Title: Healthcare students’ experiences of multi-user virtual environments for collaborative learning in team care delivery: A mixed method study

ABSTRACT

Background: There has been a dearth of collaborative learning across tertiary institutions due to challenges in scheduling and geographical locations. Three dimensional virtual environments are a viable and innovative tool to bring diverse healthcare students to learn together.

Objective: The purpose of this study is to describe the development of a multi-user virtual environment and to evaluate healthcare students’ experiences of their collaborative learning in the environment.

Methods: A mixed method study design was employed. Participants from six healthcare courses (Medicine, Nursing, Pharmacy, Physiotherapy, Occupational Therapy, and Medical Social Work) were recruited from three institutions to form six interprofessional healthcare teams who participated in interdisciplinary team care via a virtual environment. Four focus groups were conducted with 27 healthcare students after they completed questionnaires to evaluate their perceived usability, the sociability of computer-supported collaborative learning, and senses of presence. Interview transcripts were analyzed using thematic analysis.

Results: Four themes emerged from the students’ experiences: “Bringing everyone together” to learn in the virtual platform was perceived as a valuable experience; “Feeling real”, whereby the students felt immersed in their own healthcare profession’s roles; learning in the virtual environment was perceived as “less threatening” compared to face-to-face interactions; and there were some “technical hiccups” related to sound quality and navigation. The participants reported positively on the usability (mean 3.48, SD 0.64) and feasibility (mean 3.39, SD 0.60) of the virtual environment in supporting collaborative learning. With a maximum score of 168, they also perceived a moderately strong sense of presence (mean 107.24, SD 17.78) in the environment.

Conclusion: This study provides evidence for the acceptance of a virtual platform for collaborative learning in team care delivery. Given its flexibility, practicality, and scalability, this virtual platform serves as a promising tool for collaborative learning across different healthcare courses and institutions.

Keywords: Simulation; Education; Virtual patient; Deterioration; Clinical performance; Patient Safety
Introduction

With rapid advances in learning technology, virtual environments have generated interest among healthcare educators. These virtual environments have been used to create authentic three-dimensional online spaces where users are able to gain a sense of “being there” (physical presence) through animated human-like agents known as avatars. Using avatars, users can communicate with one another in a real-time environment and experience a sense of “being together with one another” (social presence). It provides an excellent platform for developing collaborative competencies among learners [1].

Earlier studies have called for the incorporation of key features when designing a virtual world to meet the learning needs of learners, which include presence (sense of being there), representational fidelity (realistic display of environment), and immediacy of control (ability of the user to interact by undertaking embodied actions such as navigation and object manipulation) [2]. According to Dalgaron and Lee (2010), representation fidelity and immediacy of control can positively influence the sense of physical presence, which in turn leads to active participation and meaningful learning [3].

With government and professional calls for collaborative teamwork and communication, healthcare educators have increasingly sought to explore virtual environments in delivering collaborative learning activities [4]. Many were influenced by team-based simulation, which places the learners in a realistic situation and is considered an authentic experiential learning activity to prepare learners for real-life work [5]. Despite growing evidence on the benefits of team-based simulation for collaborative practice, training is limited by the availability of physical facilities and scheduling challenges [6]. Moreover, as different healthcare students are often trained in a variety of institutions, bringing healthcare students together to engage in team-based simulation is another challenge. The use of virtual environments for collaborative learning has emerged as a viable innovative tool that can transcend geographical boundaries by bringing together learners from different local, regional, and international health profession institutions [7,8].

Previous studies in healthcare education have explored the use of virtual environment for collaborating learning in emergency preparedness training [9,10] and life support training [11,12] and the development of professional values [13,14]. These studies employed a variety of virtual platforms, including the Second Life and Unity 4, and Unreal Development Kit (UDK) game engines and
CliniSpace™, which takes different approaches in developing virtual reality, varying in the authenticity of the world (realistic or fantastical) and the mode of communication (text or verbal). Among these virtual platforms, Second Life was reported to be the most common virtual platform used in healthcare education [4]. However, concerns about its usability were identified, including difficulty with communication and difficulty in navigating avatars [15].

To the best of our knowledge, no study has examined the use of virtual environments for multidisciplinary team care delivery in a large group of different healthcare professionals, including doctors, nurses, pharmacists, occupational therapists, physiotherapists, and medical social workers. In an actual clinical setting, there is an increasing reliance on such team-based care delivery to provide high quality patient care through effective multidisciplinary teamwork. To achieve that, it is essential for multidisciplinary healthcare professionals to communicate effectively and understand the roles and responsibilities of each member of the healthcare team [16]. A project called “Create Real-life Experience And Teamwork In Virtual Environment (CREATIVE)” was developed to support collaborative learning in multidisciplinary team care delivery among different healthcare students.

The aim of this study is to describe the development of a multiuser virtual environment (MUVE) and to evaluate healthcare students’ experiences of the virtual environment for collaborative learning. The research questions guiding this study are how do healthcare students who experienced collaborative learning in a MUVE perceive: (1) the usability of the system, (2) the sociability of the environment, (3) the degree of presence of the environment, and (4) the overall learning experience?

Methods

Design and development of MUVE

A 3D MUVE was created using the Unity 5 games engine (Unity Technologies, San Francisco, CA). The software programme supports multiuser real-time interactions in a virtual world. A virtual hospital environment, avatars, and electronic patient records were built into this MUVE.

Virtual hospital environment

The design of the virtual hospital was based on an integrated acute and community care clinical setting, which was a recent shift undertaken by Singapore’s healthcare system to ensure seamless and integrated patient care. As shown in Figure 1, three key clinical areas, including intensive care units, general acute ward, and community care ward, were incorporated into the virtual hospital.
Figure 1. Multiuser Virtual World Physical environment; A, Intensive Care Unit (ICU); B, General Ward; C, Community Hospital; D, ICU corridor; E, Community hospital corridor
Tutorial and family conference rooms were built within each of these areas. The three clinical areas were located at the same level and were connected by corridors. The software provides the flexibility of adding other hospital layouts, such as outpatient clinics, in the future.

**Avatars**

Facilitator, six healthcare professions (nurse, pharmacist, physician, physiotherapist, occupational therapist and medical social worker), patient, and relative avatars representing both male and/or female users were developed to match their roles in the multidisciplinary team-care scenarios. The users could log into the MUVE using their avatar roles. Figure 2 illustrates the heads-up displays that were presented to the different users.

The patient avatar’s heads-up display has a control panel that allows the standardized patient (SP) to initiate specific responses or actions such as facial expressions, body positioning, and limb actions. Physiological parameters (e.g. heart rate, respiratory rate, blood pressure, and oxygen saturation) and clinical features (e.g. lung sound and pupillary reactions) can be programmed based on the virtual patient’s condition. These can be changed or programmed to respond appropriately to a healthcare team’s actions. The patient avatar responds verbally to the healthcare team using vocal sounds (e.g. moaning, groaning, etc.) from the control panel or in real time using voice through the internet protocol audio system.

Healthcare players can use the computer’s keyboard or mouse to freely navigate inside the virtual hospital or to teleport from one place to another. They can communicate with one another and with the patient avatar in real time using headsets with headphones and a microphone. The audio system only allows one user to speak at a time and this requires the user to activate the “speak” button. Healthcare avatars can also communicate non-verbally using simple gestures (e.g. waving, thumbs-up, etc.). Except for the pharmacist and medical social worker avatars, the rest of the healthcare professional avatars can perform physical assessments by clicking on various parts of the virtual patient’s body. Upon doing so, the user is presented with a pull-down menu that offers a choice of specific assessment tasks. Once selected, the assessment findings will appear in a pop-up box. The assessment tasks and generated findings are only visible to the team member who performed it. Fellow team members and the facilitator can only view the assessment tasks performed in the activity log, which records the history of all the actions taken by the healthcare avatars.
Figure 2. Heads-up display by standardized patient (A), student (B), and facilitator (C) avatars
Similar to the healthcare avatars, the facilitator avatar can move freely inside the virtual hospital and can teleport from one place to another. Except in the tutorial room, the facilitator avatar is invisible to others. The facilitator user is the main controller of the audio system, having the rights to interject or pause any ongoing conversation. Unlike other users, the facilitator can engage in one-to-one private conversations with team members. Besides communicating in real-time and using simple gestures, the facilitator is able to use the text-chat interface to communicate with the SP. The facilitator user’s head-up display also has control panels to adjust the physiological parameters and responses of the virtual patient.

**Electronic health record**

An electronic health record (EHR) was developed using HTML with an underlying MySQL database to allow the case developer to enter patients’ information based on the developed case scenario. The EHR can be retrieved and viewed by the healthcare and facilitator avatars through the Computer-On-Wheels (COW) at each patient’s bedside or laptops placed at the patient’s bedside and in the tutorial room (Figure 3). For the current MUVE learning, a comprehensive case scenario of an 80-year-old elderly man (Mr. Jin) who was admitted for right knee replacement, was developed by the interprofessional team and built into the EHR.

**Implementation of the MUVE for learning**

The MUVE learning was implemented over three days among six teams of healthcare students in a computer laboratory. Each team, comprising six healthcare students from Medicine (Med), Nursing (NUR), Pharmacy (PHAR), Physiotherapy (PT), Occupational therapy (OT), and Medical Social Work (MSW) was supported by two facilitators and a standardized patient. The healthcare students were given an orientation via a virtual exercise where they learned to walk, talk, and interact with a virtual patient. As a preparation for the application of relevant knowledge to facilitate effective communication and collaboration in multidisciplinary care planning, they also received an asynchronous online video instruction describing the use of communication tools and team care models.

The virtual simulation began with the healthcare and facilitator avatars gathered at the tutorial room with a brief introduction of one another and the learning objectives. To gather information about the first case scenario, they were given time to read the ERH from the virtual laptops and to individually assess the virtual patient (Mr. Jin) in the ward. The team then proceeded to participate in
Figure 3. Experiential learning by Multidisciplinary team; A, multidisciplinary bedside rounds; B, debrief by facilitator; C, Computer-on-wheels
a multidisciplinary bedside round for Mr. Jin, who was in his second post-operative day and presented with pain and fever. After which, they returned to the tutorial room for a debriefing session. After a break, the students received an online video instruction on the discharge team care before they began the second case scenario. Once again, they were given time to read the ERH before they undertook the multidisciplinary family conference in a virtual family room, which required them to deal with discharge and caregiving issues arising from the same case study of Mr. Jin. In this scenario, one facilitator joined the roleplay by acting as Mr. Jin’s daughter and responded according to a prepared script. The second scenario ended with a debriefing session joined by the SP.

**Evaluation of MUVE learning**

**Design and sample**

A mixed methods study was conducted in October 2017 after receiving approval from the Institutional Review Boards of two higher educational institutions. As this is a pilot study, a purposive sample of 36 healthcare students, six from each healthcare course, undertaking MED (4th & 5th year), NUR (4th year), PHAR (4th year), PT (3rd year), OT (3rd year), and MSW (3rd year) were targeted for recruitment from three higher educational institutions. The participants were assigned into six interprofessional teams. However, as a result of fixed schedules based on the availability of the computer laboratory, only 29 healthcare students were recruited into this study. Faculty and research staffs with relevant healthcare backgrounds were invited to replace the ‘missing’ healthcare students’ roles to ensure complete interprofessional teams for the MUVE learning.

**Data collection and instruments**

The participants were asked to complete the questionnaires immediately after the completion of the virtual learning. A 10-item System Usability Scale (SUS) with a five-point Likert scale, developed by Brooke (1986) [17], was used to evaluate the participants’ perceptions of the usability of the MUVE. The scale was found to have a high internal consistency with a Cronbach’s alpha value of 0.83 in this study. A 10-item Sociability of Computer-supported Collaborative Learning Environments scale, developed by Kreigns et al. (2007) [18], was adopted to measure the participants’ perceived sociability of their collaborative learning in the MUVE. The scale showed a Cronbach’s alpha value of 0.86 for this study. Finally, a 19-item French-Canadian adaption of Witmer and Singer’s Presence questionnaire was administered to assess the participants’ senses of presence [19,20]. The scale
consists of six scales (realism, possibility to act, quality of interference, possibility to examine, self-
evaluation of performance, and sounds). A high internal consistency of 0.90 for Cronbach's alpha was
reported in this study.

Following the completion of the questionnaires, focus group discussions (four in total)
facilitated by a trained researcher were conducted using an interview guide. Each focus group,
comprising six to ten participants, lasted for about 45 minutes. The focus group discussions were
audio-recorded and transcribed.

Data analysis
Descriptive statistics using percentage, means, and standard deviations were computed to examine
the study variables. Interview transcripts were analyzed using thematic framework analysis [21] by
two researchers who independently read and identified subthemes from the generated codes. They
met to discuss their generated subthemes and reorganized these through merging and re-grouping to
form the key themes with a third research who was not involved in the analysis process. Rigor and
trustworthiness of the qualitative data findings were ensured based on [22] four criteria of credibility,
dependability, transferability, and confirmability.

Results
Quantitative data
A total of 29 healthcare students completed the questionnaires. They included students from MED (n
= 6), NUR (n = 6), PHAR (n = 4), PT (n = 6), OT (n = 6), and MSW (n = 1). Most of the participants
were female (76%), Chinese (94%), and between 21 to 23 years old (79%). A total of 90% (n = 26) of
the participants reported that they had no prior learning experience in a 3D virtual environment.

As shown in Table 1, the overall means score (mean 3.39, SD 0.60) from the participants' perceived degrees of sociability on a five-point scale indicated that they were positive with the
MUVE in supporting collaborative learning. The overall means score (mean 3.39, SD 0.60) from the
indicated that they were positive with the MUVE in supporting collaborative learning. The statement
on "the environment enables us to develop into a well performing team" has the highest mean score,
with almost all participants (96%) finding this applicable to the MUVE learning. However, the
statements on the environment that allows for spontaneous informal conversation and non-task
related conversation were reported to be not applicable or rarely applicable by most respondents (51.7%).

Table 1. Perceived degree of sociability of computer-supported collaborative learning

<table>
<thead>
<tr>
<th>Items</th>
<th>Not Applicable To Rarely Applicable</th>
<th>Moderately Applicable to Totally Applicable</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. This environment enables me to easily contact my teammates.</td>
<td>2 (6.9%)</td>
<td>27 (93.1%)</td>
<td>3.45 (0.74)</td>
</tr>
<tr>
<td>2. I do not feel lonely in this environment.</td>
<td>2 (6.9%)</td>
<td>27 (93.1%)</td>
<td>3.72 (0.80)</td>
</tr>
<tr>
<td>3. This environment enables me to get a good impression of my teammates.</td>
<td>3 (10.3%)</td>
<td>26 (89.7%)</td>
<td>3.83 (0.81)</td>
</tr>
<tr>
<td>4. This environment allows spontaneous informal conversations.</td>
<td>15 (51.7%)</td>
<td>14 (48.3%)</td>
<td>2.72 (1.19)</td>
</tr>
<tr>
<td>5. This environment enables us to develop into a well-performing team.</td>
<td>1 (3.4%)</td>
<td>28 (96.6%)</td>
<td>3.62 (0.86)</td>
</tr>
<tr>
<td>6. This environment enables me to develop good work relationships with my teammates.</td>
<td>2 (6.9%)</td>
<td>27 (93.1%)</td>
<td>3.72 (0.88)</td>
</tr>
<tr>
<td>7. This environment enables me to identify myself with the team.</td>
<td>2 (6.9%)</td>
<td>27 (93.1%)</td>
<td>3.76 (0.79)</td>
</tr>
<tr>
<td>8. I feel comfortable with this environment.</td>
<td>1 (3.4%)</td>
<td>28 (96.6%)</td>
<td>3.83 (0.85)</td>
</tr>
<tr>
<td>9. This environment allows for non-task-related conversations.</td>
<td>16 (55.2%)</td>
<td>13 (44.8%)</td>
<td>2.48 (1.09)</td>
</tr>
<tr>
<td>10. This environment enables me to make close friendships with my teammates.</td>
<td>12 (41.4%)</td>
<td>17 (58.6%)</td>
<td>2.76 (1.02)</td>
</tr>
</tbody>
</table>
The overall mean score (mean 3.48, SD 0.64) from the participants’ perceived system usability on a five-point scale demonstrated that they were positive with the usability of the MUVE (Table 2). There was an almost equal balance between participants who disagreed (51.7%) and those who agreed (48.3%) with the statement “I thought there was too much inconsistency in this system”.

With a possible maximum performance score of 168, the score of 107.24 (SD 17.78) indicated that the participants perceived a moderately strong sense of presence in the MUVE. As shown in Figure 4, the subscale with the highest mean score was “self-evaluation of performance” (mean 5.55, SD 1.15) and the lowest mean score was “interface quality” (mean 4.19, SD 1.14).

Table 2. Perceived system usability

<table>
<thead>
<tr>
<th>Items</th>
<th>Strongly Disagree to Disagree</th>
<th>Moderately Agree to Strongly Agree</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I think that I would like to use this system frequently.</td>
<td>9 (31.0%)</td>
<td>20 (69.0%)</td>
<td>3.14 (1.03)</td>
</tr>
<tr>
<td>2. I found the system unnecessarily complex.</td>
<td>18 (62.1%)</td>
<td>11 (37.9%)</td>
<td>3.58 (1.02)</td>
</tr>
<tr>
<td>3. I thought the system was easy to use.</td>
<td>3 (10.3%)</td>
<td>26 (89.7%)</td>
<td>3.72 (1.03)</td>
</tr>
</tbody>
</table>
4. I think that I will need the support of a technical person to be able to use this system.  9 (31.0%)  20 (69.0%)  2.62 (1.37)

5. I found that the various functions in this system were well integrated.  2 (6.9%)  27 (93.1%)  3.48 (0.63)

6. I thought there was too much inconsistency in this system.  15 (51.7%)  14 (48.3%)  3.38 (1.05)

7. I would imagine that most people would learn to use this system very quickly.  2 (6.9%)  27 (93.1%)  3.90 (0.86)

8. I found the system very cumbersome to use.  17 (58.6%)  12 (41.4%)  3.38 (1.12)

9. I felt very confident using the system.  2 (6.9%)  27 (93.1%)  3.86 (0.79)

10. I needed to learn a lot of things before I could get going with this system.  19 (65.5%)  10 (34.5%)  3.69 (1.04)
Figure 4. Perceived presence in virtual environment
Qualitative Data

Twenty-seven students participated the focus group discussions. Four themes emerged from their experiences of the virtual learning. These include “bring everyone together”, “sense of realism”, “less threatening”, and “technical hiccups”.

Bringing everyone together

In general, the idea of bringing everyone together in the virtual platform was valued across most healthcare students.

I guess the idea is good to get everyone together. [PHA]

The participants could see the significance of this collaborating learning that brought everyone to work as a team in patient care:

I finally understand that we really need to work together in terms of interprofessional healthcare and this program helps to emphasize on that point. [MED]

The virtual platform made it feasible to bring everyone together to learn as a team. This was made possible with the convenience of virtual learning, which can be done anywhere.

You can do it at home… You can do it in your computer, no need to travel. [OT]

Feeling real

The scenario in the virtual environment was felt to mirror those in real-life, which allows the participants to be immersed in their own healthcare profession’s roles:

The program does give it a more realistic feel… You don’t feel like a student. You feel like (you are) having a responsibility on your shoulders. (MED)

The realism was better enhanced by having a standardized patient to hide behind the patient avatar and responding to the healthcare team in real-time:

I thought, like, being able to speak through the microphone was quite a nice touch of the whole virtual reality because it feels like I’m really speaking to a patient. So, I thought that was good. (PT)
However, some participants shared that the avatar took away the abilities to deliver body language and facial expression, which are essential forms of non-verbal communication for the clinicians to rely on for face-to-face interactions in the real world:

*I think having that virtual learning takes away all the non-verbal. The only thing you can hear is the tone of the voice from what the patient says. I think it does affect the communication quite a lot.* [OT]

To make it more real, the need to improve the bodily expressions of the patient avatar was highlighted:

*But I couldn’t see the patient's expressions. I couldn’t see the patient's actions. That was something that I thought could be improved on.* (PT)

**Less threatening**

Some participants agreed that the virtual environment allowed them to explore the different types of patient care within a safe environment without risks of harming a patient:

*It gives a less risky platform for newbies like us who are still undergoing education. This learning environment allows us to explore the different kind of plans for our patients.* (PT)

Some participants perceived learning in the virtual environment as less threatening compared to face-to-face learning. For this reason, they preferred to communicate in the virtual environment:

*For students of different healthcare professionals to come together for a face-to-face talk, people don’t usually want to participate in all these things, but having the virtual aspect of doing that communication, I think it's good.* [NUR]

The ability to hide behind the screen was perceived by some participants as less stressful, which enabled them to think and react more confidently:

*It is honestly quite stressful, but we can hide behind the screens. We just have to talk, and we have time to look through the information first and think through what we've got to say. I think it's much better than meeting up in real life.* [MED]
The opportunity to work with other healthcare students in the virtual environment was perceived as less threatening compared to talking to a trained healthcare professional. The learning was therefore reported to serve as a good initial exposure to prepare students to work with other healthcare professionals:

As a student, when I have to approach the professional nurses, it's a bit intimidating sometimes. So, if I get to communicate with other student nurses, I get to understand what I can ask and that will help translate into a better working experience next time. (PT)

Another participant reported a sense of gaining confidence through working with other healthcare students in the virtual environment:

Like, as a student, you don’t dare to give suggestions... But through this virtual reality, you are more encouraged to give suggestions and discuss with others. (NUR)

**Technical hiccups**

Many participants found it difficult to hear one another at times. The sound was described as choppy, which affected the flow of communication:

On the technical part, the audio is a bit choppy, and (I) cannot really hear what everyone says... So, it breaks the discussion quite a bit. [OT]

Some participants shared their difficulties in navigating through the virtual environment and suggested more opportunities to teleport from one point to another:

Like (in) the second round, we just teleport to the conference room and that one was a lot easier. Just click one button, then everybody appeared there. [OT]

A few participants indicated that clicking on the body parts to gather information distracted them from the main focus of communication among the healthcare professionals. Thus, they suggested to keep the performance of patient assessment simpler:

I feel that it is an extra step to click the virtual patient’s leg just to examine the leg. If the focus is going to be on communication, the examination could have been more straight-forward. At
the end of the day, we just want the information so that we can communicate with our colleagues. [MED]

Discussion

Principal findings

A MUVE was developed for collaborative learning among six different healthcare professions. In developing and designing the virtual environment, we took into account the three features that were identified by Whitelock et al. (1996) as characteristics for conceptual learning using a virtual environment: representational fidelity, immediacy of control, and presence [23].

In both quantitative and qualitative findings, a sense of realism in the virtual learning was reported by the participants. The environments and scenarios, including multidisciplinary bedside and conference rounds undertaken in the virtual learning, were direct representations of real hospital settings and healthcare professional activities. The degree of fidelity was enhanced by creating a hospital environment that allowed interprofessional teams to come together to work on authentic patient-related activities and to solve real-life problems. By closely matching the virtual learning environment and the real clinical setting, where knowledge is expected to be applied, it is likely to foster an effective transfer of learning in the real world [24]. However, more studies, especially those using qualitative methods, are needed to examine how learners transfer collaborative learning in the virtual environment to the real clinical setting [4].

Apart from the virtual environment, the fidelity of the avatars was considered when designing the program by having a standardized patient to act as the patient avatar and allowing the avatars to control their facial expressions and bodily actions. In the qualitative findings, the participants indicated that the use of a standardized patient has heightened the realism of the virtual learning. However, feedback from the participants on the lack of the non-verbal communication portrayed by the avatars suggests the need to further improve this aspect. Having to align a person’s spoken words to the avatar’s behavior can be a challenge [25]. One way to overcome this in the future is by providing more hands-on practices to the users to get them more familiar with controlling their bodily expressions when communicating.

As communication using spoken words can achieve a corresponding ‘realistic’ effect that illustrates high immediacy, this was incorporated in the design of the virtual environment other than
text-based communication. Conversely, the medium through which the participants undertook embodied actions by controlling the avatars and the control panels using a computer keyboard or mouse did not correspond to those used in the real world (low immediacy control). However, this medium serves to provide anonymity, which was perceived by some participants as less stressful, consequently improving their ability to think in the virtual environment. This finding supports the claim from an earlier study that learning in the virtual environment can reduce social anxiety [26]. Given the negative impact of stress on performances (i.e. impaired thinking process) [27], future studies can compare the effect of virtual simulation and ‘live simulation’ on learners’ stress levels and team performance.

In this study, the participants experienced a moderate level of presence in the virtual environment and perceived positively on the degree of sociability of the environment in supporting collaborative learning. A sense of “being there” (physical presence) and “being with another (social presence)” are important components of a virtual environment [2]. The features (representational fidelity and immediacy of control) described earlier were reported in a previous study to have positive influences on the sense of physical presence [28]. A study by Bulu (2012) reported a positive correlation between physical presence and social presence [29]. The participants in the study also reported the effectiveness of the environment in enabling them to understand each other’s roles and to develop into a well-performing team. These findings appeared to support a high level of social presence in the virtual environment, which encouraged the learners to actively engage in interactive learning activities [30].

The participants generally supported the usability of the virtual environment but provided recommendations to optimize its functionality. They suggested simplifying the navigation and assessment tasks as these might increase their cognitive load, which in turn distracted them from the meaningful task of communication. A study by Moreno and Mayer (2004) found that immersive virtual environments might increase extraneous cognitive load as the learners pay unnecessary attention to irrelevant immersive stimuli, which distract them from engaging in meaningful learning tasks [31]. Thus, to reduce the learners’ cognitive load, we decided to increase the avatars’ abilities to teleport from one place to another and reduce the clickable area for physical assessment.

The lowest rating for interface quality suggests for the need to improve the efficiency and quality of the control devices. This technical problem was also reported in the qualitative findings
where the participants related it more specifically to the audio system that affected their communication in the virtual environment. As communication is pivotal to collaborative learning and also contributes to improving presence in the virtual world [32], continued efforts to resolve the audio problems are critical. One possible cause of this technical issue was the load on the computer network when multiple users (18 users from two teams) logged in to the MUVE simultaneously. To overcome this technical challenge, we will perform bandwidth testing to determine the number of users that the network can handle. There may be a need to reduce the number of participants for each training session.

Limitations
A limitation of this study was its small sample size. As this study was intended for a preliminary pilot evaluation, only a few participants were recruited from the six healthcare courses to form six teams. However, as a result of their conflicting or busy schedules, we were unable to reach the targeted sample size of 36 participants to participate in the six-hour study. Future studies can consider conducting the intervention over a shorter period of time (e.g. four hours) to make it more feasible for the learners to participate. Another limitation was the use of the self-reported survey, which may have been subjected to social desirability. A more robust study using a randomized control study is currently underway to measure the impact on team performance.

Conclusion
A virtual hospital environment, healthcare professional avatars, and electronic patient records were built into a MUVE to provide the opportunity to train multidisciplinary team to work together. The evaluation from this study supported the usability of this virtual world platform in facilitating the training of multidisciplinary team care delivery among different groups of healthcare students. The finding also supports the feasibility of using a MUVE in supporting social interactions and collaborative practices among the six different healthcare professions to facilitate the sharing of information and planning of patient care. The learning experiences can be optimized by reducing unnecessary clicking tasks that can increase cognitive load to users, enhancing the fidelity of patient avatars with the provision of bodily expressions, and, most importantly, improving the sound quality on voice communication. With
these enhanced features, future research can evaluate how multidisciplinary teams work together as an outcome measure to justify the effectiveness of this learning platform.

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Conflict of Interest

No conflict of interest has been declared by the authors.
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