Enhancing Nursing Student Efficiency and Efficacy in Patient Care through Virtual Patient Simulation

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ABSTRACT

Novice nurses struggle with developing efficiency in their patient care as the responsibility shifts from learning under clinical faculty to the reality of caring for their own patients under increasing levels of time pressure. Studies show that when new nurses face such time pressures, they tend to prioritize patients' physical rather than psychological needs, thus yielding a lower quality of care experience for their patients (Teng et al., 2010; Vinckx et al., 2018). To mitigate these challenges, it is important to provide nursing students with training experiences that would allow them to practice and improve their communication, thus leading to higher levels of communication efficiency and efficacy, which in turn result in improved patient care and outcomes.

Virtual patient simulation provides a standardized training environment where nursing students can explore, practice, and gain critically important communication skills (Foronda et al., 2020). At the same time, their progress can be measured against competency-based learning objectives, providing for a clear assessment of their skills. This paper provides an overview of Elsevier's Shadow Health Digital Clinical Experiences™ (DCE). The DCE provides learners with standardized patient experiences in which they engage in collecting patient data, applying therapeutic communication skills, and creating care plans through natural-language conversation-based interactions, all while also exercising empathy skills. We provide background and rationale for applying a simulation-based approach to nursing education, an overview of the DCE technology, and formative data on patient care efficacy. Readers will gain an understanding of the techniques and challenges for creating realistic, compelling virtual patients and formative efficacy results from a nursing educational setting.

ABOUT THE AUTHORS

Thomas Santarelli is an Engineering Manager for Shadow Health® at Elsevier and has been supporting the training and simulation industry for 30 years with a focus in educational technology and training system design, development, and evaluation. His research interests include interactive pedagogical agents, simulation of human cognition, and the use of AR, VR, and mixed reality systems for training and education. He holds a B.S. in Liberal Studies from Neumann University and is currently pursuing an M.S. in Instructional Technology from Lehigh University.

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Cheryl Wilson is a nurse educator for Shadow Health® at Elsevier that brings together her clinical, educational, and simulation expertise in building realistic, evidence-based virtual patient simulations. Her vast background in practice as well as teaching didactic and clinical for undergraduate and graduate advanced practice nursing provides a wide range of clinical and student experiences to build upon. Cheryl has a passion for helping students improve clinical reasoning and diagnostic reasoning while building communication skills. As an expert in curriculum development and design, she advocates for integration of meaningful simulation experiences at all levels of training including for new graduates. Cheryl has a Doctor of Nursing Practice in Adult Geriatric Primary Care, Master's degree in Adult Health, and Bachelor of Science in Nursing. Dual certified as both a Family Nurse Practitioner and an Adult Health Nurse Practitioner, she is also an NLN Certified Nurse Educator and a Certified Healthcare Simulation Educator through the Society for Simulation in Healthcare.

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INTRODUCTION

The demand for nursing professionals in undergraduate nursing education has been gradually increasing, putting a strain on already overburdened training resources in most nursing programs (Cobbett & Snelgrove-Clarke, 2016; Foronda, Godsall, & Trybulski, 2013; Foronda & Bauman, 2014; Laure, Pepin, & Allard, 2015). Impact from the recent SARS CoV2 (COVID-19) pandemic added to the stress of training nurses in traditional settings given the sudden, unplanned need to replace their usual ways of addressing clinicals. Nursing programs have turned to high-fidelity simulations powered by virtual patients to supplement traditional education hours with a scalable, effective approach to meet these difficulties (Leighton et al., 2021). Research conducted by the National Council for State Boards of Nursing (NCSBN) found that replacing high-fidelity simulation experiences for traditional clinical hours was effective and that these learning experiences were similar to typical undergraduate nursing courses (Hayden et al., 2014). Subsequent studies have demonstrated that simulation offers a more concentrated and efficient learning experience than traditional clinical experiences and suggest that one hour of simulated clinical time may account for at least two hours of traditional clinical time (Curl et al., 2016, Haerling & Prion, 2021; Sullivan et al., 2019).

Virtual patient simulations use a screen-based, partially immersive platform to teach students how to effectively collect patient data, document information in electronic health records (EHRs), and synthesize data to determine appropriate nursing actions. Most virtual patient simulations provide the learner -and nurse educator- with formative feedback about their performance, as well as highlight areas for improvement. Given that virtual patient simulations can be content- or situation-specific, they are best suited for teaching concepts in the context of a patient's needs. These simulations have several advantages over other high-fidelity simulation technologies, including ease of access, adaptability, and cost-effectiveness (Duff et al., 2016, Kleinheksel & Ritzhaupt, 2017). Setup and maintenance costs can be very high in simulation laboratories since they often require many high-fidelity manikins as well as specialist staff and personnel. Furthermore, scheduling can be difficult for face-to-face nursing programs with 100 or more students because working groups in simulation laboratories are often made up of no more than eight students (Verkuyl, Romaniuk, Atack, & Mastrilli, 2017). High-fidelity manikins may not be the most effective way to account for hours of clinical training in online or mixed programs.

The use of virtual patient simulations could free faculty from having to go to multiple clinical sites to meet up with students and preceptors since student performance evaluation, and even debriefing can occur asynchronously (Foronta & Bauman, 2014). A strong body of research evidence supports the use of virtual patient simulation as an effective pedagogy to support nursing learning outcomes (Foronda et al., 2020).

BACKGROUND

The use of simulation in healthcare-focused educational settings has seen growing user within the broader simulation community, demonstrating increasing levels of fidelity and sophistication. For example, researchers at Temple University developed the *Oncology Game* for medical students to appreciate the multidisciplinary aspects of oncology patient management and promote teamwork skills with a small-scale study later showing improvements in pre- and posttest evaluations over a 3-week period (Fukuchi, Offutt, Sacks, & Mann, 2000). Game-based simulation has also been successfully applied to reinforce learning clinical reasoning skills and providing practice-based environments for nursing students (Koivisto et al., 2018). Chen and colleagues evaluated the efficacy of game-based simulation on nursing students' empathy towards older patients with evaluations of the simulation demonstrating improvements in empathy skills (Chen et al., 2015). Clinical communication skills for physicians to practice cultural and communication competencies

Nursing students must develop and practice a combination of clinical judgment skills based on structured patient work-up, critical reasoning and communication skills to elicit the most important aspects of patient symptomatology, psychomotor skills to facilitate hands-on examination, and affective skills to help guide these processes (Abdulla & Chen, 2018; Tanner, 2006). Research shows that simulation learning outcomes are at least equal to those attained in traditional clinical settings in pre-licensure nursing programs. Meyer, Connors, Hou, and Gajewski (2011) assessed the clinical performance of 116 undergraduate nursing students who spent their clinical hours in a pediatric simulation rather than in regular clinical hours. Students had 24 hours of simulation and 72 hours of clinical throughout the course of an 8-week semester, resulting in a 25% substitution of simulation for traditional clinical hours.

In a different study, Sullivan et al. (2019) found that skills, physical assessment, teaching, and critical thinking activities occurred more frequently in simulation than in traditional clinical settings, with students independently completing more patient care activities at higher levels of functioning categorized via Miller's Pyramid in a shorter timeframe than in the traditional clinical setting (i.e., data gathering, discussion of care plan, debriefing, performing nursing interventions, and patient teaching activities).

In nursing education, simulation is usually defined as the most accurate possible representation of a care situation and can be categorized relative to its degree of clinical fidelity: high, intermediate, or low (Laure et al., 2015). Virtual patient simulations are high-fidelity simulations because they are "extremely realistic and provide a high level of interactivity and realism for the learner" (Meakim et al., 2013, p.6). Virtual patient simulations have been found to be comparable or superior to other high-fidelity traditional simulation methods due to a variety of reasons. In an integrative review of 12 studies published between 2008 and 2015, Duff, Miller, and Bruce (2016) found that virtual patients and simulated scenarios were comparable or superior to traditional simulation methods for teaching diagnostic reasoning and assessment skills in terms of increased student learning, satisfaction, and engagement.

Duff et al. (2016) concluded that these patient scenarios were more realistic and challenging than manikins or standardized patient actors because they could create virtual scenarios with physical findings (e.g., abnormal heart rhythms or breath sounds) that standardized patient actors could not simulate (Gesundheit et al., 2009; Lin et al., 2012; Pucher et al., 2014; Tan et al., 2013). Other research has found that students are more engaged with virtual patient scenarios and value having a safe environment to practice reasoning skills before seeing real patients in a clinical setting (De Gagne et al., 2013; Gesundheit et al., 2009; Lin et al., 2012; Poulton et al., 2009; Poulton, Conradi, Kavia, Round & Hilton, 2009)

In a systematic review spanning over 20 years of peer-reviewed research, Foronda et al. (2020) found that virtual patient simulation positively impacts various nursing student learning outcomes. Most research (86%) showed that virtual patient simulation was an effective pedagogy to support learning (knowledge), skills/performance, critical thinking, self-confidence, and provide learning satisfaction. Furthermore, learning outcomes from virtual patient simulation were similar to those of manikin-based simulation in several studies, both in the cognitive and psychomotor domains.

Rodriguez et al. (2017) looked at how undergraduate nursing students at NYU Meyers College of Nursing assessed their learning in a clinical teaching approach that substituted 50% of traditional clinical hours with high fidelity simulation in four main medical-surgical courses. Jeffries' educational practices model (Jeffries, 2005) directed simulation sessions in their teaching approach, which focuses on the principles of active learning, cooperation, different ways of learning, and high expectations. NYU Meyers College of Nursing faculty was able to gain greater control over the range of patient scenarios and exposure to specific clinical skills that students practiced thanks to their innovative clinical teaching model, which shifted the focus to key outcomes such as therapeutic communication, care planning, and goal setting, interprofessional collaboration, and reflective practice (Richardson, Goldsamt, Simmons, Gilmartin, & Jeffries, 2014).

As nursing students complete their education and begin their careers as registered nurses, they are thrust into the role of delivering patient care without the support of their nursing program's professors. This adjustment to the realities of nursing practice brings with it a slew of new issues for the novice nurse. Time management and anxiety about their new work were highlighted as the top worries of new graduating nurses in a recent poll (Wong, Valimaki, Zimmerman, Bennett & Calero, 2021). Time management is a multidimensional issue that stems from patient assignments, the stress of prioritizing care, and a general lack of understanding of the workplace. As the responsibility switches from

learning under clinical faculty to the reality of patient care, new nurses struggle to build efficiency in their patient care.

Nurses prioritize duties when they believe they do not have enough time to perform all necessary nursing tasks. Prioritization (Vinckx, Bossuyt, & Dierckx de Casterlé, 2018) is a useful method for making the most of limited time. Nurses, on the other hand, tend to prioritize patients' physical requirements over their psychological needs when they are pressed for time (Jones, 2016). Time pressure limits nurses from identifying patient requirements, according to nurses (Vinckx et al., 2018), and patients of time-pressed nurses receive lower-quality care (Teng, Hsiao, & Chou, 2010).

Virtual Patient Simulation: Digital Clinical Experience Approach

Learners in the Shadow Health® Digital Clinical Experience™ (DCE) perform several healthcare activities in a standardized patient experience. This includes gathering subjective and objective patient information, using therapeutic communication skills, and developing care plans. Completing DCE patient contacts strengthens clinical reasoning skills through conversation-based activities while also honing empathy-building abilities. Learners interact with a diverse pool of virtual patients that present with a wide variety of health conditions, all in a safe, standards-driven environment.

DCE's include learning elements that organize the learning into functional areas including concept labs that serve as focused interactive didactics that precede patient-based interactive scenarios, *interviews* in-game with virtual standardized patients that leverage a natural language conversation engine to allow students to gather subjective data from the patient as well as provide opportunities for therapeutic communication and empathy-building, *focused exams* to allow the learner to conduct a physical examination of the virtual patient, and *patient charts* to provide the necessary patient history to the learner, a virtual EHR to allow the learner to enter the results of patient clinical workup and compare their work to an exemplar model work, and a *student performance index* to provide performance feedback that combines both subjective and objective data summarizing learner results.

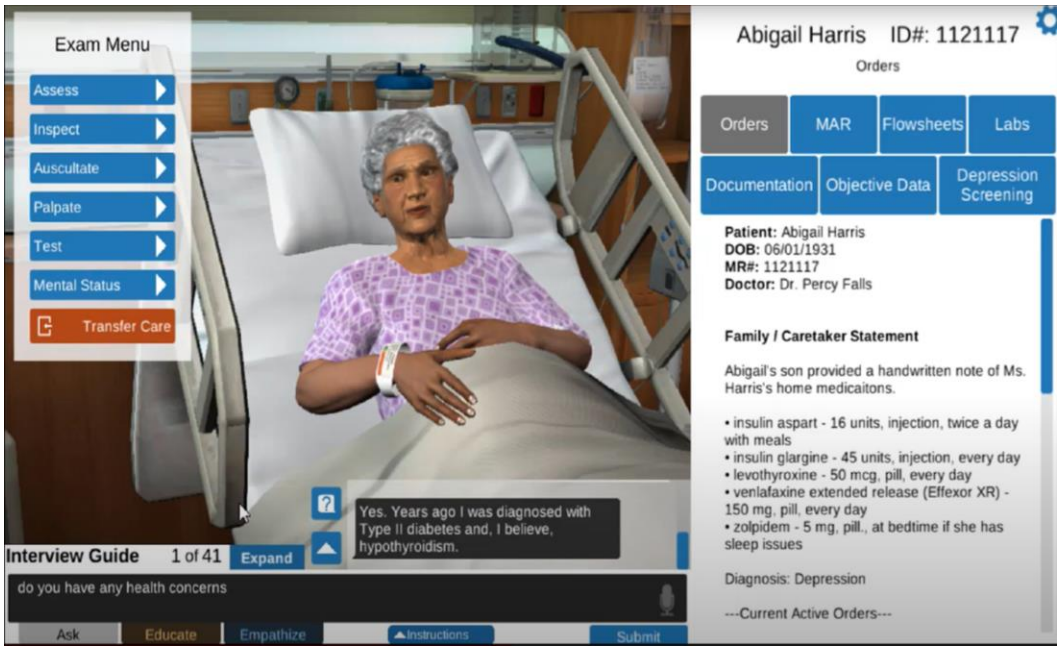

Figure 1. Virtual Patient Simulation - Shadow Health's Digital Clinical Experience (DCE)

The link between nursing communication and efficiency was recognized as an area that needed greater research as appropriate and efficient communication can help nurses manage their time while also improving the quality of their treatment (Bundgaard, Delmar & Soerensen, 2019). The results of one such study is described below, including formative results and conclusions.

Study

Purpose:
In the spring of 2021, the research team at Shadow Health and Elsevier examined whether nursing students became more efficient in collecting patient data, applying therapeutic communication, and creating care plans as they completed Shadow Health's DCEs throughout a Health Assessment course (Wilson et al., 2021).

Sample and Procedure:
The sample included first-semester, pre-licensure nursing students from a public university in the Southwestern United States that integrated the in-simulation pre- and post-test with the Chest Pain: Focused Exam DCE. Learners completed the exact same patient case with one attempt each time, no limit on time to complete, and no access to their results until the conclusion of the course. Four data cleaning rules were implemented to select assignment attempts demonstrating genuine effort, attention, and consistency. Learners had to (1) complete both pre- and post-test assignments, (2) spend at least 10 minutes but no more than four hours on the assignments, (3) ask at least five questions and perform at least one assessment action with the virtual patient, and (4) obtain an overall raw score greater than zero in each assignment. The final sample used for the study consisted of 2,246 students.

Measures:
Efficiency was measured by the number of correct findings per minute spent with the virtual patient across all aspects of learner performance, including subjective and objective patient data collecting, therapeutic communication, and the drafting of care plans. Given that the total number of correct findings for the pre- and post-test assignments was the same, findings per minute could theoretically range between 0 and 137.5.

Analysis:
From the pre-test to the post-test, descriptive statistics were used to address changes in overall efficiency, time spent with the virtual patient, therapeutic communication efficiency, and care plan efficiency. A multiple-regression analysis controlling for pre-test efficiency, time spent on the post-test, post-test assignment performance, number of interview questions asked on the post-test, and number of educational and empathetic statements made on the post-test was also conducted using post-test efficiency as the outcome variable. Assumptions of linearity, homogeneity of regression slopes, and normality of residuals were assessed in the model.

Results

Wilson et al. (2021) study results showed that students demonstrated significant efficiency gains as measured by findings per minute from pre-test to post-test assignments after being utilizing the Shadow Health DCE. Overall efficiency ranged between .14 and 5.71 findings per minute on the pre-test and between .54 and 6.78 findings per minute on the post-test. As shown in Table 1, nearly 82% of students showed an increase in overall efficiency on patient data collection. While assignment scores increased, 62% of learners showed a decrease in patient interaction time and 67% of students showed an increased therapeutic communication score.

There was also an improvement in the quality of students' care plans with 68% of students showing gains in care plan scores. Table 2 shows the results of the multiple regression analysis. After adjusting for differences in pre-test efficiency and post-test in-simulation performance, the number of interview questions asked to the virtual patient during the post-test assignment and the number of empathetic and educational statements made during the patient interaction on the post-test both had a statistically significant positive effect on post-test efficiency. Additionally, spending less time with the patient was associated with higher efficiency on the post-test. High efficiency in the pre-test was associated with high efficiency in the post-test.

Table 1: Study participant scoring averages and change in efficiency from the pre-test to the post-test

Measure	Pre-test average	Post-test average	Percentage change	Percentage of students showing positive change
Overall efficiency (findings per minute)	1.19 (.14 - 5.71)[a]	1.68 (.54 - 6.78)[a]	41%	82%
Time spent (in minutes)	68 min	58 min	15%	62%[b]
Therapeutic Communication	1	2	100%	67%
Care plan score	8	9	13%	68%

Note. [a] range of scores in parenthesis. [b] for time spent with the virtual patient, the positive change represents the percentage of students showing a decrease in time-spent from pre-test to post-test.

Table 2: Multiple regression results using post-test overall efficiency as the criterion

Predictor	*b*	*b* 95% CI [*LL, UL*]	*r*
(Intercept)	1.40**	[1.31, 1.49]	
Pre-test efficiency	.04**	[.01, .06]	.29**
Time spent (post-test)	-.03**	[-.03, -.03]	-.72**
Assignment performance (post-test)	.04	[.03, .04]	21**
Number of interview questions (post-test)	.00	[.00, .00]	.04
Number of empathetic statements (post-test)	.01	[.00, .01]	.03
Number of educational statements (post-test)	.01	[.01, .02]	-.01
Model fit			R^2 = .812** 95% CI [.80, .82]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *r* represents the zero-order correlation. *LL* and *UL* indicate the lower and upper limits of a confidence interval, respectively. * indicates $p < .05$. ** indicates $p < .01$.

CONCLUSIONS

Nursing practice requires prioritizing tasks to make the most of the time available, and new nurses frequently struggle to manage their time appropriately (Wong, et al., 2021). A high-fidelity simulation that includes virtual standardized patients provides learners with the opportunity to practice their efficiency as they gather patient data, apply therapeutic communication, and create care plans. In a sample of first year nursing students discussed in this paper, pre-licensure nursing students completing a Shadow Health Assessment DCE, learners demonstrated significant efficiency gains as measured by findings per minute from the pre-test to the post-test. These results are consistent with other research findings on the efficacy of virtual patient simulation as a useful tool for improving learners' practice readiness (Foronda et al., 2020).

This study had some limitations. First, learner demographics such as age, gender, race and ethnicity, and years of experience were not collected, and therefore the model could not control for the potential effect of such variables on patient care efficiency. Further limitations deal with the sample used. First-semester, pre-licensure nursing students who were enrolled in a health assessment course came from a single public institution in the Southwestern United States, which limits the generalizability of the study findings to other nursing programs from different institution types. Finally, in-simulation pre- and post-test data came from the Chest Pain: Focused Exam DCE, which is one of 13 assignments available in the Shadow Health's Health Assessment DCE. Future studies could examine changes in overall patient care efficiency in other virtual patient case assignments.

Shadow Health's Digital Clinical Experiences give learners a complete patient engagement experience that helps them enhance their abilities to collect patient data, communicate therapeutically, and make treatment plans. Learners become more efficient at performing these necessary skills by practicing them in the DCEs. As students complete the exercises in each course, they have a better understanding of how to gather data and how to dive deeper into their questions to identify crucial data points. Learners' ability to become more efficient in their patient contacts while still providing high-quality care improves when they develop the skill of efficient data gathering in a simulated environment.

NEXT STEPS

Given the efficacy shown in the above findings, we have been exploring potential improvements to our natural language conversation engine to further improve the effectiveness of these simulations and address user feedback. User polling and statistical analysis of user feedback reveals that there is still a further desire for users to be able to communicate with virtual patients in a way that is more reflective of natural speech patterns. Examples of current limitations include pronoun/conference resolution, contextual understanding, detecting statement vs questions, and further developing the range of response inputs per patient. Neural network-based Natural Language Processing (NLP) techniques such as Recurrent Neural Networks (RNNs), Long short-term memory (LSTMs), and more recently, attention-based transformer architectures have allowed for transfer learning to specialized tasks that are both more accurate and less brittle than prior rule-based methods.

While many of the problems encountered are active areas of research in the machine learning community, the large amounts of labeled, or partially labeled, data available to us provides us with a unique opportunity. For example, our recent analysis of potential enhancements to our NLP approach within our DCE platform using the BERT encoder (Mohammed & Ali, 2021) architecture has provided promising results, yielding a 0.95 F1 score for statement vs question classification, which would reduce user input errors by around 9.52%. Our next steps are to A/B test these changes on a single DCE product with users to determine their effectiveness and propagate the changes across our DCE platform. Beyond this, we will continue to monitor and analyze NLP efficacy to determine the most effective areas to improve our technology so that we can better meet the use needs of our nursing students.

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