This is the peer reviewed version of the following article:


which has been published in final form at:

**Access to the published version:**
https://doi.org/10.1111/bjet.12435

This article may be used for non-commercial purposes in accordance with Wiley Terms and Conditions for Use of Self-Archived Versions.
Collaborative learning across physical and virtual worlds: Factors supporting and constraining learners in a blended reality environment

Matt Bower, Mark J. W. Lee and Barney Dalgarno

Matt Bower is a senior lecturer in the School of Education at Macquarie University. Mark J. W. Lee is an adjunct senior lecturer with the School of Education at Charles Sturt University. Barney Dalgarno is a professor and co-director of the uImagine Digital Learning Innovation Laboratory at Charles Sturt University. Address for correspondence: Dr Matt Bower, Building C3A, Room 927, School of Education, Macquarie University, NSW 2109, Australia. Email: matt.bower@mq.edu.au

Abstract
This article presents the outcomes of a pilot study investigating factors that supported and constrained collaborative learning in a blended reality environment within an Australian university. Pre-service teachers took part in a hybrid tutorial lesson involving a mixture of students who were co-located in the same face-to-face (F2F) classroom along with others who were participating remotely via their avatars in a three-dimensional virtual world. Video and sound recording equipment captured activity in the classroom, which was streamed live into the virtual world so the remote participants could see and hear their instructor and F2F peers; the in-world activity was also simultaneously displayed on a projector screen, with the audio broadcast via speakers, for the benefit of the F2F participants. While technical issues constrained communication and learning in some instances, the majority of remote and F2F participants felt the blended reality environment supported effective communication, collaboration and co-presence. Qualitative analysis of participant evaluations revealed a number of pedagogical, technological and logistical factors that supported and constrained learning. The article concludes with a detailed discussion of present and future implications of blended reality collaborative environments for learning and teaching as well as recommendations for educators looking to design and deliver their own blended reality lessons.

Introduction
Blended reality collaborative environments are those that allow participants in an immersive virtual space (such as virtual world) and participants in a physical space to interact with one another in real time. It is becoming more common to see this type of setup used for conferences, seminars and other events, especially among the academic community with an interest in technology (e.g., Barrett, 2010; Jestice, 2009; Kim, 2010; Smith, 2008). Although there have been attempts to create blended reality collaborative environments for learning and teaching (see the literature review below for examples), there are few reported cases of their use within university classes, and there is a dearth of research systematically assessing their educational efficacy.

This study investigated the use of a three-dimensional (3-D) virtual world—also known as a 3-D multi-user virtual environment or MUVE—to implement a blended reality collaborative environment in a pre-service teacher education program at an Australian university. Face-to-face (F2F) students were able to see and hear their remotely located peers via a projection of a virtual world on the side wall of the classroom, and remotely located students were able to see and hear their peers and the teacher via a video feed into the virtual world. The pedagogical, technological and logistical factors that influenced the student experience were then analysed. In particular, the following overall question framed and guided the investigation:
What pedagogical, technological and logistical factors support or alternatively constrain the use of blended reality collaborative learning environments for conducting tutorial lessons in a university setting?

Qualitative analysis of student perceptions was used to investigate the research question, and gauge the impact of the approach on communication, collaboration and co-presence.

Literature review

Mixed and blended reality

Milgram and Kishino (1994) described a continuum that spans from the real-world or physical environment on one end to a purely virtual environment on the other (Figure 1). At intermediate points in between lie environments in which one’s view of the physical environment is supplemented or embellished with virtual elements—known as augmented reality—as well as those in which real-world elements are integrated into a virtual environment—called augmented virtuality. Milgram and Kishino referred collectively to these as mixed reality.

![Figure 1: Blended reality in relation to the physical–virtual environment continuum (adapted from Milgram & Kishino, 1994, in Bower et al, 2010)](image)

Augmented reality and augmented virtuality each have numerous and diverse applications in education. (For an overview of applications of the former, see FitzGerald et al, 2013; Kesim & Ozarslan, 2012; Lee, 2012; Wu, Lee, Chang & Liang, 2013. Examples of the latter can be found in Lee, Ahn, Kim & Lim, 2006; Versteegh, Bouwen, Dams, Lou & Van Raemdonck, 2014.) In some cases it may be possible or desirable to combine the two types of mixed reality. Researchers at The University of Auckland (Chen, 2011; Chen, MacDonald & Wünsche, 2009), for example, created a simulation in which a physical robot as well as the real-world objects it senses as it moves around are dynamically rendered in a virtual environment (augmented virtuality), while in the F2F environment a third-person video of the scene is overlaid with information from the virtual environment (augmented reality). Ternier, Klemke, Kalz, van Ulzen and Specht (2012) discussed challenges involved in linking augmented reality and augmented virtuality, and showcased a software framework they developed to address those challenges in the construction of mixed reality games for mobile learning. They presented three case studies of systems using the framework: a location-based application for supporting students in undertaking a scavenger hunt, an augmented Google Street View client used by students to learn about the cultural heritage of a city, and a game requiring students to take on roles and make decisions in authentic hostage situations. In all three cases, real sound and imagery were added to virtual media (augmented virtuality) and vice versa (augmented reality) to make gameplay more engaging as well as to support situated and experiential learning.

The specific focus of the present article, however, is on conducting university tutorial classes in a blended reality collaborative environment, which we define as an environment that brings together participants in augmented reality and augmented virtuality spaces, enabling them to interact within and across the spaces through the projection of live audio and/or visual information from each space into the other. The defining features of a blended reality collaborative learning environment are outlined in Table 1. A blended reality environment may also be thought of as a special instance of a blended synchronous learning environment—one that involves co-located and remote or distributed individuals communicating and undertaking joint activities in real time (see Bower, Kennedy, Dalgarno & Lee, 2011; Bower, Kennedy, Dalgarno, Lee & Kenney, 2015). Blended synchronous learning is still an emerging phenomenon in higher education but is becoming increasingly popular as a means to meet the needs of 21st-century students, who desire the flexibility to participate in campus-based classes either F2F or online depending on where they may physically be at the time of the class (Bell, Sawaya & Cain, 2014;

**Table 1: Defining features/characteristics of a blended reality collaborative environment**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Meaning</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel modalities</td>
<td>There are one or more real-world (physical) and one or more 3-D virtual environments(^1) or spaces running concurrently and in real time.</td>
<td>Essential</td>
</tr>
<tr>
<td>Augmented reality</td>
<td>Audio and/or visual information from participants in the virtual environment(s) is projected to participants in the real world.</td>
<td>Essential</td>
</tr>
<tr>
<td>Augmented virtuality</td>
<td>Audio and/or visual information from participants in the real world is projected to participants in the virtual environment(s).</td>
<td>Essential</td>
</tr>
<tr>
<td>Rich-media synchronous cross-modal communication</td>
<td>Participants in the real world and virtual environment(s) are able to communicate with one another across modes in real-time using the audio and/or visual information that is projected between the respective environments.</td>
<td>Essential</td>
</tr>
<tr>
<td>Synchronous face-to-face communication</td>
<td>Two or more of the real-world participants are able to communicate with one another in person by virtue of being co-located in the same physical space.</td>
<td>Essential</td>
</tr>
<tr>
<td>Synchronous virtual communication</td>
<td>The virtual participants are able to communicate with one another in real-time (eg, via text chat, voice chat, avatar gestures/actions) through being in a shared virtual environment.</td>
<td>Non-essential(^2)</td>
</tr>
</tbody>
</table>

\(^1\)A 3-D virtual environment is defined here as an environment that “capitalizes upon natural aspects of human perception by extending visual information in three spatial dimensions,” “may supplement this information with other stimuli and temporal changes” and “enables the user to interact with the displayed data” (Wann & Mon-Williams, 1996, p. 833).

\(^2\)Environments that do not satisfy this non-essential criterion may be considered a “weaker” form of blended reality collaborative environment.

**Blended reality collaborative environments for learning and teaching**

While there is an abundance of literature on educational applications of mixed reality in general, the research base focusing specifically on what we deem to be blended reality collaborative environments is sparse, with the few published reports of scholarly projects undertaken in the area being concerned primarily with software development and technical implementation. The empirical aspects of these projects, where present, have consisted largely of usability tests rather than attempts to deeply understand learning and teaching processes and/or outcomes. Ibáñez, Maroto, García Rueda, Leoný and Delgado Kloos (2012) built a system capable of enabling blended reality collaborative learning experiences by integrating a physical environment and a virtual replica or “mirror” of that environment. They conducted a usability study in which students of Spanish as a Second Language practised their listening and speaking skills. Students in a virtual mirror of the famous Gran Via boulevard in Madrid had to correctly answer questions posed by non-person characters (software-controlled avatars) using information obtained from partners located in the actual boulevard in the real world. Pictures and videos captured in the real world were projected at the equivalent latitudinal and longitudinal positions within the mirror world (augmented virtuality), and virtual participants’ avatars were superimposed onto their real-world partners’ mobile screens (augmented reality). Results of observations and interviews indicated that although the real-world participants were somewhat apprehensive and unsure of their roles at the beginning of the tour, they soon gained confidence, and collaboration with their partners in the mirror world emerged naturally. The researchers discovered evidence of a high level of engagement as well as a strong sense of presence (“being there”) and co-presence (“being there, together”) among students.

In contrast to the present study, systems and applications like those developed by Ibáñez et al (2012) are intended to facilitate situated learning through activities undertaken by students outside a formal institutional context. An extensive search of the academic literature yielded just four documented efforts that have to do with blended reality collaborative environments for learning and teaching within traditional class settings. In the first of these, Müller, Bruns, Erbe, Robben and Yoo (2007) explored how mixed reality laboratory setups accessible by both local and remote students can be composed of a mixture of real and virtual equipment. Their “Hyper-Bond” interface enabled them to implement a hybrid
environment of this kind for mechatronics engineering education, where physical workbenches in a real lab were coupled with software-simulated workbenches in a 3-D virtual space. Müller et al later built on this work, extending their prototype system by incorporating CAVE automatic virtual environment (CAVE) technology. Multiple distributed CAVEs, each made up of three rear-projection walls surrounding a real workbench, were connected to one another via the Internet. While seated at the real workbench, students could see the virtual environment displayed on the wall in front of them and other, remotely located students at their respective workbenches displayed on the walls on either side of them.

The remaining three examples of blended reality collaborative environments for formal learning and teaching that can be found in the scholarly literature are centred around instructor-led classes, making them more akin to the scenario of the present study. The MiRTLE (Mixed Reality Teaching and Learning Environment) project (Horan, Gardner & Scott, 2009) used the Project Wonderland virtual world platform (now called Open Wonderland—http://www.openwonderland.org) to build a system for simultaneously delivering a lecture or tutorial to a F2F cohort in an on-campus classroom and a remote cohort in a virtual world. F2F students could see and hear remote students’ avatars via a projection of the virtual world in the physical classroom, and remote students could see and hear their F2F peers via a video stream within the virtual world. Cochrane, Atkins and Sutcliffe (2008) outlined similar plans for the simultaneous dual-mode delivery of live classes in a Computer Systems Architecture course. As well as increased flexibility of access to the lesson they believed pedagogical benefits would accrue through the ability of all students to exploit the learning affordances of virtual worlds (see Dalgarno & Lee, 2010). While Cochrane et al did not subsequently evaluate nor report their implementation experiences and outcomes, small-scale evaluations of the MiRTLE system were done at the University of Essex, albeit only with high-level observations being formally written up (Gardner & O’Driscoll, 2012); most notably, the results suggested there were affordances for impromptu and naturalistic cross-modal interaction between the two student cohorts, which the MiRTLE project team postulated could facilitate a breaking down of the barriers between the virtual and the physical, thereby increasing sense of presence for all students and instructors involved. Another key finding was that instructors recognised the potential value of the blended reality approach, claiming that aside from some initial overhead at the start of the lesson and minor logistical issues during the lesson there was minimal impact on their normal patterns of teaching as well as on their perceptions of the learning occurring in their classes.

Schmidt, Kevan, McKimmy and Fabel (2013) of the University of Hawai’i are the only authors to date who have published substantive empirical findings relating to blended reality collaborative learning environments. They reported on a design-based research project in which they designed, developed and formatively evaluated an environment similar to MiRTLE called the Holodeck@UH that was based on OpenSim (http://www.opensimulator.org). They administered an online survey aimed at eliciting educational technology students’ and practitioners’ perceptions based on video vignettes of activities making use of the system, and additionally ran a usability study incorporating eye tracking and think-aloud protocols as well as post-test interviews for assessing students’ perceived ease of use. Preliminary analysis of the survey data suggested participants thought the environment was innovative, engaging and exciting and that they saw its potential for enhancing the sense of community for learners studying at a distance. Their responses suggested they believed the blended reality modality made the learning experience for virtual participants more personal, but at the same time agreed that learning and teaching in this modality appeared to be logistically complicated and that systems like the Holodeck@UH should be used in a complementary way to existing online technologies as opposed to seeking to replace them. As for Schmidt et al’s usability study, that part of the research focused primarily on the ability of users to navigate the virtual environment and locate the in-world “classroom” area. (An attempt was not made to understand perceptions from the perspective of participants in the real-world classroom.) The usability tests revealed participants found the environment fairly easy to use overall. Importantly, they had a clear view of the real-world classroom and could also easily zoom in on the screen intended for displaying the presenter’s visual aids as well as on other parts of the virtual environment. However, the results did point to a number of issues that needed to be addressed, including better navigational support (eg, embedded guidance/directions) and training for users, leading the researchers to conclude that more work was needed before their system was ready to be used for offering classes in earnest.

Thus presence and co-presence emerged as key design elements amongst all five explorations of blended reality learning environments, and are therefore worthy of further investigation because of their centrality and for comparative purposes. Interaction and communication were central to the environment
constructed by Ibáñez et al. (2012), and proposed as critical in analysis by other researchers (Gardner & O’Driscoll, 2012; Horan, Gardner & Scott, 2009; Schmidt et al., 2013), and so warrant further investigation. Co-creation and sharing was tangentially addressed in the study by Ibáñez et al. (2012), but only in a fieldwork context. Yet an understanding of issues relating to sharing and co-creation is essential if teachers are to capitalise on the educational potential of blended reality learning environments.

Given the absence of studies that have examined the learning and teaching issues surrounding the use of blended reality collaborative environments in real classes, the present pilot study sought to identify and understand the pedagogical, technological and logistical factors that support and constrain communication, collaboration and co-presence in these environments, based on the perceptions of students.

Method

Context, participants and overview of study

The pilot study took place at a large metropolitan Australian university. Participants were undergraduate students who were undertaking an ICT education subject aimed at encouraging pre-service teachers to consider how new and emerging technologies and social media might be used to support new forms of learner interaction and participation. These students were typically in their second year of the four-year full time undergraduate pre-service teacher program. In Week 9 of Semester 1 in 2013, for which the designated topic was virtual worlds, two blended reality tutorials were held that were attended by 45 students in total. In the first class there were 11 co-located students and 12 remotely located students, while in the second class there were 12 co-located students and 10 remotely located students. Approximately even numbers were selected to attend via both modes in order to avoid the number of students participating in one mode dominating the activity or focus of the lesson. The 22 remotely located students joined the 23 students in the F2F classroom by logging in to a virtual world based on the AvayaLive Engage (http://www.avayalive.com/engage) platform from other on- and off-campus locations.

In planning and designing the pilot setup, the researchers, working in conjunction with the university’s information technology support staff, were able to draw on experience and lessons learnt from earlier technology trials and a proof-of-concept blended reality implementation in early 2010 that used Second Life (http://www.secondlife.com) as a platform (see Bower, Cram & Groom, 2010). As previously mentioned, the following question framed and guided the investigation:

What pedagogical, technological and logistical factors support or alternatively constrain the use of blended reality collaborative learning environments for conducting tutorial lessons in a university setting?

This was addressed by a number of sub-questions, principal of which were:

a) How is communication by remote and F2F participants supported or constrained in the blended reality collaborative learning environment?

b) How is co-creation and sharing by remote and F2F participants supported or constrained in the blended reality collaborative learning environment?

c) How is co-presence and representation of status by remote and F2F participants supported or constrained in the blended reality collaborative learning environment?

d) What other elements were generally supported or constrained in the blended reality collaborative learning environment?

Based on the previous studies identified in the literature review, communication, co-creation and co-presence were selected as critical elements of blended reality lessons that could be influenced by pedagogical, technological and logistical factors occurring in the environment. The fourth research sub-question left open the possibility that there were other previously unidentified or unreported elements that may be observed in blended reality collaborative learning settings.

Physical learning space design and technical setup
The purpose of the physical space design was to enable remote students to participate in the live class, as well as enable F2F students and the teacher to interact with remotely located students. The F2F class was situated in a computer laboratory with an interactive whiteboard (IWB) at the front of the room and a separate screen on one of the side walls of the room. The instructor presented slides and operated his avatar in AvayaLive using the computer attached to the IWB. Also connected to the instructor’s computer was an audio conferencing device equipped with an omnidirectional microphone to capture the audio from the F2F classroom and relay it into the virtual world as well as speakers to broadcast the virtual world audio into the F2F classroom.

A second computer was used in order to provide F2F with a view of the virtual world by projecting the screen onto the side wall of the physical classroom. To achieve this, the instructor accessed the virtual world on that computer using a separate account for an avatar that remained logged in but was left unmanned for the duration of the lesson.

A video camera located on a tripod below the projector screen and attached to a third computer captured the activity in the F2F classroom. The captured video was relayed to a media streaming server to be streamed live into the AvayaLive environment so participants in the virtual world could see, in real time, what was happening in the F2F class.

The actual physical space used for the activity is shown in the photograph on the left side of Figure 2. The right side of the figure depicts schematically the arrangement described above.

![Figure 2: Appearance (left) and layout/configuration (right) of the physical classroom](image)

**Virtual learning space design and technical setup**

The virtual world environment was designed so as to allow remotely located students to participate in the F2F class, as well as provide them with a means to collaborate with one another. The space consisted of a main conference room that functioned as a central meeting point along with several separate, smaller satellite or “breakout” rooms outside the main room where students had access to notes areas for formulating their responses to group-work tasks. The video feed of the F2F class, the IWB (from the instructor’s computer), and three student computer screens were streamed from the physical classroom onto the walls on the main virtual world room so that remotely located students could see activity taking place in the F2F classroom. Three notes areas linked to surfaces in the virtual world breakout rooms were also displayed on the side walls of the main virtual world classroom so that remote and F2F students could compare all student group work responses in the same space.

In order to render the in-world view of the F2F class, the video output from the streaming server had to be embedded on a webpage with the help of a Flowplayer plugin. It was this webpage that was then displayed on the relevant surface in the virtual world. There was an approximately 7-second delay in the video feed from the F2F classroom as each of the technology components involved introduced a small amount of latency. To accomplish the streaming of selected F2F student computer screens into the virtual world, three avatars were logged in to the machines at which the groups of students were working, and the screen sharing facility of the virtual world was employed. Linking the notes areas in the breakout
rooms to displays in the main room was accomplished using a native feature of the virtual world platform that allowed notes areas to be displayed by name.

Figure 3 portrays the layout and appearance of the main room within the virtual world.

Figure 3: Appearance (left) and layout/configuration (right) of the virtual world main room

Lesson objectives, preparation and activities
The main learning objectives of the blended reality tutorial lesson were to enable participants to articulate advantages and disadvantages associated with the use of virtual world technology in education as well as to give them the opportunity to create high-level learning designs for use in their primary and secondary school classrooms that leverage the capabilities of the technology. Earlier in the week, the students had attended a lecture on virtual worlds, including some material about their features and affordances (Dalgarno & Lee, 2010) for learning. In the preceding week, all participants were asked to complete a virtual world orientation activity in the form of a treasure hunt that was designed to help them develop the requisite technological skills for the lesson, including the ability to navigate through the AvayaLive environment, communicate via audio and text, gesture, write on notes areas, and share their screen. These pre-tutorial learning activities served to inform students about the key issues at stake when using virtual worlds in the classroom, as well as help familiarise them with the layout and use of the virtual world space.

The lesson was designed in order to test how teacher instruction, guided discussion, and student-centred group work could be facilitated using blended reality environments. The tutorial began with a short slide-supported presentation in which the instructor revisited the content that was covered in the lecture. The concepts of blended reality and blended synchronous learning were also briefly introduced. Thereafter, a class discussion activity was conducted in which F2F students in the physical classroom and remote students in the virtual world were asked to stand on pre-placed floor markers within their respective environments to indicate how useful and relevant they felt virtual worlds were for learning and teaching (Figure 4). The instructor then invited selected students in both modes to explain the reasoning for their perceptions, spurring a whole-class discussion.
Next, students were divided into groups, each containing three or four members participating via the same mode, and asked to brainstorm a list of the advantages and issues associated with the use of virtual worlds in schools. One member from each group was allocated as a scribe. Students in the virtual world completed the task in the breakout rooms, using notes surfaces whose contents were automatically mirrored on linked surfaces in the main room. The F2F students typed their responses into a word-processing program and then shared their screens in the virtual world main room. The instructor circulated among the F2F groups and also the remote groups (using his avatar) to provide encouragement and any technical support that was required. Upon conclusion of the allocated time, the remote students returned to the virtual world main room and the instructor facilitated a whole-class debriefing discussion comparing and contrasting the points contributed by the various groups.

A second group activity challenged students, working in the same groups as before, to come up with an interesting lesson idea that made use of virtual worlds, accompanied by teaching strategies needed to make it work well. Students recorded and shared their ideas using the same approach as for the previous task. After a review of each group’s lesson design, all students voted on the best design by raising their hands. A nominal prize was awarded to the group receiving the most votes.

In a final self-reflection task, students were asked to position themselves along the floor markers again to represent their perceptions about the educational utility of virtual worlds. They talked about whether—and if so, why—their perceptions had changed since the start of the lesson.

During the lesson, the instructor had to work extremely hard to simultaneously manage the content delivery, provide guidance to students and troubleshoot technology issues such as audio feedback loops caused by students who had not muted their microphones. The instructor applied several general teaching strategies, including setting tight time constraints on tasks, providing guidance and encouragement to both the remote and F2F student groups, and directing questions to selected individuals so as to structure the lesson discourse. Network and software issues constrained communication at times, with choppy audio or frozen video. Performance was good enough for remote students to be able to participate in the lesson, but appeared to compromise the overall experience for some students.

Data collection and analysis

Following the lesson, students were asked to complete a survey and participate in a focus group interview. Student perceptions were used to gauge pedagogical, technological and logistical factors that influenced the lesson, as a) participating students had first-hand experience of the issues that impacted on the blended reality collaborative learning environment, and b) the sample size meant that a wider variety of perceptions could be harvested and triangulated, as opposed to only a few from researchers and/or teachers. This overcame limitations of previous studies that had only drawn upon researcher perceptions or perceptions of simulations of the environment rather than of actual classes.

The survey inquired as to students’ perceived ability to communicate with both cohorts of students, to share visual artefacts, to create and share materials, and to indicate their status to others. The survey also asked the extent to which students felt present with both cohorts of participants, how much they felt they learnt compared to traditional classes and whether they would like the approach to be used in other classes. Participants were asked to provide a Likert-type response to each question on a 7-point scale (with the options ranging from Strongly Disagree to Strongly Agree). Each Likert-type item was followed by an open-ended section where students were encouraged to explain their response. The focus group interview pursued similar lines of inquiry as the survey, but offered students the opportunity to elaborate on their responses and to be stimulated by the thoughts of others. Thus the Likert-type items, provided a standardised means for comparing the extent of an effect relating to the research sub-questions, whereas the focus group interviews and open-ended survey responses could be used to understand the reasons for each effect. To this end the survey and the focus group interviews were both used to address the research question and sub-questions.
The open-ended survey responses and focus group transcripts were analysed using qualitative analysis in line with Neuman (2006). Qualitative methods were applied in order to provide a structured approach to understanding the explanatory nuances that existed within the data with relation to the research questions. During the open coding phase, initial passes were made through the data to identify preliminary analytic categories within each survey response item. Considerable time was spent during the axial coding phase to ensure all key supports and constraints had been identified. This involved tabulating all issues for each survey item, separated out according to whether students had participated F2F or remotely. All factors that had been identified were then classified into the pedagogical, technological and logistical themes that were evident in the data. Finally, the selective coding phase involved choosing responses that were either representative of key issues or pertinent in terms of explaining key learning supports and constraints in blended reality collaborative learning environments. Student voices as primary sources of data have been used to promote reliability of reporting throughout the Results section below.

Results
Of the 33 students who volunteered to participate in the survey and focus groups, 17 were F2F students and 16 were remote students. Aggregate responses to the Likert-type survey questions about their experiences are presented in Table 2.

Table 2: Summary of student responses to key evaluation questions

<table>
<thead>
<tr>
<th>Item</th>
<th>Face-to-face (F2F)</th>
<th>Remote</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 17)</td>
<td>(n = 16)</td>
</tr>
<tr>
<td></td>
<td>% Agree % Neutral % Disagree</td>
<td>% Agree % Neutral % Disagree</td>
</tr>
<tr>
<td>I was able to communicate verbally in an effective manner with people in the face-to-face class</td>
<td>100 0 0</td>
<td>56 6 39</td>
</tr>
<tr>
<td>I was able to communicate verbally in an effective manner with people who participated remotely</td>
<td>33 20 47</td>
<td>78 6 17</td>
</tr>
<tr>
<td>In this lesson I was able to effectively share visual artefacts with others (eg, images, photos, etc)</td>
<td>87 13 0</td>
<td>69 25 6</td>
</tr>
<tr>
<td>In this lesson I was able to jointly create, edit and share material with others in an effective manner</td>
<td>85 15 0</td>
<td>89 6 6</td>
</tr>
<tr>
<td>In this lesson I was able to effectively indicate my status to others (eg, wanting attention, etc)</td>
<td>77 23 0</td>
<td>72 6 22</td>
</tr>
<tr>
<td>In this lesson I felt like I was present with people who were participating remotely</td>
<td>67 13 20</td>
<td>76 12 12</td>
</tr>
<tr>
<td>In this lesson I felt like I was present with people who were in the same room as the teacher</td>
<td>71 14 14</td>
<td>61 11 28</td>
</tr>
</tbody>
</table>

The proportion of students agreeing with the question items in Table 2 indicates that students had generally positive perceptions with regard to how the collaborative technology was able to mediate the experience. A comparison between the responses of remote and F2F students indicated that the pattern of responses was broadly the same for many of the items—that is, approximately two thirds to three quarters of students, regardless of their participation mode, agreed that they were able to indicate their status to others, that they shared a feeling of presence with both their remote and F2F classmates, and that the technology provided a clear and accurate representation of information and people. While there were participants who were neutral or did not agree this was the case, they were in the minority (although close to 30% of remote students indicated they did not feel co-present with people in the classroom). Students in both modes were, by and large, very positive about their ability to jointly create, edit and share material with others.
Communication
The clearest point of difference between students who participated F2F and those who participated remotely was for the first two items in Table 1. For example, while all F2F students agreed that they were able to effectively communicate with people in the F2F class, well over one third (39%) of remote students indicated this was not the case for them. Conversely, for the second item in Table 1, the majority of the remote students (78%) agreed that they were able to effectively communicate with remote participants, whereas almost half of the F2F students (47%) indicated they felt that they were not.

Remote students explained that the main issue for them was the audio quality:

With the issues with the audio some of the conversations and instructions were missed due to drop outs.

Several students indicated that latency and clarity were also problematic. Perceptions of the audio varied from “as a general rule it was OK” to “very flakey [sic].” Three remote students pointed out that “it was also hard to decide when would be an appropriate [time] to talk.” This was because there was a lack of cues, as one remote student explained:

The facial cues of the other participants in the room restricted my verbal communication. When we were in the breakout room working on the [notes area] it was difficult to work out if others were understanding what was going on.

Remote students further indicated that the slight audio delay and the “lag on the video” contributed to the difficulty in knowing when to speak, at times leading to students “speaking over each other.” Some students indicated that more opportunities could have been created to speak with F2F students.

Some F2F students appreciated the fact that the audio and video channel provided the capacity to interact with remote students via their avatars:

I was able to talk to the remote learners from the classroom and I was also able to hear them speak to me.

However, others felt restricted because of audio issues (broken communication, latency and echoing) and also because they could not directly address and converse with specific individuals in the virtual environment:

It was difficult to talk to a certain person as the verbal message would be carried to everyone in the virtual world.

Whereas F2F students could interact naturally with their co-located peers and instantly see their body language, this was not necessarily the case when they attempted to communicate with remote students. Some remote students felt it was easier to verbally communicate with their remote peers than with people in the F2F classroom because there was a level playing field:

People who were remote and by themselves had clear audio and it made it really easy to chat with them as we were both remote.

They could engage in one-to-one communication using audio, and additionally had the ability to use text chat. Students also pointed out that the instructor’s questioning strategies were helpful in encouraging verbal communication between participants.

Sharing and co-creation
Students in F2F and remote locations were positive about their ability to effectively share visual material with other students, although those in remote locations slightly less so. A F2F student explained:

Screen sharing worked quite well to be able to share things on our desktop with those in the virtual world. However, the screens in the virtual world were a little difficult to read unless you zoomed in or stood right up close.

Distortion of the shared screen image in the virtual world was also identified as a factor that constrained F2F students’ ability to share their ideas with remote groups. Some F2F students indicated that initial unfamiliarity with how to share their screens temporarily constrained their ability to share visual artefacts.
Students in the virtual world were able to use the notes areas to share text, but commented that latency and turn-taking were sometimes issues:

The text was easy to share but there was lag with typing so you’d have to wait to see if what you had typed was actually going to show up and other people could overtype your work or delete it very easily.

F2F students generally agreed that they could effectively co-create and share work with their co-located peers:

I was participating in the face-to-face classroom, working with a group to jointly create and edit materials. We then were able to easily share these materials with the virtual class through the share screen function. I was also able to communicate our ideas verbally to the virtual class through the speakers set up in the classroom.

Some F2F students also noted that there was no opportunity to undertake group work with remote students during the lesson.

Remote students were, likewise, generally positive about how the virtual world allowed them to co-create and share:

Typing from different people could occur... with different colours to help differentiate.

Having breakout spaces where remote students could hold audio discussions was seen to support collaborative work, with one remote student reporting that they had to “divide work and delegate jobs and roles in order for us to effectively produce any kind of work.”

Indicating status and sense of co-presence
Survey responses from the F2F students indicated that they were able to naturally signal their status in the same way as they would in a normal classroom situation, by way of hand raising and voice. Several appreciated that the collaborative technology enabled them to be heard and seen by both cohorts of students. The less-than-unanimous F2F student agreement (77%) about ability to indicate status may have been because they perceived the question to relate solely to the use of avatars (which were not being used by individuals in the F2F classroom, other than on the three group-work machines). The design of the activities also constrained and supported students’ ability to indicate their status in various ways—in some activities there was little opportunity to show their sentiments, for example, whereas the activities involving standing along a scale and voting on the best student response encouraged student expression.

The majority (72%) of remote students also felt they could effectively indicate their status, for instance through “gestures... [including] jumping, waving, etc,” though one student was “unsure on what keys to press.” Others felt their ability to indicate their status was impeded by their understanding of what was appropriate in this new environment:

I didn’t know if I should jump around to let the teacher know I could hear or see something. I wasn’t sure of the etiquette in the on line classroom so was not able to indicate my status to others.

The ability to communicate using voice supported remote students in indicating their status, despite the fact that audio issues sometimes compromised this. Moreover, remote students suggested it was difficult to know if their status indications had been registered by other participants.

F2F students felt there were several features of the setup that supported a sense of being present with remote students:

We were able to interact successfully with the virtual world and it was as if these virtual participants were inside our classroom. The virtual participants were able to talk to us, jump, wave, type information. Giving the avatars these human qualities like the hand gestures and the verbal interaction made me feel like I was communicating with my classmates face-to-face when they were actually avatars!

Similarly:
Being able to easily see their names and have them respond to requests like clapping or waving was entertaining and inclusive.

F2F students also expressed how the instructor could affect the sense of co-presence by providing opportunities for the two cohorts to interact with one another and by encouraging them to express themselves. However, some F2F students identified impediments to their sense of co-presence, including comments like “can’t really see who the avatars are in real life,” “technological difficulties meant there were restrictions on interaction between the two parts of the classroom” and “only working with people in the real world made me feel like I wasn’t connected to those in the virtual world.” Some F2F students observed that more opportunities to communicate with remote students one-on-one rather than through instructor-mediated conversations might have enhanced their sense of co-presence:

Students in the face-to-face classroom never got a chance to talk directly to students in the remote room. All the cross-room communication [went through] the classroom teacher so I think next time there should be discussion between students in the different rooms.

Of the remote students, 61% felt they had a sense of co-presence with their F2F peers. According to them, their ability to see what was happening via the video feed contributed to this, as did their ability to express themselves in the environment:

The use of gestures and text and voice was sufficient to make me feel that I had the same attention as others.

One student who was located off campus commented:

Yeah I thought it was really good, I really enjoyed it; really connected us with everybody else and I think it worked well. I felt like I was engaged in it, and felt like I was in the classroom. I was there—that was me. I wasn’t just like a little character on the screen; that was me.

Remote students also felt that the opportunity to interact in groups and being able to see people’s names above their avatars enhanced their sense of co-presence with other remotely located students, as did being in the same 3-D environment together. There was little lag in communication between remote students in the virtual environment, and in fact remote students did not raise any issues that constrained their sense of co-presence with their remotely located peers.

The above having been said, remote students did allude to how factors such as the lesson design and the technology (bandwidth and software) constrained their sense of co-presence with the F2F students:

[We] didn’t do any collaborative work with them, plus the uploading of their work and verbal sharing of their ideas was lost through the audio and delayed screen picture.

Remote students also felt that the ability to communicate using text and the responsiveness of the instructor to their enquiries all supported a sense of co-presence with the F2F environment.

F2F students of course felt co-present with their F2F peers because of the ease with which they could naturally communicate with one another. They suggested that their sense of co-presence was also enhanced by a feeling of engagement that was brought about through the interactive tasks (voting, discussions and group work). However, one F2F student made the interesting observation that the focus on the virtual world restricted the sense of being present in the F2F classroom for them.

Other perceptions
There was a range of other elements that emerged as impacting on the quality of student learning experience (in response to research sub-question 4). Participants in both modes acknowledged that there were advantages to having remote and F2F students come together using the blended reality approach. They agreed that the approach enabled students to access learning from anywhere, allowed for exchange of ideas and promoted higher levels of engagement. Remote students also pointed out that the virtual world provided a “stronger sense of being in a classroom,” could increase willingness of shy people to participate remotely and enabled transcending of physical constraints that may otherwise limit activity (eg, cost, space).
At the same time, students had a number of recommendations for educators who may be attempting blended reality lessons in the future. F2F students suggested synchronising instruction for remote and F2F students to avoid repetition, keeping everyone actively involved (eg, by having tasks for F2F groups that finish early), ensuring students and educators possess the requisite technical skills, and making certain that the network and technology performance can support the desired interactions. Remote students indicated that they may need extra troubleshooting support, that they may need the lesson to progress slower to account for their technology-mediated communication overhead and that it would be wise to provide written instructions to supplement verbal directions. They also suggested that it was important to include both cohorts, to continually monitor activity in the remote classroom to check for gestures and other forms of communication, and to offer regular opportunities to make verbal contributions using audio.

When asked whether they learnt “less,” “the same” or “more” compared to a situation where the lesson was conducted in a normal F2F mode, 11 students (33%) reported that they learnt more and 14 students (42%) reported that they learnt less. F2F students who felt they learnt more attributed this to reasons such as increased motivation, collaboration, engagement and active learning, as well as the fact that they were learning experientially about virtual worlds. Some F2F students felt they learnt less because the instructor needed to focus considerable attention on the virtual world, which slowed the pace and progress of the learners in the F2F classroom. Remote students who claimed they learnt more provided reasons such as active learning, greater engagement and more fun. Remote students who felt they learnt less gave reasons such as audio quality and the need to slow down the lesson to accommodate for operation of the technology.

Consistent with the generally positive responses, the majority of students (79%) indicated that they would be happy to see the approach used in other subjects they studied. The reasons cited generally pertained to greater access to and engagement with learning activities. Some students were neutral on this point (12%), while only three students (9%—one remote, two F2F) indicated they would not like this to be the case, citing the technological problems and the impression that they would learn less.

The range of factors that supported and restricted remote and F2F learners is shown in Table 3, categorised according to the emergent themes of pedagogical, technological and logistical effects.

Discussion

It was possible to conduct instructor presentations, whole-class discussions and small-group activities using the blended reality approach. The need to simultaneously teach the two cohorts of students and manage the technology under this learning design placed considerable demands on the instructor, and at times this hindered the progress of the lesson. Several students indicated that the affordances of the virtual world (eg, the ability to gesture and move) contributed to the learning experience, though some remote students were frustrated at not knowing what sorts of behaviour were appropriate, due to lack of cues from the F2F environment. Groups were selected for teamwork so that remote students were separated from F2F students in order to simplify communication, though in future it would be possible to attempt group work with remote and F2F students working in cross-modal teams in order to extend the nature and type of collaboration that occurred.

The factors that supported and constrained learning in the blended reality collaborative environment are summarised in Table 3. These have several implications for educators. It was apparent that learning was supported by the technological features of the blended reality environment, including the ability for remote and F2F students to see and hear one another, for F2F students to share their screens into the virtual world, and for remote students to collaboratively work on notes areas. Thus it is important for instructors to employ these features during classes in ways that enable communication, facilitate co-creation and enhance co-presence. It was equally apparent that the performance of the technology at times compromised the learning experience, with broken or delayed audio and video streaming. Because improving the reliability of the technology performance can require a great deal of work and is often beyond the control of educators, it is crucial for the instructor (or available support staff) to not only have the ability to troubleshoot technology issues but also be adaptable to work around constraints imposed by the technology during a lesson. In order to avoid in-class interruptions or delays, it is imperative, as well, for the students to have acquired the necessary skills to operate the technology, which may be achieved through pre-class tasks that prepare them to complete the lesson activities.
Table 3: Factors supporting and restricting face-to-face (F2F) and remote learners in the blended reality collaborative learning environment

<table>
<thead>
<tr>
<th>Factors supporting F2F learners</th>
<th>Factors restricting F2F learners</th>
<th>Factors supporting remote learners</th>
<th>Factors restricting remote learners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedagogical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Instructor prompts for responses</td>
<td>• Lack of opportunities to interact and co-create with remote peers</td>
<td>• Instructor prompts for responses</td>
<td>• Lack of opportunities to interact and co-create with F2F peers</td>
</tr>
<tr>
<td>• Working in a group with F2F peers</td>
<td>• High proportion of instructor-mediated communication</td>
<td>• Opportunities to interact</td>
<td>• Repetition of instructions</td>
</tr>
<tr>
<td>• Activities that encourage sharing between students (eg, voting activity)</td>
<td>• Repetition of instructions</td>
<td>• Being in groups together</td>
<td>• Lack of cues</td>
</tr>
<tr>
<td>• Heightened engagement</td>
<td>• May finish faster than remote students</td>
<td>• Delegating roles and dividing work</td>
<td>• Difficult to determine who was speaking</td>
</tr>
<tr>
<td>• Active learning</td>
<td>• Heightened engagement</td>
<td>• Active learning</td>
<td>• People talking over each other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Recognising voices of friends</td>
<td>• Knowing when and how to communicate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Willingness of shy students to contribute</td>
<td>• Difficulty of capturing F2F participants’ attention</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• People overwriting each other’s notes area contributions</td>
</tr>
<tr>
<td>Technological</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Being able to speak to remote students</td>
<td>• Audio issues (echo, broken communication, delay)</td>
<td>• Gestures</td>
<td>• Audio issues (echo, broken communication, delay)</td>
</tr>
<tr>
<td>• Being able to see remote student avatars</td>
<td>• Issues sharing screen (fragmentation, delay)</td>
<td>• Verbal communication</td>
<td>• Issues viewing shared screens (fragmentation, delay)</td>
</tr>
<tr>
<td>• Being able to see avatar names</td>
<td>• Students not knowing how to share the screen</td>
<td>• Text chat</td>
<td>• Unfamiliarity with how to gesture</td>
</tr>
<tr>
<td>• Being able to hear remote students</td>
<td></td>
<td>• Notes areas for sharing text ideas</td>
<td></td>
</tr>
<tr>
<td>• Being able to screen share (eg, Word document)</td>
<td></td>
<td>• Visual presence in form of avatar</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Names of avatars</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Minimal communication lag between remote students</td>
<td></td>
</tr>
<tr>
<td>Logistical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Could communicate naturally with F2F peers (voice and body language)</td>
<td>• Unable to communicate one-on-one with remote students</td>
<td>• Learning more accessible</td>
<td>• Unable to communicate one-on-one with F2F peers</td>
</tr>
<tr>
<td></td>
<td>• Cannot see people behind the avatars</td>
<td>• Could communicate one-on-one with remote students</td>
<td>• Lack of troubleshooting support</td>
</tr>
<tr>
<td></td>
<td>• Could be distracted by focus on remote participants</td>
<td>• Level playing field with remote peers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Having breakout room in the virtual space</td>
<td></td>
</tr>
</tbody>
</table>
While technological factors in blended reality and other blended synchronous learning environments are in many cases difficult to affect, there are a range of pedagogical factors that are well within the instructor’s control. Based on this study, it appears that several strategies support learning and interaction in blended reality collaborative environments. To begin with, it is obviously important to encourage active learning by setting tasks that require interaction and collaboration (eg, group-work tasks). The instructor can also play a vital role in terms of supporting communication, co-creation and co-presence by providing structure and protocol for social activity. Examples of strategies to support interaction include providing students with cues to stimulate their contributions, delegating roles during group-work activities and suggesting techniques for efficient interaction using technology features and tools (eg, how to effectively use the notes areas together). There are also steps that can be taken to mitigate the demands arising from the need to simultaneously teach across the two modes. In order to avoid having to announce different sets of task specification for the two cohorts of students, the instructor can offload instructions to the environment (eg, by providing written rather than spoken task descriptions). The instructor may decide to adjust the nature of tasks given to remote students if operation of the technology will constrain their pace of completion. Blended reality collaborative learning environments can be used to provide affective support for students, for instance by promoting familiarity through audio and offering a safe environment in which shy students are more likely to be willing to contribute. Instructors may choose to intentionally make use of these potentials to educational effect.

Logistically speaking, educators may decide to take advantage of the ease of communication between students attending a blended reality lesson in the same mode. This was the reason that F2F teams in the present study were separated from remote student teams for the purpose of group-work activities. However, in order to establish a sense of class unity and co-presence it appears necessary to provide students with more opportunities to communicate with peers participating via the alternate mode. Having students design their avatars to resemble their own appearance and always use their real names may support a sense of co-presence. Instructors can also choose to leverage the advantages of virtual worlds in their lessons, for instance by creating more space for students and conducting activities that may not be possible in the physical classroom. This accords with suggestions made by Cochrane et al (2008). Regardless, the operation skills required in blended reality learning environments and the need to deal with problems caused by the reliability of the technology may call for extra technical support in the design and implementation of the lesson so as to optimise communication, collaboration and co-presence.

Interestingly, it was possible for two people to participate in the same mode and undergo essentially the same experience yet have vastly different perceptions of the lesson as evidenced by their responses to the various survey items. This might have been because some individuals were more willing to immerse themselves in the experience and overlook the technological issues than others. Indeed, there were 10 students whose open-ended feedback signified highly positive perspectives about the possibilities subtended by blended reality classes, with comments like “I believe that these lessons have immense potential when they are eventually fully developed.”

Many students appeared to have fun during the lesson. Behaviours observed included laughing (F2F students), changing outfits (some remote students), and jumping up and down as part of activities (both remote and F2F students). From this single case study it is not possible to tell whether this was a novelty effect or whether the new way of participation would result in sustained increases in engagement. This study is the first to comprehensively report on pedagogical, technological and logistical factors impacting upon students’ perceived effectiveness of learning and teaching in a blended reality tutorial class; as it constitutes only one case, further research is required to determine whether the factors and effects reported here are generalisable to other contexts.

One limitation of this study was that it used student perceptions in order to determine the impact of learning through a blended reality collaborative environment. Future studies could use pre- and post-tests and a control group (traditional F2F class) in order to more accurately gauge differences in student experience and learning outcomes in traditional versus blended reality classes. Another limitation was the delay introduced by attempting to stream the video feed of the F2F class into the virtual world as a non-standard feature. In future iterations of this approach the delayed video broadcast of the F2F classroom into the virtual world would need to be reduced in order to provide a better sense of synchronicity.
The extensive setup and testing that were required mean that substantial effort would be needed to transfer this learning design to other settings. However, there are a range of interesting research possibilities relating to the sense of co-presence and the types of interactions that are possible in blended reality learning environments. For instance, it would be interesting to investigate how role-play and spatial design tasks could be facilitated using a blended reality approach.

Future directions
With holographic telepresence (see Grossman, 2010; Musion, 2015; VanDervoort, 2013; Wildstrom, 2011) and other next-generation mixed reality systems for enabling embodied synchronous remote collaboration in 3-D still being some years away from entering the mainstream, our goal in the present study was to use relatively mature, present-day technology to illustrate and explore the opportunities that exist for creating hybrid class environments combining both real and virtual modalities. Our hope was to uncover a window of insight into some of the possibilities and pitfalls that await educators and students as the boundaries between the modalities become increasingly blurred and eventually start to fade away.

Several of the remote participants in the pilot study commented that the ability to gesture through their virtual world avatars (by jumping, waving, raising hands, etc) was an effective way to indicate their status to others. Yet some reported that it took additional effort on their part, for instance, to remember which button or key corresponded to each gesture. Motion-sensing and gesture-recognition controllers, including emerging consumer-level products like Leap Motion (http://www.leapmotion.com) as well as other existing controllers originally targeted at gamers (eg, Microsoft Kinect—http://www.microsoft.com/en-us/kinectforwindows) might open up possibilities for this aspect of communication to occur in a more naturalistic manner. Further non-verbal cues may be projected into the virtual world by means of technologies that are able to detect and reflect or mimic users’ facial expressions and movements on their avatars, similar to those seen in Microsoft’s Avatar Kinect virtual chat room service for the Xbox console (http://www.xbox.com/en-IN/Kinect/KinectAvatars) as well as in High Fidelity (http://www.highfidelity.com), a forthcoming virtual world platform whose development is being spearheaded by the founder of Second Life (see Murphy, 2014).

Another observation is that blended reality collaborative virtual environments like the one used in our pilot study, as well as other similar environments like MiRTLE and the Holodeck@UH, maintain a hard distinction or partition between the physical and virtual spaces. This causes the need for participants to consciously and deliberately “switch” between communicating within and across spaces, directing their attention, gaze and voice accordingly. Systems like the Mirror World Interactions (MWI) prototype developed at the VTT Technical Research Centre of Finland (2011), while not completely merging the real and the virtual, soften the borders separating them. In the MWI system, which was intended to be used for business meetings, video feeds from the real world were placed around a table in the virtual world at which the virtual participants’ avatars are also seated. While the developers did not seek to create the illusion that the spaces were one, this arrangement would appear to enhance the contiguity between them (see VTTAugmentedReality, 2011). We posit that by narrowing the perceived gap between modalities in this way, the extraneous cognitive load (Sweller, van Merriënboer & Paas, 1998) imposed on students and instructors can be effectively reduced, freeing up space in their working memory to focus on more pertinent aspects of the lesson and on the learning objectives and tasks at hand.

A number of other technological advances in the virtual and mixed reality arenas have been made in recent years—with more on the horizon—that have the potential to further increase participants’ sense of presence and connectedness with one another despite being physically dispersed. For example, real-time image processing algorithms allowing a person’s image to be extracted from a live video feed and transplanted into a virtual environment (a form of augmented virtuality) have been in existence for quite some time (see, for example, Yura, Usaka & Sakamura, 1999), but they have tended to be based on chroma-keying techniques and so have typically called for large and expensive sets with blue or green screens, severely limiting or precluding their use in desktop conferencing. Software products like Silhouette by Integrated Virtual Networks (2012) are now commercially available that enable virtual world avatars to be replaced with video of human users without the need for specialised equipment or hardware beyond standard webcams already readily accessible in most homes, workplaces and educational institutions. Torrejon, Callaghan and Hagras (2013) explain how this type of “video avatar” can be augmented with panoramic audio in a way that enables captured sound to be recreated and spatially controlled by the user. Developed at the University of Wollongong, iSee (http://www.iseevc.com) is a...
hybrid videoconferencing and 3-D virtual world platform that avoids the need for image extraction and transplantation by representing each user as a floating video window called a “me-vatar” that he/she can control and move around the virtual space. The use of real video, together with directional audio that is sensitive to users’ relative proximities to one another, is purported by the developers to afford more natural, authentic interactions than is possible with videoconferencing or virtual worlds alone (Safaei, Pourashraf & Franklin, 2014; Safaei, Wood & Pourashraf, 2012).


Conclusion
Blended reality collaborative learning environments strive to enhance engagement and interactivity by giving remote students an embodied presence in F2F classes. Ideally, remote and F2F students would feel as though they were interacting naturally in one physical space, together, to jointly achieve learning outcomes. Findings from this study indicate that several pedagogical, technological and logistical factors did work toward these objectives by enabling communication, collaboration and co-presence, but there are also corresponding issues that need to be addressed. As well, the technological setup required in order to achieve a blended reality learning environment currently makes it unrealistic for regular classes. Nevertheless, this article evidences there are a range of strategies that instructors can apply in order to support effective interaction and learning in such environments.

We predict there will eventually be a merging of real and virtual worlds, so that the two are almost indistinguishable. Remote student gestures may be automatically detected and enacted by their avatars to provide cues for F2F participants, who can not only see and hear but also walk around and mingle with the avatars. At the same time, instructors will be able to seamlessly and naturally take advantage of the unique affordances of 3-D virtual spaces, such as the ability to transcend physical boundaries, teleport and conduct previously inaccessible or impractical learning activities such as nuclear physics experiments or transcontinental travel. Until the technology evolves to a point where it becomes invisible in the learning and teaching process, educators need to work hard to facilitate effective communication, enable productive co-creation and establish a sense of co-presence between remote and F2F participants. This article provides educators with evidentially grounded strategies and approaches they can draw upon to design and instantiate effective blended reality collaborative learning environments using current and future technologies.

Acknowledgement
The work reported in this article is one of seven case studies carried out as part of the Blended Synchronous Learning project (http://www.blendsync.org), which was funded by an Innovation and Development Grant from the Australian Government Office for Learning and Teaching (OLT). The grant number for the project is ID11-1931. The views expressed in this article do not necessarily reflect the views of OLT.

Statements on open data, ethics and conflicts of interest

Open data
Requests for anonymised copies of the data relied upon for this research may be directed to the corresponding author and will be considered on a case-by-case basis, taking into regard the intended use and whether it is permitted by the terms and stipulations under which ethical approval for the original research was obtained. Republication of the data will not be allowed.

Ethics
The ethical aspects of this study were approved by the Macquarie University Human Research Ethics Committee, which requires researchers to conform to the National Health and Medical Research
Council’s Australian Code for the Responsible Conduct of Research (NHMRC, 2007a) and National Statement on Ethical Conduct in Human Research (NHMRC, 2007b).

Conflicts of interest
None to report.

References


