into two separate but interrelated groups – those in the real world and those in the virtual world. The rules/customs relate to the conventions that guide the actions of community members. Because subjects are divided between real and virtual worlds, different sets of communicative conventions may be required in different cases. Subjects interacting with each other in the virtual world may require different conventions to subjects interacting with one another in the face-to-face environment. Subjects in the virtual world who are attempting to interact with those in the face-to-face class may require different conventions to subjects in the face-to-face class attempting to interact with those in the virtual classroom.

Division of labour represents the way in which tasks as shared between the community in order to accomplish the desired 'outcome', which in the case of a blended reality classroom environment is in most instances 'learning'. Division of labour (for instance, for collaborative learning tasks) may be particularly challenging in a blended reality environment because all activity between worlds is necessarily facilitated through the mediating technologies.

The face-to-face environment receives all information from the virtual reality environment using a projection of the virtual classroom space. The virtual classroom receives all information from the real world using a video feed of the face-to-face classroom. The challenge is to use these communication channels to shift from parallel but separated environments to a community of learners interacting as seamlessly as possible in one unified environment.

Method

This paper reports on observations drawn from a trial of a blended reality classroom environment in mid-2010. A blended reality environment was constructed in order to test the feasibility of having remote students access and interact with face-to-face classes using virtual reality environments. Participants included student and staff volunteers associated with the Department of Education at Macquarie University. The technical construction of the site to facilitate the two-way interaction between the real-world and virtual world required several items of equipment, which were configured as shown in Figure 3 in order to facilitate the audio and visual channels of communication in each direction.
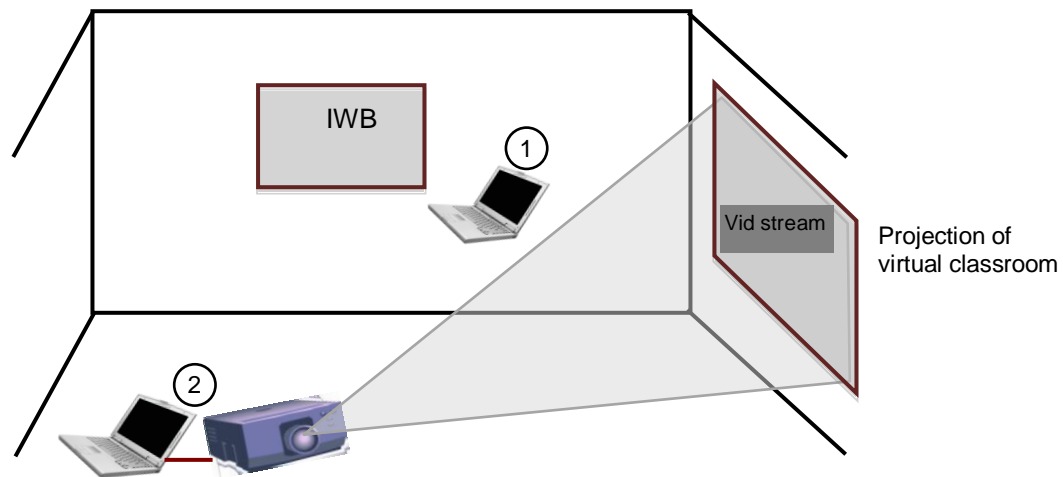

Figure 3: Technical configuration in order to facilitate blended reality classroom

In order to transmit information from the real world to the virtual world, a microphone and video camera in the face-to-face class feed audio and visual information from the room into a computer (1). The computer then feeds that information to a web-based video-streaming server (in this case, Ustream). In the virtual world classroom (in this case in Second Life™) the video stream is then allocated to the surface of an object, allowing participants in the virtual world to observe activity in the face-to-face classroom. Note that the Second Life Viewer 2 client is currently required because other clients do not support Prim 2 objects needed for video streaming.

Communication from the virtual world to the real world starts with virtual world participants' audio, movement and text-chat contributions (via their avatar). These are then relayed via the virtual world server to a computer in the real world class (2). Being logged into the virtual world environment allows the computer in the face-to-face class to project the audio (via speakers), as well as visual and text-chat (via data projector) information emanating from the virtual classroom.

Two of the researchers and all seven volunteers were in the face-to-face classroom, and one of the researchers was off-site. All three of the researchers logged into the classroom in the virtual world. One of the researchers in the face-to-face classroom then simulated the following teaching activities in order to gauge technical and pedagogical issues:

a) presenting an explanation on the interactive whiteboard to both the real and virtual classroom participants,
b) interacting with the virtual participants and real participants; and
c) organising within world student groups and then interacting between worlds.

The researchers then documented key issues based on their observations and collaboratively reflected upon those issues retrospectively. Photographs (both in the face to face and the virtual world) were taken to provide a visual archive of activity. On this basis issues were organised into themes, potentials of the approach were identified, and a framework for evaluating blended learning was devised.

Observations

It was possible for the teacher to simultaneously present an explanation on the interactive whiteboard to both the face-to-face and virtual classroom subjects. Figure 4 shows subjects in the real room receiving IWB instructions from the teacher, with the projection of the virtual classroom on the sidewall. Figure 5 shows avatars in the virtual world watching the video stream of activity in the face-to-face classroom. Figure 6 shows the view of an avatar watching the video stream of real-world activity from within the virtual world.

Figure 4: Teacher simultaneously presenting to face-to-face and virtual participants

Figure 5: Avatars in the virtual world watching a video stream of activity in the face-to-face class

Figure 6: Avatar view of activity occurring in the face-to-face classroom

It was found that the quality of audio feeding into the virtual world via the video streaming server made it difficult for virtual world participants to comprehend the teacher's speech. The quality of the video stream was sufficient to interpret people and activity, with a frame rate of between two and three frames per second. However the video quality was not sufficient for virtual participants to read the material on the

interactive whiteboard, both because of the resolution of the video feed and because of the lighting. As well, the latency of the video feed meant that virtual participants were viewing activity approximately four seconds than it occurred in the face-to-face classroom. The fact that the teacher was attempting to present to two audiences did not negatively impact upon face-to-face students.

Interaction between the teacher and virtual participants was possible but difficult. An attempt to accomplish this is shown in Figure 7. The main difficulties incurred were due to the latency and broadcast quality issues, which caused a delay in the image received in the virtual world and audio in the virtual world difficult to hear. As well, there were orientation issues caused by the inconsistent perspectives of the location and direction of the camera in the real world and the avatar providing the viewpoint in the virtual world. Because the laptop capturing audio-visual information from the face-to-face classroom was pointing parallel to the projector screen on the side-wall and not perpendicular to it, when the teacher approached the screen it appeared to the avatars that the teacher was at 90 degrees to where they were actually positioned. Similarly, because the position of the avatar that was providing the viewpoint for the projection in the real world was not facing directly outwards from the surface showing the video stream in the virtual space, face-to-face participants could not interact with the avatars in the virtual world without performing mental re-orientation.

Figure 7: An attempt to interact with both virtual and face-to-face participants

Groupwork activities between participants within one world were relatively feasible. Figure 8 shows how a face-to-face group and a virtual group could operate simultaneously and side-by-side. Once the instructions for a task have been allocated, virtual subjects could collaborate with one another entirely according to the interaction protocols and techniques availed in the virtual world and thus circumvent any issues related to receiving information from the face-to-face classroom. This meant that collaborative difficulties were constrained only to the functionality of the virtual world environment and students ability to utilise those functionalities. On the other hand students in the face-to-face classroom could interact with one another in a traditional classroom manner.

However difficulties were once again experienced when attempting to interact between the real and virtual worlds. Figure 9 shows an attempt to have groups in the real world interact with groups in the virtual world.

Figure 8: Groups in the face-to-face world and the virtual world

Figure 9: Attempting to facilitate inter-group interaction between the real and virtual worlds

Apart from the latency and broadcast quality issues, orientation issues were exacerbated because the camera was not positioned to capture groups of students around the face-to-face classroom. Adjustments of the camera require virtual participants to reorient themselves with respect to the visual information being fed from the video stream. The microphone in the face-to-face classroom was not sufficient to capture the audio of all of the face-to-face students. Thus again while students in the face-to-face classroom were able to interpret and respond to activity occurring in the virtual classroom, virtual world participants were not easily able to interpret and therefore respond to activity in the face-to-face classroom.

Discussion

Optimising the technical configuration

The communication between the two worlds relies on relay through several instruments. In order to optimise the performance of the blended environment it is necessary to maximise quality and minimise latency at each stage, as outlined below.

Real to virtual world transmission optimisation
1. Video-capture should be of sufficient quality for virtual classroom yet not so large as to impede streaming performance.
2. Audio-capture needs to be of sufficient quality but not too high so as to overload bandwidth, with a radius sufficiently large to capture whole class discussions but not capturing all of groupwork discussions in a way that may cause interference.
3. The quality of the computer and software uploading the video and audio should be of sufficient quality to minimise latency.
4. The Internet connection from the capture computer to the video-streaming server (better than wireless) should be of high quality so as to not impede broadcast.
5. The video-streaming server should minimise latency between upload and broadcast.
6. The virtual world environment should have close to immediate response times and be able to broadcast video feeds with as little delay as possible.
7. The Internet connection and multimedia processing capabilities on the virtual participants' computers should be high enough so as not to induce latency.

Virtual to real world transmission optimisation
1. The microphone of virtual participants is of sufficient quality to transmit voice messages.
2. The Internet-upload capabilities on the virtual participants' computers should be sufficient to upload voice data without lags or breaks in broadcast.
3. The virtual world provides high quality (minimal latency) audio and visual upload and download, both for remote participants to the virtual world and from the virtual world to the face to face class.

4. The projection computer in the face-to-face classroom needs to have a high quality Internet connection and multimedia processing capabilities.
5. The radius of audio (and text chat) capture of the avatar providing the face-to-face class viewpoint needs to be sufficiently large to capture the conversations in the virtual world.
6. The speakers of the projection computer are of sufficient quality to broadcast virtual world audio throughout the face-to-face classroom (ie active speakers).
7. The projector is of sufficient quality to broadcast an image of the virtual world that is large enough for all face-to-face participants to see.

There is also the possibility of providing an enhanced view of the interactive whiteboard by having a separate higher quality video feed and overlaying this within the virtual world. The lighting of the real world room also needs to be considered when attempting to project an image of the interactive whiteboard into the virtual classroom. To improve the quality of audio feed received in the virtual world it may be possible to stream the audio from the face-to-face classroom to the virtual participants via another application, for instance Skype or even the through the Second Life Viewer 2 client.

Orientation and perspective

Ideally the capture and projection of each world into the other would be such that the mental manipulation required to orient oneself with respect to the other world is minimised. One way to accomplish this would be to setup the views and projections so that participants feel as though the two classrooms were looking through a window into one another. In order to accomplish this, the video and audio capture points in one world need to be placed at the centre of the projection space of the other world, and orthogonal to that projection space. In the face-to-face world the video and audio capture would need to be close to the centre of screen and pointing directly out from it, and in the virtual world the avatar view would need to be at the centre of the video stream and facing directly out towards the rest of the virtual classroom. This poses difficulties in terms of where to place the projection space so that it provides a reasonable view to the participants in both worlds without interfering with the space within either world. There are also pragmatic difficulties in terms of placing equipment in the centres of the projection spaces. These are issues that require further attention for an optimal solution to be derived.

Integrating other interactive and collaborative modes

In the current configuration, it would be possible for face-to-face participants to login to the virtual classroom to interact with their virtual peers. This would also enable all participants to utilise other features of the virtual classroom, including teleportation, construction of objects, flight, advanced preparation of simulation environments and so on. The video-stream that was fed into the virtual classroom space was embedded within a Ustream web-page. This meant that some of the chat and discussion features could be shared between face-to-face and virtual participants, if desired. In the form that was used, virtual participants would need to open a separate web-browser and access the page, however it would be possible to feed other discussion tools into the virtual classroom.

Other issues

Conducting tutorial activities previously designed for face-to-face classrooms in a blended reality environment will in most cases require the activity to be transformed in some way. Some activities that were previously completed in face-to-face classes may be more difficult or not possible, and other activities that were previously impossible may now be supported by virtual worlds. In order to run a tutorial, teachers need to consider, design, develop and effectively implement learning activities that may be supported simultaneously within virtual worlds and traditional classrooms. This is the central challenge to blended reality learning environments. Not only do teachers need to understand how to function effectively on both sides of the 'membrane' between the virtual and physical worlds, but they also need to be simultaneously manage and blend both environments for an optimised learning experience. Additional unexplored ICT tools may facilitate this (for instance by more closely integrating information streams in the virtual and physical locations). This includes both hardware infrastructure and software.

An additional teacher challenge is how to most effectively support students to interact between worlds. Teachers need to have the competence and confidence to deal with breakdowns in activity caused by technical functionality or understanding. Managing classes effectively in blended reality environments will require a range of new strategies and pedagogical patterns not yet determined. In terms of division of labour it may be that some roles may be more suited to either face-to-face or virtual modes, which may result in different tasks being completed in each space, potentially creating different learning opportunities for students. Equitable learning principles will require that as far as possible, students on both sides of the membrane receive an equal educational experience, and are not disadvantaged due to the characteristics of the virtual or physical space in which they chose to participate. This will become of heightened importance if conducting formative or even summative assessment in blended reality classes.

An evaluation framework

Drawing on the observations and conceptualisation of blended reality learning outlined above, a framework for evaluation is proposed. The framework is directly based on the Activity Theory framework, and incorporates quantitative measures allowing for objective comparison between blended reality environments as well as qualitative elements to provide insight into how the design of the blended reality environment impacted upon the learning experience.

World identification
   0. Through which environment did you participate in this class? (Face-to-face or virtual)
Subjects
   1. How effectively were you able to interact with people who were participating through the same environment as you? (0% to 100%, increments of 10%)
   2. What worked well? How could this have been improved?
   3. How effectively were you able to interact with people who were participating through the other environment to the one you were using? (0% to 100%, increments of 10%)
   4. What worked well? How could this have been improved?
Content
   5. How effectively were you able to engage with the content being learnt? (0% to 100%, increments of 10%)
   6. What worked well? How could this have been improved?
Tools
   7. How effective were the technologies being used to mediate communication? (0% to 100%, increments of 10%)
   8. What worked well? How could this have been improved?
Rules
   9. How effective were the customs and conventions that were established to facilitate interaction and collaboration? (0% to 100%, increments of 10%)
   10. What worked well? How could this have been improved?
Division of labour
   11. To what extent did the allocation of people to roles support the learning process? (0% to 100%, increments of 10%)
   12. What worked well? How could this have been improved?
Community
   13. To what extent do you feel like this approach established a unified learning community? (0% to 100%, increments of 10%)
   14. What worked well? How could this have been improved?

The open-ended responses allow researchers to better understand cause-and-effect relationships that operate in blended reality classes. This in turn can inform iterative refinement of the learning environment to provide situated principles for learning and teaching in blended reality classes (for instance using a design-based research process). The final section of the survey (community) provides an overall indication of the extent to which the virtual and face-to-face environments were able to be seamlessly merged using the blended reality approach.

Concluding comments

In the future augmented reality technology where virtual objects are overlayed on our physical world (for instance, see Total Immersion, 2004) will most likely be used to have virtual reality avatars enter into the face-to-face classroom in real time so that they are actually interacting with real people and objects. However until such a time blended reality classes such as the one presented in this study may be the next best and most cost effective approach to blending virtual and face-to-face classes. This may provide an effective solution to current learning and teaching space issues such as access to burgeoning lecture theatres and more true-to-life participation for off-campus students. While conducting blended reality classes was found to be difficult in this pilot, the potential advantages of accessibility, interactivity and embodied remote learning provide motivation to further develop and refine blended reality teaching.

It is intended to initiate a design-based research project aimed at optimising blended reality learning spaces and pedagogies. This project will seek to iteratively evaluate and improve the blended reality design, as well as contribute to our understanding of how people participate in synchronous social practices, such as tutorials, across the membrane between physical and virtual worlds. An invitation to participate in this project is extended to researchers interested in jointly researching this area, as part of an Australian Learning and Teaching Council project application. It is hoped that this study generally provides impetus for further exploration and refinement of blended reality learning and teaching.

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