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Designing for online computer-based clinical simulations: Evaluation of instructional approaches

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A R T I C L E I N F O

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A B S T R A C T

Background: Online computer-based simulations are becoming more widespread in nursing education. Therefore, an understanding of when and how to implement the variety of instructional strategies related to these simulations is fundamental.
Objectives: This study compares the effectiveness of online computer-based simulations designed using two alternative instructional approaches—Productive Failure and Simple-to-Complex sequencing—on learning of clinical reasoning skills.
Participants: Participants in this study were undergraduate nursing students ($n = 103$, mean age $= 23.4 \pm 2.1$) enrolled at a university in Israel.
Methods: Participants completed two online simulations designed using Productive Failure approach (emergency medicine, mental health) and two online simulations using Simple-to-Complex approach (cardiovascular health, pediatrics). Pre- and post-test clinical reasoning evaluations were administered prior to and immediately following each simulation.
Results: Clinical reasoning learning gains were significantly higher for online simulations designed with the Simple-to-Complex approach than simulations designed with Productive Failure approach ($F (3, 288) = 9.656$, $P < 0.001$). Students devoted significantly more time ($F (1, 102) = 260.15$, $P < 0.001$) and more attempts ($F (1, 102) = 167.39$, $P < 0.001$) in learning with Simple-to-Complex simulations than they did with Productive Failure simulations. The amount of time that students were engaged in learning with simulations was significantly associated with learning gains scores.
Conclusions: This study proposes that well-designed online simulations can improve nursing students' clinical reasoning. The Simple-to-Complex approach was found to be more efficient than Productive Failure for online learning. Learning with Simple-to-Complex approach was behaviorally more engaging and students' achievements were higher, which implies that instructional process facilitates learning, and therefore have to be taken in consideration by nurse educators. Integration of computerized educational modalities within nursing education is discussed.

1. Introduction

Simulations provide a safe, low-stakes environment for students to practice new skills and apply new knowledge. There is a strong evidence that the use of simulations can help students achieve identified learning objectives while increasing their self-confidence and satisfaction, enhancing their decision-making, and improving learning outcomes related to patient safety (Cant and Cooper, 2017; Cook et al., 2011). As a result, promising efforts have been made in the nursing domain involving the creation of a variety of simulations for practicing skills in a broad range of professional activities. In recent years, mannequin simulations (low- to high-fidelity patient simulations) have become increasingly popular educational tools. These simulations are "an attempt to replicate some or nearly all of the essential aspects of a clinical situation so that the situation may be more readily understood and managed when it occurs for real in clinical practice" (Morton, 1995, p. 76). The National Council of State Boards of Nursing report suggests that simulations can be used as a substitution for up to 50% of traditional clinical experiences as long as certain conditions are met during implementation (Hayden et al., 2014).

However, although mannequin patient simulations are becoming widely accepted as an adjunct to actual clinical practice, several challenges and limitations that have been identified as preventing many nursing schools from using these platforms, including financial

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challenges and limited access to on-campus clinical laboratories, (Dean et al., 2017; Lapkin and Levett-Jones, 2011; Nagle et al., 2009). With the advancement of online technologies, the development of clinical reasoning and skills among students and practitioners from healthcare disciplines no longer needs to be confined to classrooms and laboratories (Webb et al., 2017). An online, computer-based simulation can provide a mechanism to train large numbers of nursing students, engaging them as active participants in any geographic location at any time of day. Computerized simulations have the unique advantage of allowing students to observe and manipulate otherwise unobservable phenomena, such as molecular interactions. Further, a recent meta-analysis that compared both high- and low-fidelity simulations to computer-based simulation, proposed that computer-based simulation is the most effective approach for promoting nurses' knowledge and skills (Hegland et al., 2017).

In light of these findings, we must recognize the need for additional evaluation of the effectiveness of learning with online computerized simulations. Moreover, further information is needed about instructional design of such environments to support students learning.

1.1. Instructional approaches for computer-based simulations design

Instructional design is the systematic process of planning events to facilitate learning (Gagné et al., 2005). Instructional theorists argue that a well-designed instructional process activates learners' internal cognitive structures and increases the likelihood of successful learning. Instructional pathways of learning can be operationalized in a variety of forms, which result in qualitatively different instructional approaches. Educational literature suggests two apparently contradictory instructional approaches—Simple-to-Complex and Productive Failure.

The Simple-to-Complex (S2C) approach assumes that novice learners benefit from fully-guided, simple components that gradually build up to a more complex, whole-task structure (Van Merriënboer et al., 2003). A detailed, step-by-step sequence of instruction that increases in complexity may provide an opportunity to strengthen knowledge before proceeding to more complex tasks, which some argue reduces intrinsic cognitive load.[1] In addition, S2C design contains learning tasks that are in the students' zone of proximal development and that reduce the probability of encoding of errors and misconceptions. Hence, this learning approach has positive effects on learning, performance, and motivation (Van Merriënboer and Sweller, 2005).

In contrast to the S2C approach, a Productive Failure (PF) approach proposes beginning the learning process with complex challenges that are beyond learners' current skills and abilities (Kapur, 2008; Kapur and Bielaczyc, 2012; Schwartz et al., 2011). PF is characterized by students exploring the problem, struggling, and even failing before guidance is provided in the knowledge assembly phase. Several scholars and research programs have spoken about the role of failure in learning, suggesting that having novices try and fail at tasks can support more flexible learning skills and be productive for deeper understandings (Kapur, 2008, 2014; Kapur and Bielaczyc, 2012; Jacobson et al., 2017). These scholars have proposed theoretical mechanisms of effective learning with PF that include the activation of prior knowledge, which in turn prepares students for deeper learning and, as a result, enhances transfer performance.

Considering the relevance of these two alternative instructional approaches, S2C and PF, to the design of online computer-based simulations, this study investigates and compares the effectiveness of each of these strategies on learning achievements.

1.2. Research questions

1. What impact does learning with online computer-based simulations have upon the students' clinical reasoning?
2. How effective at fostering nursing students' clinical reasoning are online simulations designed using Productive Failure and Simple-to-Complex approaches?
3. How does instructional approach affect students' behavioral engagement (operationalized as time devoted to the learning process and attempts to retry the module; Fredricks et al., 2004) while learning with computer-based online simulation?

2. Methods

2.1. Research design

Research design was within-group pre- and post-test, time-series design using a quantitative approach.

2.2. Participants and procedure

Participants were undergraduate nursing students at University of Haifa in Israel (n = 103; 31 males, 72 females; mean age = 23.4 ± 2.1) who had not yet started their clinical practicum. Between October 2016 and October 2017, participants completed online clinical simulations covering four topic areas: emergency medicine, mental health, cardiovascular health, and pediatric medicine. The emergency and the mental health simulations were designed using PF; the cardiovascular and the pediatric simulations were designed with S2C. Students were required to complete all of the simulations individually within 6 h. Pre- and post-test evaluations were administered immediately prior to and following each simulation.

The study was conducted following the approval of University of Haifa ethics committee.

2.3. Data collection instruments

2.3.1. SimNurse environment

National League for Nursing (NLN) (2015) made a statement that "Simulation can take many forms, including human patient simulation (using manikins and/or standardized patients), virtual and computer-based simulations…". Herein, SimNurse, represents the computerized-based simulations platform that was created for this study with the goal of enabling students to practice clinical reasoning in a remote, simulated environment (The Cheryl Spencer Department of Nursing, 2013). SimNurse integrates a variety of educational e-learning tools designed to provide multiple clinical online experiences—case study scenarios with virtual patients, games, virtual mentoring, self-assessment tools, 3D visualizations, interactive videos, digital-dynamic tools for exploration, and biochemical models for discovery learning (e.g., Dubovi et al., 2017a; Dubovi et al., 2018). These online learning experiences are embedded within a learning management system (LMS) that enables tracking, reporting and delivering the internet-based simulations and that can be accessed from any computer at any time. SimNurse experiences are assembled in modules in accordance with the students' clinical rotations. This study evaluated four SimNurse modules: pediatric and cardiovascular simulations that were designed with the S2C approach; and mental health and emergency modules that were designed with the PF approach.

The S2C approach incorporates components of knowledge that are explicitly decomposed into simplified subcategories and then gradually combined through authentic, case-based scenarios. For example, the

[1] An instructional theory based on knowledge of human cognitive architecture which specifically addresses the limitation of working memory (Pass and Sweller, 2014). There are three categories: 1. Intrinsic cognitive load caused by the natural complexity of the biologically secondary information that must be processed; 2. Extraneous cognitive load caused by instructional design; 3. Germane cognitive load refers to working memory resources that are devoted to dealing with intrinsic cognitive load rather than to the extraneous, thus facilitating learning.