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Design and evaluation of a 3D virtual environment for collaborative learning in interprofessional team care delivery

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A B S T R A C T

Background: Collaborative learning in interprofessional team care delivery across different healthcare courses and institutions is constrained by geographical locations and tedious scheduling. Three dimensional virtual environments (3D-VE) are a viable and innovative tool to bring diverse healthcare students to learn together.
Aim: The aim of this study is to describe the development of a 3D-VE and to evaluate healthcare students' experiences of their collaborative learning in the environment.
Method: A mixed methods 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 teams to participate in team care delivery via a 3D-VE. Pre- and post-tests were conducted to evaluate the students' attitudes toward healthcare teams and interprofessional collaboration. 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.
Result: The students demonstrated significant improvements in their attitudes toward healthcare teams ($p < 0.05$) and interprofessional collaboration ($p < 0.001$) after the collaborative learning. Four themes emerged from the focus group discussions: “feeling real”, whereby the students felt immersed in their own roles; the virtual environment was perceived as “less threatening” compared to face-to-face interactions; “understanding each other's roles” among different healthcare professionals; 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), feasibility (mean 3.39, SD 0.60) and perceived sense of presence (mean 107.24, SD 17.78) of the 3D-VE in supporting collaborative learning.
Conclusion: Given its flexibility, practicality, and scalability, this 3D-VE serves as a promising tool for collaborative learning across different healthcare courses and institutions in preparing for future collaborative-ready workforces.

1. Introduction

With government and professional calls for collaborative teamwork and communication, healthcare educators have increasingly sought to explore three-dimensional (3D) virtual environments in delivering collaborative learning activities (Liaw et al., 2018). The rapid advancement in learning technology has created 3D virtual environments where learners can collaborate and communicate in real time. These environments have been used to create authentic 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 (Veltman et al., 2012).

The use of 3D-VE for collaborative learning is known to be

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influenced by the success of the team-based simulation. This conventional simulation places the learners in a realistic situation and is considered an authentic experiential learning activity to prepare learners for real-life work (van Soeren et al., 2011). Despite growing evidence on the benefits of team-based simulation for interprofessional education, training is limited by the availability of physical facilities and scheduling challenges (Liaw et al., 2014a). Moreover, a recent review identified gaps in team training at the pre-registration level which included small team compositions with primarily medical and nursing students, and limited evidence on the best way to implement team training (Nelson et al., 2017). As different healthcare students are often trained in a variety of institutions, bringing healthcare students together to engage in a conventional team-based simulation is another challenge (Liaw et al., 2014b). The use of a 3D-VE for interprofessional learning has thereby emerged as a viable innovative tool that can transcend geographical boundaries by bringing together learners from different health profession institutions (Umoren et al., 2014).

The 3D-VE exhibits a set of characteristics to support collaboration among people. An earlier study called for the incorporation of key features when designing a virtual world to meet the learning needs of learners, which include presence, representational fidelity, immediacy of control (Dalgarno and Lee, 2010). According to Dalgarno 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. Social presence, the feeling of "being there together" with other users, is an essential feature of collaboration in the 3D-VE (Cruz et al., 2014). This sense of presence is recognized to be achieved by verbal and non-verbal social interaction (Wang et al., 2017). Future testing of different design elements of 3D collaborative learning is warranted to gain a deeper understanding of how 3D-VE could transform collaborative learning (Wang et al., 2018).

Previous studies in healthcare education have explored the use of virtual environments for collaborating learning in emergency preparedness training (Pucher et al., 2014; Cohen et al., 2013), life support training (Khanal et al., 2014), and the development of professional values (Palumbo et al., 2016; Tiffany and Hoglund, 2014). These studies employed a variety of virtual platforms, including the Second Life and Unity 4. A systematic review on the various applications of 3D-VEs for higher education recommended further research to examine the issues and barriers of using 3D-VEs in higher education (Ghanbarzadeh and Ghapanchi, 2018).

To the best of our knowledge, no study has examined the use of 3D-VE for interprofessional 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 interprofessional teamwork. To achieve that, it is essential for different healthcare professionals to communicate effectively and understand the roles and responsibilities of each member of the healthcare team (Ndoro, 2014). Thus, the aims of this study are to describe the design of a 3D-VE for interprofessional team care delivery and to evaluate healthcare students' perceptions and experiences of the virtual environment for collaborative learning.

2. Methods

2.1. Design and development of the 3D-VE

A 3D-VE was created using the Unity 5 games engine (Unity Technologies, San Francisco, CA). The software program supports multiuser real-time interactions in a virtual world. A virtual hospital environment including intensive care units, general acute ward, and community care ward, were incorporated into the 3D-VE. Tutorial and family conference rooms were built within each of these areas.

Fig. 1 illustrates the views that were presented to the different users. Facilitator, six healthcare professions (nurse, pharmacist, physician, physiotherapist, occupational therapist, and medical social worker), patient, and patient's relative avatars representing both male and female users were developed to match their roles in the multidisciplinary team-care scenarios. Users were able to log into the 3D-VE using their avatar roles.

The patient avatar's view has a control panel that allows the standardized patient 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) could be programmed based on the virtual patient's condition. 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.).

Similar to healthcare avatars, the facilitator avatar can move freely inside the virtual hospital and can teleport from one place to another. The facilitator user is the main controller of the audio system, having the rights to interject or pause any ongoing conversation. The facilitator user's view also has a control panel to adjust the physiological parameters and responses of the virtual patient.

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 healthcare and facilitator avatars through the Computer-On-Wheels (COW). For the current 3D-VE 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.

2.2. Implementation of the 3D-VE for learning

The 3D-VE 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 preparation for the application of relevant knowledge to facilitate effective communication and collaboration in interprofessional 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 healthcare and facilitator avatars gathered in 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 teams then proceeded to participate in an interprofessional bedside round for Mr. Jin, who was in his second postoperative 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 interprofessional family conference in a virtual family room, which required them to deal with discharge and caregiving issues arising from the same case study. In this scenario, one

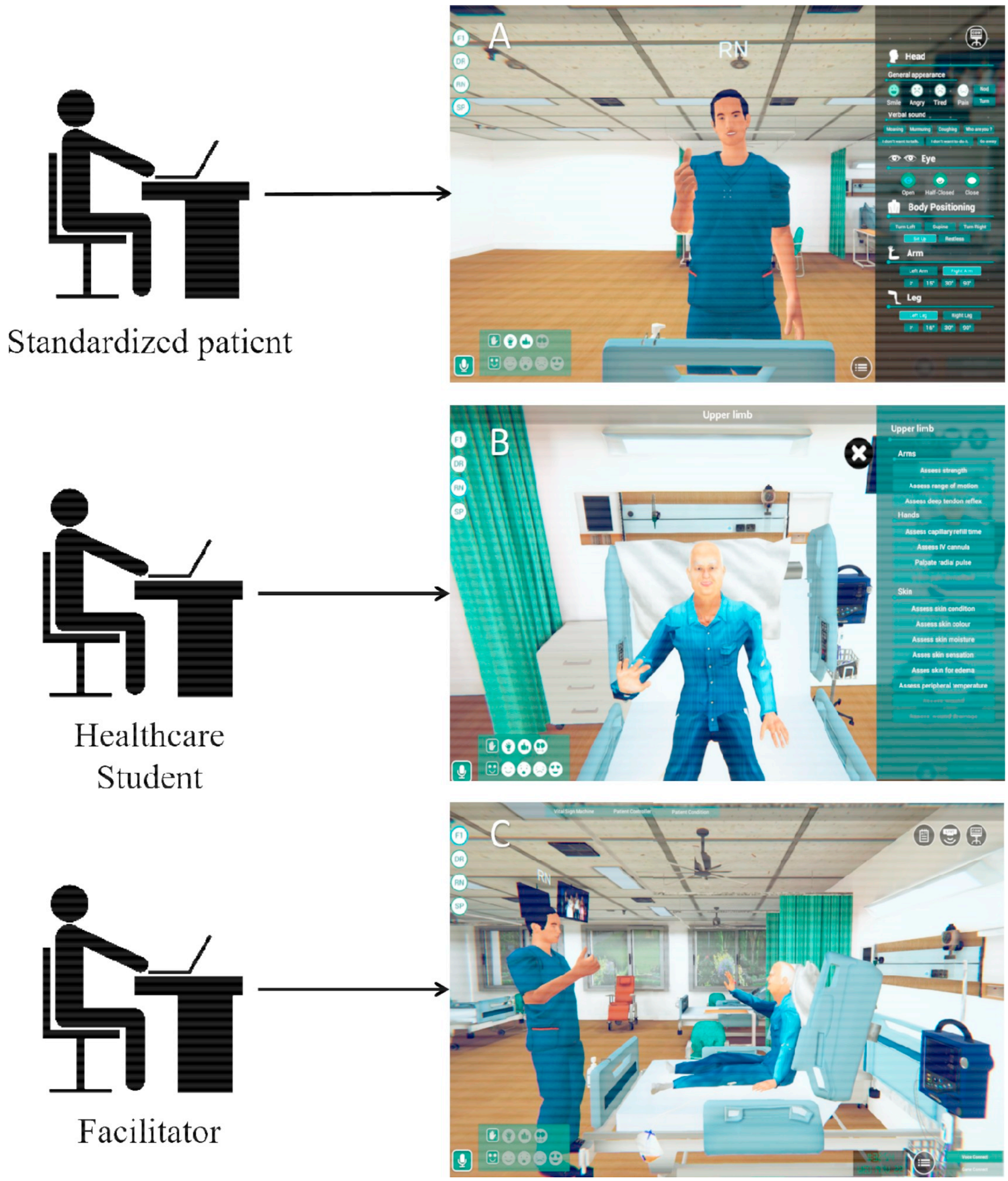

Fig. 1. Views by standardized patient (A), student (B), and facilitator (C) avatars.

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 standardized patient.

2.3. Evaluation of the 3D-VE learning

2.3.1. 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. The sample size was computed based on the qualitative study method that aimed to examine the primary research question. As we targeted to conduct at least four focus group discussions with six to eight students in each group, 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 aimed 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. There were one or two missing healthcare students' roles (e.g. medical social worker and pharmacist) in each team which were replaced by faculty and research staff with relevant healthcare backgrounds to ensure complete interprofessional teams for the 3D-VE learning (Fig. 2).

2.3.2. Data collection and instruments

The 14-item Attitudes toward Interprofessional Health Care Teams (ATHCT) and the 24-item Interprofessional Socialization and Valuing Scale (ISVS) were administered before and immediately after the virtual learning. The ATHCT with 5-point Likert scale was first developed by Heinemann et al. (1999) and adapted by Curran et al. (2007) to measure undergraduate students' attitudes toward interprofessional health care teams. The ISVS with 7-point Likert scale was developed by King et al. (2010) to measure participants' perceived interprofessional

Fig. 2. Experiential learning by interprofessional team: A, interprofessional bedside rounds; B, debrief by facilitator in the virtual tutorial room; C, Computer-on-wheels.

competencies. The psychometric properties of the ATHCT and the ISVS were validated in previous studies (Curran et al., 2007; King et al., 2010). This study reported high Cronbach's alpha values for the ATHCT ($\alpha = 0.735$–0.874) and the ISVS ($\alpha = 0.938$–0.946).

Three questionnaires were administered to evaluate the usability of the system, the sociability of the computer-supported collaborative learning, and the sense of presence in the 3D-VE. A 10-item System Usability Scale (SUS) with a five-point Likert scale, developed by Brooke (1986), was administered to evaluate the participants' perceptions of the usability of the 3D-VE. 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 Kreijns et al. (2007), was adopted to measure the participants' perceived sociability of their collaborative learning in the 3D-VE. 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' sense of presence (Witmer and Singer, 1998; Robillard et al., 2002). 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 min. The focus group discussions were audio-recorded and transcribed.

2.3.3. Data analysis

Descriptive statistics using percentages, means, and standard deviations were computed to examine the study variables. Wilcoxon signed-rank test was used to evaluate changes between pretest and posttest scores. Interview transcripts were analyzed using Clarke and Braun's (2013) six phases of thematic analysis. Two researchers independently read the data, coded, and identified subthemes from the generated codes to enhance the confirmability of the findings. They then met to discuss their generated subthemes and reorganized these subthemes through merging and re-grouping to form the key-themes with a third researcher (Guba and Lincoln, 2005).

3. Results

3.1. Quantitative data

Participants were 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 (n = 22, 76%), ethnically Chinese (n = 27, 94%), and between 21 and 23 years old (n = 23, 79%). A total of 26 participants (90%) reported that they had no prior learning experience in a 3D virtual environment.

As presented in Fig. 3, posttest scores for the overall ATHCT ($p < 0.05$) and ISVS ($p < 0.001$) scores were found to be significantly higher than the pretest scores, indicating that the participants demonstrated improvements in their interprofessional competencies on attitudes toward working in an interprofessional team.

As shown in Table 1, the overall mean score (mean 3.39, SD 0.60)

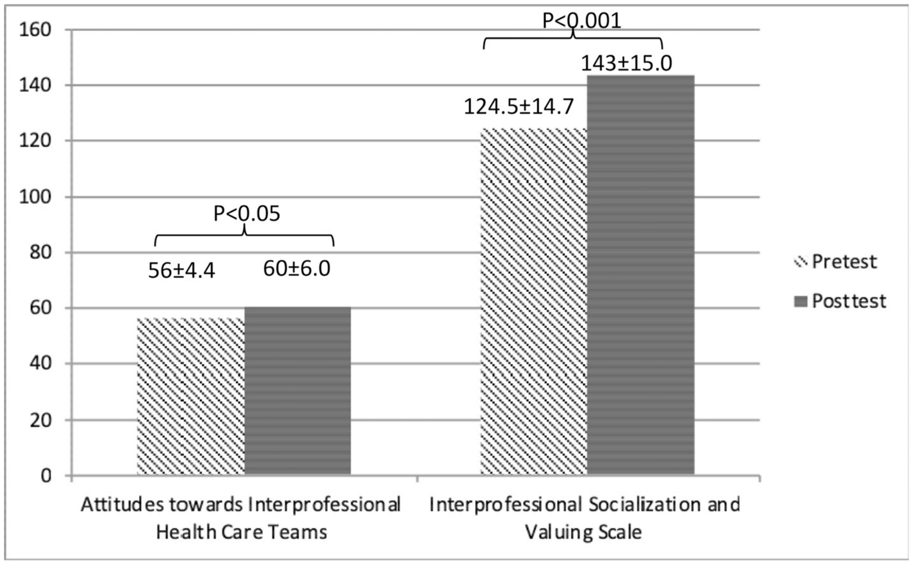

Fig. 3. Comparison of pretest and posttest scores before and after virtual learning.

from the participants' perceived degrees of sociability on a five-point scale indicated that they felt positively about the 3D-VE in supporting collaborative learning. The statement "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 3D-VE learning.

As presented in Table 2, the overall mean score (mean 3.48, SD 0.64) demonstrated that the participants were positive with the usability of the 3D-VE. 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 3D-VE. 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).

3.2. Qualitative data

Twenty-seven students participated in the focus group discussions. Four themes emerged from their experiences of the virtual learning: "feeling real", "less threatening", "understanding each other's role", and "technical hiccups".

3.2.1. Feeling real

The scenario in the virtual environment was felt to mirror those in real-life, which allowed 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 hiding 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.*"
>
> (PT)

However, some participants shared that avatars took away the abilities to deliver body language and facial expression, which are essential forms of non-verbal communication:

> "*I think having that virtual learning takes away all the non-verbal (aspects). The only thing you can hear is the tone of the voice from what the patient says.*"
>
> [OT]

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

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

Items	Not applicable to rarely applicable	Moderately applicable to totally applicable	Mean (SD)
1. This environment enables me to easily contact my teammates.	2 (6.9%)	27 (93.1%)	3.45 (0.74)
2. I do not feel lonely in this environment.	2 (6.9%)	27 (93.1%)	3.72 (0.80)
3. This environment enables me to get a good impression of my teammates.	3 (10.3%)	26 (89.7%)	3.83 (0.81)
4. This environment allows spontaneous informal conversations.	15 (51.7%)	14 (48.3%)	2.72 (1.19)
5. This environment enables us to develop into a well-performing team.	1 (3.4%)	28 (96.6%)	3.62 (0.86)
6. This environment enables me to develop good work relationships with my teammates.	2 (6.9%)	27 (93.1%)	3.72 (0.88)
7. This environment enables me to identify myself with the team.	2 (6.9%)	27 (93.1%)	3.76 (0.79)
8. I feel comfortable with this environment.	1 (3.4%)	28 (96.6%)	3.83 (0.85)
9. This environment allows for non-task-related conversations.	16 (55.2%)	13 (44.8%)	2.48 (1.09)
10. This environment enables me to make close friendships with my teammates.	12 (41.4%)	17 (58.6%)	2.76 (1.02)

Table 2
Perceived system usability.

Items	Strongly disagree to disagree	Moderately agree to strongly agree	Mean (SD)
1. I think that I would like to use this system frequently.	9 (31.0%)	20 (69.0%)	3.14 (1.03)
2. I found the system unnecessarily complex.	18 (62.1%)	11 (37.9%)	3.58 (1.02)
3. I thought that the system was easy to use.	3 (10.3%)	26 (89.7%)	3.72 (1.03)
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 that there was too much inconsistency in this system.	15 (51.7%)	14 (48.3%)	3.38 (1.05)
7. I 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)

"*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)

3.2.2. Less threatening

Some participants perceived learning in the virtual environment as less threatening compared to face-to-face learning.

"*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:

"*As a student, when I have to approach 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)

3.2.3. Understanding each other's role

The participants across different healthcare courses expressed an improved understanding on each other's professional role:

"*An interesting experience to hear different perspectives and to better understand the different roles that each healthcare professional plays.*"

(OT)

A pharmacy student iterated:

"*The opportunity to hear what the other professionals have to say about the patient's care was a learning experience for me to understand what the rest of the healthcare professionals do.*"

(PHA)

Through understanding their roles, the participants also acknowledged that different healthcare professionals have different priorities in providing patient care.

"*Everybody has different priorities. It makes it very hard for everyone to agree on one single plan that will work for the patient. It will require a lot of discussion and training to know each other and understand the priority for the patient.*"

(NUR)

3.2.4. 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]

4. Discussion

This study uniquely addressed a gap in the literature on the lack of collaborative learning in interprofessional team care delivery at the pre-registration level. To the best of our knowledge, this is the first study that designed and evaluated a 3D-VE for collaborative learning on team care delivery among different healthcare professions from multiple institutions. The strengths of our study were the representation of study participants from six different healthcare courses, the mixed method design, which allowed the triangulation of findings from different methods to explore perspectives more in-depth, and the comprehensive evaluation of the 3D-VE using validated and reliable questionnaires.

The quantitative measures provided proof-of-concept evidence of the effectiveness of a 3D-VE in improving healthcare students' interprofessional competencies of their attitudes toward working in an interprofessional team. As triangulated by qualitative findings, these improvements could have resulted from the exchange of ideas and information on patient-centered care within an interprofessional team that enabled the students to gain an understanding of each other's professional roles. As interprofessional team-based care plays an increasingly important role in healthcare delivery, these findings support earlier studies on the huge potential of 3D-VEs in developing collaborative competencies to prepare collaborative-ready healthcare workforces (Palumbo et al., 2016).

In both quantitative and qualitative findings, a sense of realism in the virtual learning was reported by the participants. The environments and scenarios, including interprofessional bedside and conference rounds undertaken in the virtual learning, were direct representations of authentic 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 authentic clinical setting, where knowledge is expected to be applied, it is likely to foster an effective transfer of learning in the real world (Dalgarno and Lee, 2010). However, more studies, especially those using qualitative methods, are needed to examine how learners transfer collaborative learning in the virtual environment to an authentic clinical setting (Liaw et al., 2018).

Apart from the virtual environment, the fidelity of the avatars was considered when designing the program by having a standardized patient act as the patient avatar and allowing avatars to control their facial expressions and bodily actions. In the qualitative findings, the participants indicated that the use of a standardized patient heightened the realism of the virtual learning. However, feedback from the participants on the lack of 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 behaviors can be a challenge (Georgescu et al., 2014). 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.

In contrast to face-to-face learning, 3D-VE serves to provide anonymity which was perceived by some participants as less stressful and consequently improving their abilities to think in the virtual learning environment. This finding supports the claim from earlier studies that learning in the virtual environment can reduce social anxiety (Hammick and Lee, 2014) and can create effective non-threatening simulated role playing environments (Coram, 2015). Given the negative impact of stress on performances (i.e. impaired thinking process) (Liaw et al., 2012), 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 positively perceived the degree of sociability of the environment in supporting collaborative learning. These findings appeared to support the application of experiential learning and social constructivism to inform the learning activities in the 3D-VE, which encouraged the students to actively engage in social interactions through role playing and debriefing (James et al., 2012). Although the quantitative findings showed that the participants generally supported the usability of the virtual environment, the triangulated qualitative findings provided valuable recommendations to optimize its functionality. They suggested simplifying the navigation and clicking tasks as these might increase their cognitive loads, which in turn distracted them from the meaningful task of communication. A study by Van der Land et al. (2013) found that immersive virtual environments might increase extraneous cognitive loads as learners pay unnecessary attention to irrelevant immersive stimuli, which distract them from engaging in meaningful learning tasks. Thus, to reduce the learners' cognitive loads, we decided to allow avatars to teleport from one place to another and reduce the clickable area for physical assessments.

With nearly half of the participants reporting too much inconsistency in the system usability, the need to improve the efficiency and quality of the control devices is apparent. This technical problem was also reported in the qualitative findings, in which the participants related it more specifically to the audio system that affected their communication in the virtual environment. 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 3D-VE 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.

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 participants to participate in the six-hour study. Future studies can consider conducting the intervention over a shorter period of time (e.g. 4 h) to make it more feasible for learners to participate in. Another limitation was the use of the self-reported survey, which may have been subjected to social desirability. Future research can undertake a more robust study using randomized control studies to measure the impact on team performance.

5. Conclusion

A virtual hospital, healthcare professional avatars, and electronic patient records were built into a 3D-VE to provide the opportunity to train interprofessional team to work together in the delivery of team-based care. The evaluation from this study supported the usability of this virtual world platform in facilitating the training of interprofessional team care delivery among different groups of healthcare students from multiple institutions. The finding also supports the feasibility of using a 3D-VE in supporting social interactions and collaborative practices among the six different healthcare professions to facilitate the sharing of information and the planning of patient care. With these enhanced features, future research can evaluate how interprofessional teams work together as an outcome measure to justify the effectiveness of this 3D-VE. Given its flexibility, practicality, and scalability, the 3D-VE serves as a promising tool for collaborative learning across different healthcare courses and institutions in preparing for future collaborative-ready workforces.

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Ethics approval

The study was approved by the National University of Singapore Institutional Review Board (Reference Code: S-17-107).

Declaration of Competing Interest

No conflict of interest has been declared by the authors.

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