Title: Multiuser Virtual Worlds in Healthcare Education: A Systematic Review

ABSTRACT

Background: The use of multiuser virtual worlds (MUVWs) for collaborative learning has generated interest among healthcare educators. Published evidence to support its use is growing, but none has synthesized the evidence to guide future work.

Objective: This study sought to provide a comprehensive and systematic evaluation of MUVWs in healthcare education.

Design: A systematic review

Methods: A systematic search of five databases including CINAHL, Cochrane library, EMBASE, PubMed, and Scopus, was conducted from inception up to January 2017. Two independent researchers selected studies that met the inclusion criteria and assessed for methodological quality using the Medical Education Research Study Quality Instrument (MERSQI). A total of 18 studies were reviewed and their data were synthesized narratively using a 3-P model (presage-process-product).

Results: Average scores in the MERSQI for methodological quality are 10/18, which is modest. A rally by the government or professional bodies towards more collaborative working among healthcare professionals is a key driver behind implementing MUVWs. Funding is important for its development and evaluation. Team training in acute care and communication training were the most frequent learning objectives, and predominant learning activities include practice on simulation scenario and debriefing. Two-third of the studies did not explain their theoretical framework that underpinned their design and implementation of MUVWs. While MUVWs in healthcare education is generally well-received, learning outcomes remain inconclusive.

Conclusion: Despite a growth of studies on the use of MUVW in healthcare education, there is a need for more understanding of the application of theories to inform the learning activities. Therefore, we suggest educators to incorporate a theoretical model to explain the learning processes behind MUVWs. To improve the quality of evidence, we call for researchers to employ a more rigorous and broader approach to evaluation that explicates longer-term outcomes, including cost benefit analyses.

INTRODUCTION

The use of a multiuser virtual environment world (MUVW) for learning is gaining popularity in education (Cho and Lim, 2017). This learning environment is generated by a computer using a three-dimensional realm where users are able to create a representation of themselves called avatars (Boulos et al., 2007). These avatars can gain a sense of presence by interacting with spaces, objects, and each other in a real-time environment (Veltman et al., 2012). By mimicking real-world settings and practices, the virtual world can promote the learning of real-world knowledge and skills (Loke, 2015). As a MUVW supports social presence among learners, it can also provide an excellent platform for developing collaborative competencies (Veltman et al., 2012). Fidelity of the representation and interactivity are two key features of a three-dimension virtual learning environment that distinguish it from other types of computer applications (Dalgarno and Lee, 2010).

The use of MUVWs for collaborative learning has generated interest among healthcare educators, many influenced by the success of the team-based simulation. Team-based simulation education has become an increasingly popular training for different healthcare professionals across a range of clinical contexts (van Soeren et al., 2011). Although there is growing evidence on the effective use of simulations for collaborative practice (Zwarenstein et al., 2009), logistical issues in organizing such activities, including scheduling and ensuring the availability of simulation facilities, have been proved challenging (Baker et al., 2008). For these reasons, the use of simulation in the virtual environment has been increasingly explored as a viable option to overcome time and space constraints (Liaw et al., 2014a).

Although both MUVW and team-based simulation utilize different learning mediums, they appear to share similar learning affordances which include experiential learning, engagement, contextual learning and collaborative learning. Drawing on the application of

3

experiential learning approach, both learning strategies could offer opportunities for the learners to experience working together and practice skills in problem solving, decision making and communication through role playing exercise. They also allow for reflective practice through interaction between learners and their facilitators in a safe environment (Greci et al., 2013; Liaw et al., 2014b). The MUVW can overcome the limitation of face-to-face team-based simulation by allowing real-time experience of (Khanal et al., 2014). Another key advantage is its feasibility in providing repetitive learning and deliberate practice which is essential for achieving long-term retention of learning (Ericsson, 2004).

Despite the growing number of studies exploring the potential of MUVWs in healthcare education, there is a paucity of contextual and synthesized evidence on its effectiveness. Furthermore, there is generally a lack of understanding of the purpose of using MUVWs in healthcare education and its developmental approaches. Thus, this paper seeks to provide a comprehensive and systematic evaluation of the MUVWs literature in healthcare education. This review was guided by three research questions:

1) What are the characteristics of the learning contexts and individuals involved in a MUVW?

2) What are the learning processes involved in the delivery of MUVW?

3) What are the outcomes associated with MUVW learning?

METHODS

This review was conducted according to the standards of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Figure 1) (Moher et al., 2009). The search was not limited to a certain period of years to ensure a wide range of research papers covered. The protocol is registered in the PROSPERO database (CRD42017059504).

Selection criteria

Studies were selected for this systematic review if they have described the outcomes of MUVW interventions performed by practicing staff or students undertaking pre-registration or post-registration health-related courses or training programmes. MUVW interventions are those that involved two or more learners from the same or different healthcare professions for the purpose of a simultaneous interactive learning experience. Only primary studies that used quantitative, qualitative, or mixed-methods and were published in English were included.

Search strategy and study selection

An extensive search strategy was developed in collaboration with an experienced senior librarian. The search was employed from inception up to January 2017. The identified index terms and keywords (Appendix A) were used in the following databases: CINAHL, Cochrane Library, EMBASE, PubMed, and Scopus. Reference lists of the eligible studies were also reviewed to identify additional studies that might meet the inclusion criteria.

The search process is illustrated in Figure 1 using the PRISMA flow diagram. The initial review yielded 32 potential articles. The full-text versions of the articles were reviewed independently by two researchers to verify the eligibility of the studies based on the inclusion criteria. Any disagreement was resolved by adjudication with a third independent researcher. Among the 32 articles, 14 articles were excluded for various reasons, as indicated in Figure 1. Eventually, 18 studies were selected for reviewed.

Quality assessment and data extraction

The quality of the 18 included studies was assessed independently by two researchers using the Medical Education Research Study Quality Instrument (MERSQI) developed by Reed et

al. (2007). The two researchers independently extracted information from the included studies and sorted them into:

- Development and design of MUVW, including project topic, healthcare discipline, institution, country of the main author, funding, virtual platform, virtual environment, learning topics, learning activities, underpinning theory, duration of learning/intervention, facilitator led, and number of participants per group.

- Evaluation of MUVW, including study design, study participants, measures, findings based on Kirkpatrick's level, and MERSQI scores.

Data analyses and syntheses

Interrater reliability between the two researchers on the methodological quality of the included studies based on the MERQSI scores was determined by the intraclass correlation coefficient (ICC). Data extracted were presented using tables and synthesized in a narrative manner, using a structural and integrative approach. Study outcomes were synthesized according to the adapted Kirkpatrick's four levels of evaluation. These included reactions to the learning experience (level 1), changes in perceptions/attitude (level 2a), and acquisition of knowledge and skills (level 2b). However, none of the studies reported outcome related to change in behavior (level 3), change in organizational practice (level 4a), or benefits to patients (level 4b) (Tochel et al., 2009).

RESULTS

A total of 18 studies met the criteria and were included in the analyses. Table 1 represents a brief description on the development and design of the MUVW interventions. Table 2 summarizes the studies on the evaluation of the MUVW interventions. This included four mixed method studies and 14 quantitative studies. Methodological quality assessed from the

MERQSI scores ranged from to 6.5 to 14, with an average of 9.76 out of 18. The interrater agreement calculated by ICC was 0.95 for the MERQSI items.

The 3-P (presage-process-product) model of learning and teaching, originally devised by Biggs (1993), was used as the analytical framework to synthesize data from all the included studies. Biggs regarded 'presage factors' as the socio-political learning context and the characteristics of an individual (developer, teaching staff, and learners) who participates in the educational experience. Process factors were seen as learning or teaching approaches for the delivery of an educational experience and the product factors were regarded as the outcomes of the learning (Biggs, 1993). The 3-P model was applied in previous systematic review studies on interprofessional initiatives and has proved to provide new insights by making connection between presage, process, and product (Hammick et al., 2007; Reeves et al., 2016).

Presage

In relation to presage factors, we reported the drivers for MUVW, characteristics of institutions and learners, and required resources.

Drivers for MUVW

Drivers for developing MUVW in healthcare education occurs as the results of a desire to improve safe and quality patient care through improving clinical competencies. These drivers were identified as links to government policies or professional bodies. Caylor et al. (2015) cited the call by the World Health Organization (WHO) and health professional associations to incorporate core competencies of interprofessional collaborative practice into health professional education programs to prepare students to work together. Another important top-down driver for developing MUVW is the necessity to develop an emergency preparedness

training program for healthcare professionals. Cohen et al. (2015), Greci et al. (2013), and Pucher et al. (2014) stated the requirements of law and health accreditation agencies on the implementation of emergency response exercises to be at least twice each year in order to ensure the preparedness of a healthcare system and hospital staff on a national or world disaster response. Pucher et al. (2014) further linked this with the WHO's recommendation of regular training exercises to keep the response planning up-to-date.

Organizational support in ensuring access to training resources is critical in translating the top-down drivers into action. Five reviewed studies acknowledged the use of high-fidelity simulations as the gold standard for team and communication training (Khanal et al., 2014; Creutzfeldt et al., 2010; Tschannen et al., 2012; James et al., 2012; Youngblood et al., 2008). However, the barriers, including high cost associated with the set-up (Khanal et al., 2014; Tschannen et al., 2012), scheduling issues (Khanal et al., 2014; Caylor et al., 2015), and the availability of simulation facilities (Khanal et al., 2014), to support such simulations were raised. The need to overcome these barriers was identified as a key driver for developing simulation in the virtual environment.

The implementation of educational activities using MUVWs that evolved from 'bottom-up' interests (e.g. educator) in making use of the emerging technologies was reported. The availability of virtual reality software and environment such as Second Life has provided an opportunity for nurse educators to develop innovative teaching strategy that simulate real-world situations (Tiffany and Hoglund, 2014; Aebersold et al., 2012).

Institutional and learner characteristics

All reviewed studies provided the names of the institutions where the MUVW interventions were undertaken. Of the eighteen institutions, fifteen (n=15) were universities while three

(n=3) were colleges. The majority of these institutions were situated in the USA (n=13) and the rest were from the UK (n=3), Australia (n=1), and Sweden (n=1).

The learners involved in the reviewed studies (n=12) were primarily undergraduates. Six studies included trained professions exclusively (Greci et al., 2013; Khanal et al., 2014; Cohen et al., 2015; Pucher et al., 2014; Billingsley et al., 2013; Wiecha et al., 2010). Most studies involved students or trained professions from the field of nursing (n=9) or medicine (n=10). Only five studies were involved in IPE where two or more professions learn with one another in a MUVW (Khanal et al., 2014; Caylor et al., 2015; James et al., 2012; Palumbo et al., 2016; Seefeldt et al., 2012). The medical profession (n=5) was most commonly involved in IPE, followed by nursing (n=4) and pharmacy (n=3).

Resources

Eleven (61%) reviewed studies acknowledged the availability of specific project funding to develop and evaluate the MUVW interventions. However, time limitation imposed by funding sources can challenge the efforts in sustaining MUVW activities. Menzel et al. (2014) reported that the requirement of "island" purchase and annual renewal to maintain learning in Second Life can be costly. Greci et al. (2013) and Billingsley et al. (2013) advocated for institutions to provide access to computers with hardware requirements (e.g. gaming graphic card and special headsets) in order to enable the learners to participate in MUVW learning.

Process

The findings on the process of teaching and learning were grouped into learning topics, virtual platform and worlds, and learning activities.

Learning Topics

Team training in acute care (n=9) and communication training (n=4) were common learning topics that implemented MUVWs for educational purposes. In three reviewed studies, the concepts of teamwork, including Advanced Course Life Support and Advanced Trauma Life Support, were introduced as part of life support training Khanal et al., 2014; Creutzfeldt et al., 2010; Youngblood et al., 2008). Three reviewed studies used MUVWs to instill professional values towards poor people, marginalized persons, and elders Tiffany and Hoglund, 2014; Palumbo et al., 2016; Seefeldt et al., 2012). The rest of the studies focused on the development of critical thinking, which were based on specific patient case studies (Wiecha et al., 2010; Seefeldt et al., 2012) or research critiques (Billingsley et al., 2013).

Virtual platform and worlds

A variety of virtual world environments were created in the reviewed studies. The most common environment is a hospital setting (n=8) follow by a classroom setting (n=5). Second Life was the most common virtual platform used by the reviewed studies (n=12). Two studies employed the Unity 4 games engine while the rest used uncommon virtual platforms including Atmosphere by Adobe Systems Inc., Unreal Development Kit (UDK) gaming engine, CliniSpace™, Forterra Systems Inc., and OLIVE game development platform.

Learning theories and activities

Only six studies (33%) used learning theories to inform their MUVW learning. These included Kolb's experiential learning (Youngblood et al., 2008; Kolb, 1984), Jeffries's simulation theory (Foronda et al., 2014), Benner's novice to expert theory (Palumbo et al., 2016), situated learning theory, theory of constructivism, and reflective learning theory (James et al., 2012).

Practice on simulation scenario using MUVWs was the key learning activity featured in almost all reviewed studies (n=16). Only two MUVWs interventions involved virtual interaction and/or lecture focusing on the acquisition or application of knowledge. The duration of learning varied ranged from 10 minutes to 2 hours. Two interventions lasted six or more weeks. The size of learners per group ranged from 2 to 17. Prior to undertaking simulation activities, the learners were provided an orientation of the virtual environment. The format of orientation varied from online learning (Tschannen et al., 2012; Youngblood et al., 2008) to face-to-face tutorial learning (Khanal et al., 2014; James et al., 2012; Tiffany and Hoglund, 2014) to video demonstration (Foronda et al., 2014) to small group virtual exercise using a demonstration scenario (Conradi et al., 2009). Besides familiarization to the virtual world, the learners in four reviewed studies also received online pre-learning on the acquisition of relevant knowledge to prepare them for the simulation scenario (Greci et al., 2013; Caylor et al., 2015; Aebersold et al., 2012; Foronda et al., 2014). Most simulation scenarios were followed by debriefing sessions with the majority (n=8) conducted in the virtual environment. While Tshannen et al. (2012) employed face-to-face debriefing in a classroom setting, Greci et al. (2013) used a combination of virtual and face-to-face debriefing. The use of recorded video during debriefing was reported by Greci et al. (2013) and Youngblood et al. (2008).

<u>Product</u>

As shown in Table 2, the outcome data was reported some levels of the adapted Kirkpatrick's four levels of evaluation (Tochel et al., 2009).

Learning Reaction

Learners' reactions to MUVW learning were evaluated by 14 studies, in which all reported favorable responses on the learning strategy. These include supporting the use of MUVWs for effective learning (Billingsley et al., 2013; Wiecha et al., 2010; Seefeldt et al., 2012), valuing the authentic learning environment (Pucher et al., 2014; Tiffany and Hoglund, 2014; Conradi et al., 2009) and reporting that their learning in the MUVW was fun and enjoyable (Creutzfeldt et al., 2010; James et al., 2012). Additionally, learning in a MUVW was perceived as superior to other learning strategies (Pucher et al., 2014; Wiecha et al., 2010)

Despite the overall positive reactions, barriers related to technology were reported by six studies. The issue of accessibility was reported by James *et al. (2012)* and Conradi et al. (2009). The relatively high technology demands in MUVWs can cause downloading problem (Conradi et al., 2009). The usability issues in the Second Life environment, including difficulty with communication (Seefeldt et al., 2012), identity confusion (Caylor et al., 2015), and difficulty in navigating avatars (Menzel et al., 2014), were raised. The need for proper orientation before conducting a virtual simulation was highlighted (Caylor et al., 2015; Tiffany and Hoglund, 2014; Menzel et al., 2014).

Learning outcomes

Learners' changes in perceptions or attitudes (level 2a) and knowledge and skills (level 2b) were evaluated by 16 primary studies. Of the eight studies that reported level 2a, all reported positive changes to learners' attitudes and self-perceived efficacy. Three of these linked their evaluation to interprofessional learning outcomes, including attitudes toward interprofessional education (Caylor et al., 2015) and interprofessional competencies (Greci et al., 2013; Palumbo et al., 2016). The remaining studies, which employed pretest-posttest designs, reported an improvement in attitudes (Palumbo et al., 2016) or self-perceived

efficacy (Creutzfeldt et al., 2010; Billingsley et al., 2013; Wiecha et al., 2010) in the application of the learning concepts.

Two studies that reported knowledge outcomes at level 2b showed mixed results. Greci et al. (2013) reported a significant improvement in disaster preparedness knowledge from a self-reported questionnaire. In contrast, using an objective knowledge measurement, Creutzfeldt et al. (2010) reported a significant decline in knowledge between two post-tests with a six-month interval. All six studies that reported changes in performance showed significant improvements from the baseline after learning in MUVWs. However, two of these, both RCTs using pretest-posttest study designs and a robustly developed observational scale, did not demonstrate that the virtual learning was superior to patient simulator learning (Khanal et al., 2014; Youngblood et al., 2008). In contrast, Tschannen et al. (2015), who employed a less rigorous study using a quasi-experimental posttest only design, showed that the virtual simulation intervention produced better performances compared to the hands-on simulation intervention.

DISCUSSION

A key presage factor for developing MUVWs in healthcare education was government or professional calls for collaborative teamwork and communication, often with the aim to address patient safety or ensure the preparedness of hospital staff on a disaster response. High-fidelity simulation has become one of the major pillars of team training, allowing different professions to learn how to collaborate effectively through experiential learning without risk to patients (Boet et al., 2014). Although this simulation team-based learning has been shown to provide positive outcomes, it presents many logistical challenges, including simulation facilities, scheduling, and manpower (Baker et al., 2008; Liaw et al., 2012). In the studies reviewed, the need to overcome these challenges is identified as the key impetus for

the implementation of simulation via MUVWs. Given the accessibility (not bound by time or place), flexibility (permits adaptable integration into the curricula), and scalability (potential to cater to large numbers of learners simultaneously) of MUVWs, it appears to provide a more promising learning strategy towards a successful implementation and sustainability of team training.

The findings suggest that the development and implementation of MUVW interventions are feasible in both pre-licensure and post-licensure healthcare education, particularly in medical and nursing education. External funding was acknowledged in more than half of the reviewed studies, although few details were provided on the use of funding in relation to developing and implementing the MUVW interventions. While the set-up and running costs were reported to be low particularly on the use of Second Life, literature was relatively silent on long-term costs regarding the use of MUVW learning. According to Walsh (2016), long-term cost associated with the maintenance of e-learning resources and scaling up to large number of users (purchase of user licenses) can be prohibitively expensive. Three robust studies identified in this review were all funded, indicating the influential of funding in enabling rigorous evaluation to provide evidence on the effectiveness of MUVW interventions. In addition to evaluating effectiveness, an economic evaluation could be undertaken in the future to justify the cost of providing the educational intervention (Walsh, 2014).

The reviewed studies explored the potential of MUVWs for diverse learning purposes in healthcare education, with a growing number of studies looking into team and communication training. In addition, the reviewed studies indicated a variety of MUVW software being used in healthcare education for collaborative learning. Second Life was found to be the most well-known virtual world used in healthcare education, which is consistent to what was reported by Wang & Burton (2013). After investing considerable

resources in a virtual world learning space, it is imperative for the institutions to have sustainability plans to ensure the viability of the learning resource. However, many existing learning environments fall into disuse or are underutilized by education. The provision of funding, technical, and teaching support by institutions is essential to continue upgrading or utilizing the adoption of virtual worlds for learning and research (Gregory et al., 2015).

In the reviewed studies, the majority (67%) did not have a clear theoretical model to inform the use of the learning activities in the MUVWs. This finding is congruent with a previous study that critically reviewed theories underpinning the design of virtual worlds for education (Loke, 2015). Although most studies did not explicitly mention the use of theory, learning activities including role-playing a scenario followed by debriefing were predominantly applied in the virtual world. Theories including experiential learning, constructivism, and social constructivism could be used to underpin these learning activities. Kolb's (1984) experiential learning theory, which constitutes the process of active experimentation followed by reflection, can be applied to support the learning mechanisms of role-playing and debriefing. The theory of constructivism emphasizes learning from the interaction between learners and their environment (Piaget, 1970), whereas the theory of social constructivism highlights learning results from social interactions (Vygotsky, 1978). Thus, the application of constructivism seems more relevant when learners are role-playing in MUVWs in which learner-environment interactions occur. As the process of role-playing and debriefing involve social interactions, social constructivism can be applied to explain how the MUVWs might bring about learning. In the reviewed studies, unlike role-playing that occurs solely in the virtual world, debriefing was found to take place in two different learning platforms—virtual and face-to-face. The combination of role-playing in the virtual world with face-to-face debriefing is defined as the blended learning method (Garrison and Kanuka,

2004). To the best of our knowledge, there is a paucity of studies that supports the effectiveness of this blended learning approach over virtual learning in MUVWs.

Most studies sought to answer research questions about learners' reactions to MUVWs. Despite the positive reactions to learning in MUVWs, technical problems posed the greatest challenge. Further work is warranted on the usability by making the technology simpler and more intuitive (Conradi et al., 2009). Our findings showed that measures of changes in attitudes and self-perceived efficacy are more likely to show positive results than knowledge and performance outcome measures. Caution is nonetheless advised on the validity of self-reported measures as these may not predict actual performance (Liaw et al., 2012). However, due to the high requirement of resources to measure observation of performance, only a few studies which were predominantly quasi-experimental study designs assessed this outcome. Although all of these studies demonstrated significant improvements in performance after the MUVW interventions, the outcomes from comparative studies with control groups that received an educational intervention remains unclear. More rigorous research employing the RCT study design is needed to demonstrate the impact of MUVW on clinical performance.

None of the review studies reported longitudinal outcomes related to changes in behavioral, organizational, and patient outcomes. The short-term nature of evaluations in these studies is unsurprising, given that most of the MUVW interventions were part of pre-qualification health professional courses. The measurement of organization and patient outcomes arising from pre-qualification educational intervention would be less feasible and difficult to pinpoint due to a variety of confounding variables (Reeves et al., 2008). In addition, a single MUVW educational intervention may not be likely to have an impact on healthcare delivery and patient care. Thus, there is a need to move beyond 'a single factor cause-effect thinking (Wadsworth, 2010) to understanding how the learning process can lead

to behavioral and system change (Yardley and Dornan, 2012). This calls for a broader approach of evaluation, including qualitative methods to unravel the complex process involved in MUVW learning.

Limitations

This review has some limitations. Firstly, it is possible that not all relevant articles were identified in this study even though a thorough and careful search strategy was undertaken. Secondly, the study only reviewed publications in the English language and from refereed journals. Other possible sources of publication were excluded. Thirdly, although some studies yielded high methodological quality as reflected by their MERQSI scores, the overall quality was relatively average. Fourthly, some studies did not provide detailed descriptions of their interventions or outcome measures. Finally, given the lack of heterogeneity of the small number of articles that fit the inclusion criteria, it was not possible to perform a meta-analysis.

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CONCLUSIONS

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A review of 18 eligible studies demonstrated that the use of MUVWs in healthcare education is not uncommon, especially in higher educational institutions, as a result of government and professional calls for collaborative teamwork and communication in clinical practice. Funding was acknowledged to be an important resource of support to the development and evaluation of MUVW learning. The reviewed studies have explored the potential of MUVWs for diverse educational purposes, with a growing number of studies exploring team and communication training and incorporating the experiential learning approach to support the learning process. Although the evaluations showed some positive outcomes related to the use of MUVWs, its effectiveness remains unclear at this time due to methodological limitations.

We propose that the following five gaps should be filled in order to move forward an evidence-based learning agenda for the use of MUVWs: 1) incorporate a theoretical model to inform learning activities in MUVWs, 2) compare learning in MUVWs with a blended learning method (virtual world with face-to-face learning), 3) an RCT study design to evaluate the impact of MUVW intervention on clinical performance, 4) a qualitative study to examine the learning process and practice changes, and 5) cost benefit analyses including long-term maintenance cost.

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