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Designing and evaluating the effectiveness of a serious game for safe administration of blood transfusion: A randomized controlled trial

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ABSTRACT

Background: Preparing nursing students for the knowledge and skills required for the administration and monitoring of blood components is crucial for entry into clinical practice. Serious games create opportunities to develop this competency, which can be used as a self-directed learning strategy to complement existing didactic learning and simulation-based strategies.

Aim: To describe the development and evaluation of a serious game to improve nursing students' knowledge, confidence, and performance in blood transfusion.

Method: An experiential gaming model was applied to guide the design of the serious game environment. A clustered, randomized controlled trial was conducted with 103 second-year undergraduate nursing students who were randomized into control or experimental groups. After a baseline evaluation of the participants' knowledge and confidence on blood transfusion procedure, the experimental group undertook a blood transfusion serious game and completed a questionnaire to evaluate their learning experience. All participants' clinical performances were evaluated in a simulated environment.

Results: The post-test knowledge and confidence mean scores of the experimental group improved significantly ($p < 0.001$) after the serious game intervention compared to pre-test mean scores and to post-test mean scores of the control group ($p < 0.001$). However, no significance difference ($p = 0.11$) was found between the experimental and control groups on the post-test performance mean scores. The participants evaluated the serious game positively.

Conclusion: The study provided evidence on the effectiveness of a serious game in improving the knowledge and confidence of nursing students on blood transfusion practice. The features of this serious game could be further developed to incorporate additional scenarios with repetitive exercises and feedback to enhance the impact on clinical performance. Given the flexibility, practicality, and scalability of such a game, they can serve as a promising approach to optimize learning when blended with high-fidelity simulation.

1. Introduction

Human error in the administration of blood product leading to adverse events was recognized as the highest risk of transfusion error which can be preventable (Serious Hazards for Transfusion, 2013; Smith et al., 2010). There has been an increased responsibility for nurses to perform this procedure, in which two registered nurses are required to conduct various levels of checks before administration of the blood product (Royal College of Nursing, 2004). Besides safe administration of the blood product, nurses must know how to recognize and manage adverse transfusion reaction. The deficiencies in nurses' knowledge and skills were reported as barriers for safe practice of blood transfusion (Hijji et al., 2013; Serious Hazards for Transfusion, 2013). Nurses were found to be non-compliant with the national standards of blood transfusion, including suboptimal vital sign monitoring and documentation deficiencies (Rowe and Doughty, 2000; Hijji et al., 2013). Education and training are therefore essential to ensure blood transfusion safety.

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A review of the nursing literature identified an increasing number of studies that examined the use of innovative learning strategies to improve nursing students' competency in blood transfusion. The blended learning strategies using didactic approaches followed by simulation learning were examined by several studies (Flood and Higbie, 2015; Prentice and O'Rourke, 2013; Smith et al., 2010). The incorporation of simulation into didactic learning enabled students to apply the theory that they learned through practice in the simulation scenario (Smith et al., 2010). A quasi-experimental study conducted by Flood and Higbie (2015) revealed that students who received a didactic lecture preceding the simulation learning have a better acquisition of knowledge than those who received only the simulation learning. Although this blended learning approach yielded immediate knowledge improvement for blood transfusion safety, this improvement was not sustained over time (Mole et al., 2007; Prentice and O'Rourke, 2013). A study conducted by Smith et al. reported a clear degradation of knowledge six months after the educational programme, which may result in adverse events in transfusion practice. Although the existing studies did not measure clinical performance as a learning outcome, regular reinforcement of learning is recommended to optimize the retention and transfer of learning.

The benefits of simulation in enhancing blood transfusion practice may be optimized through repetitive training, but with significant resource challenges (Al-Ghareeb and Cooper, 2016). Expensive faculty time, the availability of simulation facilities, and scheduling issues are major challenges faced when implementing this resource-intensive modality (Miller and Bull, 2013). For this reason, the use of serious game is taking on a greater role in healthcare education. Serious game, which encompasses the component of simulation, is gaining attention in healthcare education to support the development of knowledge and skills (Wang et al., 2016). A serious game is defined as an interactive computer application, with or without significant hardware component, that has a challenging goal, is fun to play and engaging, incorporates some scoring mechanism, and supplies the user with skills, knowledge, or attitudes that are useful in reality (Bergeron, 2006). According to Killi and Lainema (2008), where game elements are involved in simulation, learning occurs as a result of being focused in a goal directed activity. Serious games and hands-on simulation have similar key features, including the use of a synthetic world structured by rules, feedback mechanisms, and challenges to guide learners in developing competencies (Aldrich, 2009). These strategies should be used as complementary learning tools to optimize clinical competency gain (Cook et al., 2012).

Serious games are emerging as a new pedagogical approach in nursing education. The PUSLE (Platform for Undergraduate Life Support Education) is an example of a game developed for nurses to enhance and maintain life support skills. A randomized controlled trial (RCT) study on 34 nurses demonstrated the effectiveness of the PULSE in improving nurses' key resuscitation skill sets during life support training. In addition, the game was positively evaluated as a learning tool to complement traditional life support training (Cook et al., 2012). While the PULSE was targeted to support Intermediate Life Support (ILS) training (Cook et al., 2012), Life Support Simulation Activities (LISSA) was developed as a serious game to focus on Basic Life Support (BLS) (Boada et al., 2015). A RCT study conducted by Boada et al. (2015) revealed that students who received LISSA performed better in laboratory sessions than students who engaged in reading of the theory material. Although a systematic review conducted from 2007 to 2014 has identified 42 serious games in training health care professionals (Wang et al., 2016), there were only three serious games articles related to nursing education (Blake and Goodman, 1999; Hahn and Bartel, 2014; Cook et al., 2012). Thus, the application of serious games in nursing education is still in its infancy. More works need to be done for development and evaluation to continue the growth of serious game in training healthcare professionals (Wang et al., 2016).

All nurses upon graduation are expected to have the ability to administer blood product safely and monitor for potential adverse reactions. Nurse educators must ensure that student nurses are equipped with the skills and knowledge to perform the procedure. To enhance existing learning strategies, a serious game on blood transfusion was developed as a self-directed learning strategy to complement the high-fidelity simulation. It could be used as a preparatory course prior to their simulation experience as well as a refresher course to maintain their competence after the hands-on simulation. To our knowledge, no serious game on blood transfusion has been developed for nursing education. Therefore, the aim of this study is to describe the development and evaluation of a serious game for developing nursing students' knowledge, confidence, and performance on safe blood transfusion practice.

2. Methods

2.1. Serious Game Design and Development

The serious game was created using a game design platform known as 3DHive by a team comprised of an undergraduate student, a faculty educator, a researcher, and a game developer. The experiential gaming model developed by Kiili (2005) was applied to guide the design of the game environment. The flow elements proposed by the model, which include *clear goals, frame story, challenges, focus attention, playability, gamefulness, feedback, and a sense of control,* were applied in this serious game to optimize game-based learning.

The game is designed to enable players to go through the process of checking and administering blood to a patient who requires it. The *game goal* is to enable its players to experience and understand the blood transfusion procedure. To achieve this, the players are required to go through three stages: pre-transfusion, during transfusion, and post-transfusion. Specific learning objectives were identified for each stage. The players are required to achieve the learning objectives in each stage before moving on to the next stage. An adult female patient with anemia who was admitted to hospital for blood transfusion was used as a *frame story* to situate the learning in a meaningful context. As shown in Fig. 1, the player performs the role of a staff nurse in a virtual hospital ward to undertake the tasks of preparing the patient to receive blood transfusion, administering the blood product safely to the patient, and providing appropriate nursing interventions to manage the patient with transfusion reaction.

Multiple mini games *challenges* were developed from the learning objectives to test the player's knowledge and problem-solving skills. These were developed based on the theory and practical learning contents acquired by the second year nursing students from their prior learning. The level of challenge was therefore adjusted according to the learners' abilities. The mini games were related to specific tasks to keep the player's *attention in focusing* on the task at hand. Some examples include choosing the appropriate equipment to proceed with the blood transfusion and checking the correct blood product using the appropriate documents. The players must provide correct answers in the mini games before they were allowed to move on to the next stage. A scoring system and time challenges were incorporated into some of the mini games to enhance its *gamefulness*. Artificial avatars including a nurse clinician, a doctor, a staff nurses, and a student nurse were also included to enhance the interactivity and engagement of the game, thereby promoting the game's *playability*. Immediate *feedback* on a player's action was provided after each mini game. For example, in a mini game on reporting of transfusion reaction, feedback on the proper structure of communication to the doctor was included. To augment the players' *sense of control*, features including free navigation around the virtual ward and opportunities to redo the mini games were included. The entire game takes about 30 min and the player can only participate once.