PILL-VR Simulation Learning Environment for Teaching Medication Administration to Nursing Students

Ilana Dubovi
University of Haifa
iduboui@staff.haifa.ac.il

Sharona T. Levy
University of Haifa
stlevy@edu.haifa.ac.il

Efrat Dagan
University of Haifa
edagan@univ.haifa.ac.il

Abstract

This paper presents an effective way to provide formal and practical learning in higher education of professionals. The Pharmacology Inter-Leaved Learning-Virtual Reality (PILL-VR) simulation was designed to promote situated and connected learning among nursing students by enabling practice and problem-solving in a safe environment. This study is part of the larger PILL learning environment, which connects the VR to more formal learning of related math and science topics. The purpose was to design and evaluate the effectiveness of the PILL-VR simulation as a setting for learning processes of medication administration in a virtual ward. Sophomore-year nursing students (n=88) role-played nurses in a 3D virtual ward in guided activities. We used both qualitative and quantitative design, and pre- and post-test questionnaires, interviews and screen capture of the learning process. The results revealed a significant increase in students' scores following simulation on the Medication Administration Procedure questionnaire. Thematic analysis of the interviews (n=4) showed the greatest improvement in students' knowledge of guidelines-implementation. Usability measures demonstrated a high sense of presence. Results are discussed in terms of ways to support bridging the theory/practice gap in nursing education and more generally, education in professions.

Keywords: Virtual Reality, Simulation, Nursing Education, Higher Education, Pharmacology.

Introduction

This paper presents the Pharmacology InterLeaved Learning Virtual Reality (PILL-VR) environment (Dubovi, Levy & Dagan, 2015) that supports nursing students to learn medication procedures in a safe environment and the first design into learning within this setting. PILL-VR is designed as part of a larger architecture aimed to address the problem of bridging between theory and practice in academic teaching of practical professions. PILL-VR forms an experiential transitional space between the two.

Higher education is assumed to provide graduates professional competencies and a good theoretical understanding for a broad future range of abilities. However, there are concerns regarding a gap between higher education and professional practice, and between the graduates' competencies and the requirements they faced in the 'real world' setting (Burnet & Smith, 2000; de la Harpe & Radloff, 2000). Practitioners of all sorts, including nurses and other medical practices (Hatlevik, 2012; Michau et al., 2009), pilots (Roth, Mavin & Dekker, 2014), engineers (Pascail, 2006) teachers (Boshuizen, Bromme & Gruber, 2006) and athletes (Streveler, 2013), express their experience about the gap between what they learn in university and what they practice at the working place. The theory-practice gap is especially alarming for teaching lifesaving procedures in the academic settings, which require practical procedural knowledge and skills.

Simulations can be used as a strategy to support professional education by integrating the theoretical components into practice. McCaugherty (1991) stated that theory and practice have a complementary role, “Theory without practice is sterile, practice without theory is blind” (p. 1061). Simulations, which represent real-life procedures and experiences, provide the ability to bring the realism of the practical world to students in the academia. Here we demonstrate our experience to teach practices such as nursing medication administration, within the university using VR simulations.

Literature Review

Nursing Education

Since Florence Nightingale, nursing education has changed significantly, from apprentice bedside training to academic education (American Nurses Association, 1965; The Institute of Medicine, 2010). Many positive changes have accompanied this shift: advancement of nursing research, growing recognition of nursing as a distinct academic discipline, and better patient outcomes (i.e., lower mortality, failure-to-rescue rates) (Aiken et al., 2003). However the limited access to practice nursing skills with patients has formed problems with students’ abilities to transfer or in ‘applying’ the appropriate knowledge to hospital wards (Waldner & Olson, 2007).

The theory-practice gap can be illustrated through medication administration process, the focus of the current study. Registered nurses are the primary practitioners responsible for the administration of medication and spending between 20-40% of their time on this task (Westbrook, Duffield, Li & Creswick, 2011). Despite the need for effective preparation of nurses for administration of medications according protocols, the literature identifies issues regarding students’ application of this knowledge into practice (King, 2004; Manias & Bullock, 2002). Even in their junior years, nurses do not feel confident with patient’s administration of medications (Latter, Yerrell, Rycroft-Malone & Shaw, 2000).

Virtual Reality Simulations

Virtual simulations can be a strategy for delivering scenarios that focus on nursing skills both cognitive and manual. VR, a three-dimensional computer environment, is a fully-immersive and interactive experience of an alternate reality in which the participants are avatars who can feel and touch simulated objects, giving the perception that these objects really do exist. The students can interact with the virtual environments in an intuitive and natural way. It allows involving real-world problems, analyzing and communicating with other avatars (Ghanbarzadeh et al., 2014).

Today, VR environments have been used as educational platforms in many areas: art, architecture, business, sociology, urban planning, game design and health care (review: Delp et al., 2007). In health-care, such virtual platforms have demonstrated improvement in medical performance- anesthesia crisis management, cardiac arrest treatment, disaster response, trauma management, and laparoscopic skills (Gaba et al., 2001; Youngblood et al., 2008; Wayne et al., 2008; Zhang, Hünerbein, Schlag & Beller, 2008).

Regardless of the educational opportunities that VR affords in nursing research, it has limited use and lacks of large sample of participants. For example Aebersold et al. (2012) used VR to discuss the implementation of a virtual hospital unit to train safety treatment, difficult interpersonal communications and priorities in decision making process, however with only a sample of 15 students. Likewise, Honey et al. (2012) reported how they taught in a Second Life medium, the management of postpartum hemorrhage, still, in a small unreported number of undergraduate nursing students. Smith and Hamilton (2015) designed a VR simulation to support the procedure of Foley catheterization proficiency, also for small numbers of nursing students (n=20). Jenson and Forsyth (2012) evaluated eight of faculty readiness to use VR simulation of intra venous catheter insertion. Evaluation of nursing student’s decision-making skills in a second life simulation was conducted with five volunteers by McCallum, Ness and

Price (2011). In summary there is a lack of empirical evidence for learning with VR environments due to methodological concerns. Therefore designing and offering undergraduate simulation studies in virtual environment is needed.

PILL-VR Environment for Medication Administration

PILL-VR environment was designed by us, on early 2014 year. The environment was developed with OpenSim, an open source 3D desktop VR multi-platform (http://opensimulator.org/wiki/Main_Page). Participants enter as nurse-avatars into a virtual ward in a hospital setting which designed as a standard medication room with a range of medical equipment ready to be used, a variety of different medication and an animated patient lying on a bed. There are two simulation scenarios (A and B) of basic medication exercises, including, assessing patient's clinical condition, interpret the physician orders and perform the medication administration procedure (Figure 1). Students used a booklet of guided activities, specifically developed to learn independently with PILL-VR at the computer laboratory. The PILL-VR environment enables students to move between two additional spaces: a pharmacological model-based learning space and a mathematical medication learning space (not reported in the current paper).

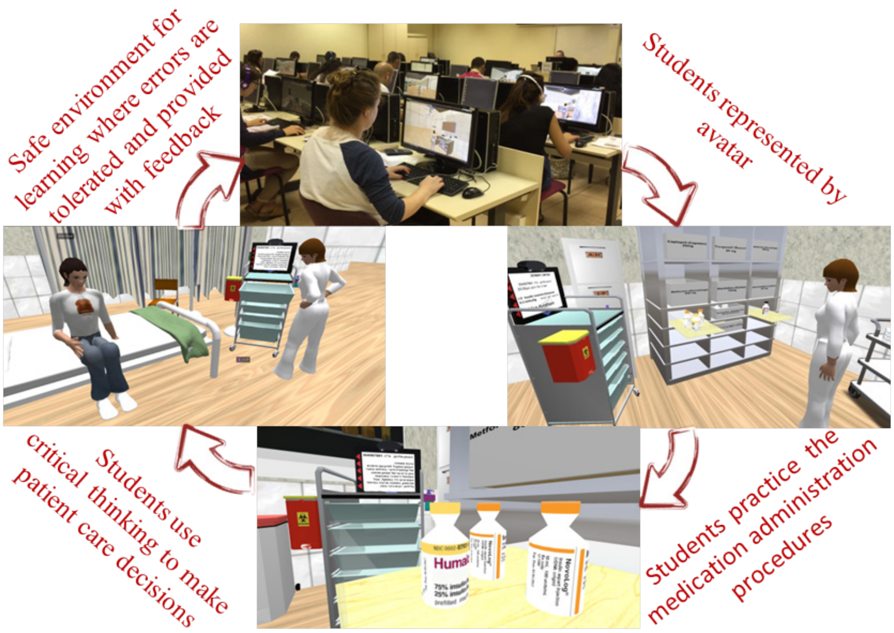


Figure 1. Photographs and screenshots of students following guided inquiry activities which are scripted as scenarios into the PILL-VR environment

Research Aim

The purpose of this research was to evaluate the effectiveness of PILL-VR simulation as a teaching strategy for medication administration among nursing students.

Methods

Research Design, Procedure and Participants

A mixed-method triangulation convergence model was selected for the current study (Creswell & Plano Clark, 2007): qualitative approach and an experimental pre-test-intervention-post-test quantitative method. This research design was chosen based on the practical use of multiple instruments to gather data within the same timeframe and to take advantages of the "differing strengths and non-overlapping weaknesses of quantitative methods (large sample size, trends, generalization) with those of qualitative methods (details, in depth)" (p. 62). In addition, the use of various data collection methods, supporting the validity and reliability of the data and enhances the confidence of the study findings (Glesne, 2006). The current study based on the initial design of the PILL-VR environment that was developed on early 2014 year, by us (Table 1).

Table 1. Research design

Goals	Method and participants (All participants are sophomore year nursing students)	Instruments and procedure	Data Analysis
Assess content learning with PILL-VR environment	Qualitative approach (n=4)	*Semi structured interviews for 30 minutes* was undertaken to better understand students' professional- responsibility, reasoning and critical-thinking skills, and guidelines-implementation. The interviews take place a week before and a week after the learning with PILL-VR	Analysis of semi structured interviews went through repeated open coding to identify cross-cutting patterns, categories and themes. Then themes were analyzed for correctness and for alternative conceptions
	Quantitative approach (n=88)	*Pre- and post-test questionnaire*: Medication Administration Process (MAP) questionnaire	Descriptive statistics and comparative statistics, t-test
Explore patterns in using the PILL-VR environment	Quantitative approach (n=88)	*Pre- and post-test questionnaires*: Presence questionnaire (PQ); *Demographic* questionnaire	Descriptive statistics and comparative statistics, MANOVA test
	Quantitative approach (n=4)	*Screen recording* of students' learning with PILL-VR.	Analysis of time to complete scenario at PILL-VR

Data Collection Instruments

Demographic questionnaire

The questionnaire comprised information about the participant's gender, age, religion and previous work experience in health organizations.

Content Assessing of learning with PILL-VR environment

The semi-structured interview

For better understanding the experience of learning with PILL-VR environment and to refine our simulation model a semi-structured interview was conducted, as regards two different cases that involving nurses during the medication administration process. The scenarios were filmed at a real ward with academic teachers as actors. During the interview the participants were asked to estimate the nurse's behavior which present at the case, to justify their decisions or to explain why they were incorrect. We conducted a thematic analysis of the content (table 1).

MAP questionnaire

Medication Administration Procedure (MAP) questionnaire was developed specifically for this study, in order to assess the conceptual aspects and the practical applications of medication administration guidelines, and students' decision making and critical-thinking skills. For example, see Appendix-A. The items were validated by experienced lecturers in the nursing department, to ensure content-alignment and an appropriate level. It includes 11 multiple-choice questions with a time limit of 10 minutes. A total MAP questionnaire score is calculated by taking the sum of all correct answers

Patterns Exploration in using the PILL-VR environment

Presence questionnaire (PQ)

The PQ was developed by Witmer and Singer (1998), to measure a sense of presence. The instrument addresses three subscales: Involved/Control (11 items), Natural (three items), and Interface Quality (three items). Internal consistency of α=.88 was calculated (Witmer & Singer, 1998). The PQ was translated and validated to Hebrew by Kizony (2006) with high internal consistency α=.89. The overall internal consistency in the current study was- α=.88. We used PQ in order to evaluate the usability of PILL-VR environment.

Video recordings

Screen recordings and interactions during the activities were captured on video, which enable us to measure time-performance. Additional analyses are planned for the future based on this data.

Results

Content Assessing of learning with PILL-VR environment

Semi-structured interviews

The semi-structured pre-test and post-test interviews revealed three categories of knowledge:

(1) *Professional-responsibility*. Before the intervention students had several misconceptions regarding a nurse's role. The following student statement shows a reduction of nurse responsibilities and duties:

> 'The nurse just has to carry out the physician's orders; she doesn't have to decide anything'. Another example of student's statement shows decreasing patients' safety by passing on incomplete tasks to other practitioners:
>
> 'You can have faith in others that work with you at the ward, so it is OK to administer medications that another practitioner has prepared'.

(2) *Reasoning and critical-thinking*. For example, before the intervention, the students did not notice or raise dilemmas regarding the medication practice, while after the intervention, the students were able to identify and to reason about some dilemmas, e.g. which patient treat first.

(3) *Guidelines-implementation*. All students made several errors when using the medication administration VR-scenarios. By making a mistake they were able to realize the importance of guidelines and understood when and how to implement these guidelines. The number of students' utterances that reflected guidelines-implementation shows the greatest change following the VR activity (Figure 2).

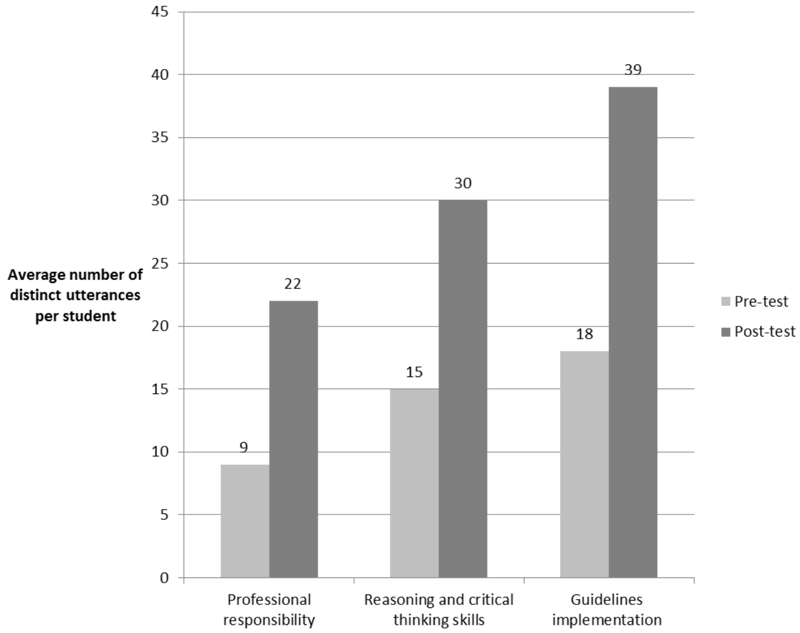


Figure 2. Average number of distinct utterances per student (n=4) regarding each of the three categories of knowledge, in pre-test and post-test interviews

Students' learning gains

The students' MAP score significantly increased from 69.8% to 96.7%, from pre-test to post-test, respectively (Table 2). The procedure sequence component of medication administration shows the most substantial gain (196%).

Table 2. Descriptive and comparative statistics of students' MAP questionnaire pre- and post-intervention (n=88)

MAP questionnaire	Pretest Mean in % (SD)	Posttest Mean in % (SD)	Learning gain[1]	Paired t-test (n=88)
Overall	69.8 (14)	96.7 (5.0)	38%	-17.00***
Procedure sequence	30 (30)	89 (21)	196%	-15.7***
Reasoning and critical-thinking	84 (20)	97(8)	19%	-6***
Identification of right medication, right dose, right time, and the correct route	90 (28)	100 (0)	11%	-2.9 **

[1]Learning gain was computed to compensate for differences in prior knowledge of content knowledge questionnaire: (post-score –pre-score)/(pre-score), the proportion of change with respect to initial understanding

**** p<0.01**, ***** p< 0.001**

Patterns Exploration in using the PILL-VR environment

The amount of time which took for the four students to complete the medication administration process was measured. The results from the repeated time trials shows that less time was taken on scenario B than scenario A (see PILL-VR Environment for Medication Administration section) (Figure 3).

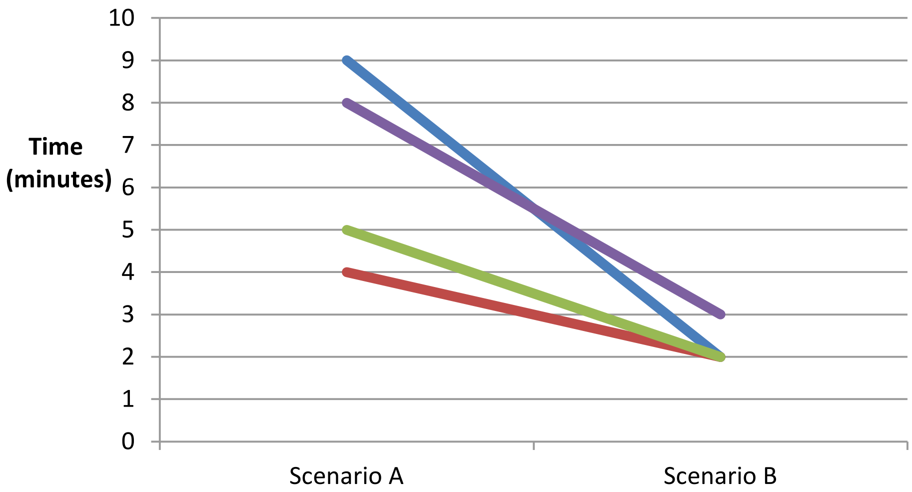


Figure 3. Time measured to complete a correct administration of medication process on scenarios A and B by the four students?

Students with previous health-care experience (see demographic questionnaire) showed the significant higher score on the PQ subscales compared to students with no such experience. The highest difference was emerged within the interface quality subscale.

Table 3. Descriptive statistics and MANOVA results for previous experience / no previous experience at medical area on PQ subscales

	Previous health-care experience (n=19) Mean, SD	No previous health-care experience n=62 Mean, SD	F (1,82)
Control/Involved	0.88±5.4	0.87±4.9	6.66*
Natural	1.13±5.2	1.26±4.4	5.77*
Interface Quality	1.26±5.2	0.82±4.5	9.39**

Wilk's Lambda=.85, MF(3,78)=4.28 p<0.01, * p<0.05 , ** p<0.01

Discussion

This exploratory study provides evidence as to the benefits of using a VR simulation in nursing education and possibly, other disciplines as well. Our designed PILL-VR simulation provides for practice and training opportunities within academic institutions, a crucial step in developing students' expertise. We have found that two of the PQ subscales scores (Natural and Interface scales) were higher than means reported by Witmer and Singer (1998). Additionally, the sense of presence within the PILL-VR environment was higher for students with previous healthcare experience than students with no such experience**.** These differences between groups may reflect the resemblance of the PILL-VR simulation to real hospital settings.

Although most of our sophomore students have already observed other nurses in hospital wards during medication administration process, using the PILL-VR simulation was the first time they were able to perform the process by themselves. These may explain the greatest improvement at MAP questionnaire procedure sequence component and at guidelines implementation category during the interviews.

Further research is required with case-control research design to assess the validity of learning with PILL-VR compare to other learning environments.

The aim of our further studies is to show how to integrate pharmacological model-based and mathematical medication spheres of knowledge to our PILL-VR simulation. Furthermore, to study the role of PILL-VR environment to the evolution process of students from novice to experts and its contribution to narrowing the gap between theory and practice.

References

Aebersold, M., Tschannen, D., Stephens, M., Anderson, P., & Lei, X. (2012). Second Life®: a new strategy in educating nursing students. *Clinical Simulation in Nursing*, *8*(9), e469-e475.

Aiken, L. H., Clarke, S. P., Cheung, R. B., Sloane, D. M., & Silber, J.H. (2003). Educational levels of hospital nurses and surgical patient mortality. *JAMA, 290*(12), 1617-1623.

American Nurses' Association, & American Nurses Association. Committee on Education. (1965). *Educational preparation for nurse practitioners and assistants to nurses: A position paper*. The Association.

Boshuizen, H. P., Bromme, R., & Gruber, H. (Eds.). (2006). *Professional learning: Gaps and transitions on the way from novice to expert* (Vol. 2). Springer Science & Business Media.

Burnet, D., & Smith, K. (2000). Lifelong learning: bridging the gap between higher education and employers' needs: The UK Prospects programme-a case study. *Industry and Higher Education*, *14*(5), 347-350.

Creswell, J. W. & Plano Clark, V. L. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage.

Delp, S. L., Anderson, F. C., Arnold, A. S., Loan, P., Habib, A., John, C. T., ... & Thelen, D. G. (2007). OpenSim: open-source software to create and analyze dynamic simulations of movement. *Biomedical Engineering, IEEE Transactions on*, *54*(11), 1940-1950.

de la Harpe, B., & Radloff, A. (2000). Helping academic staff to integrate professional skills. *Integrating key skills in higher education. London: Kogan Page*, 165-179.

Dubovi, I., T. Levy, S., & Dagan. E. (2015, underdevelopment). PILL-VR: Pharmacology InterLeaved Learning Virtual Reality, simulated 3D hospital ward. Created with Opensim (http://opensimulator.org/wiki/Main_Page), University of Haifa.

Gaba, D. M., Howard, S. K., Fish, K. J., Smith, B. E., & Sowb, Y. A. (2001). Simulation-based training in anesthesia crisis resource management (ACRM): a decade of experience. *Simulation & Gaming*, *32*(2), 175-193.

Ghanbarzadeh, R., Ghapanchi, A. H., Blumenstein, M., & Talaei-Khoei, A. (2014). A decade of research on the use of three-dimensional virtual worlds in health care: a systematic literature review. *Journal of Medical Internet Research*, *16*(2).

Glesne, C. (2006). *Becoming qualitative researchers: an introduction* (3rd ed.). New York: Pearson.

Hatlevik, I. K. R. (2012). The theory-practice relationship: reflective skills and theoretical knowledge as key factors in bridging the gap between theory and practice in initial nursing education. *Journal of Advanced Nursing*, *68*(4), 868-877.

Honey, M., Connor, K., Veltman, M., Bodily, D., & Diener, S. (2012). Teaching with Second Life®: Hemorrhage management as an example of a process for developing simulations for multiuser virtual environments. *Clinical Simulation in Nursing*, *8*(3), e79-e85.

Jenson, C. E., & Forsyth, D. M. (2012). Virtual reality simulation: using three-dimensional technology to teach nursing students. *Computers Informatics Nursing*, *30*(6), 312-318.

King, R. L. (2004). Nurses' perceptions of their pharmacology educational needs. *Journal of Advanced Nursing, 45*(4), 392-400.

Kizony, R. (2006). *Task performance in virtual reality and its feasibility for rehabilitation of individuals following stroke and spinal cord injury*. Dissertation submitted to Hebrew University, Jerusalem, Israel.

Latter, S., Yerrell, P., Rycroft-Malone, J., & Shaw, D. (2000). Nursing, medication education and the new policy agenda: the evidence base. *International journal of nursing studies*, *37*(6), 469-479.

Manias, E., & Bullock, S. (2002). The educational preparation of undergraduate nursing students in pharmacology: clinical nurses' perceptions and experiences of graduate nurses' medication knowledge. *International Journal of Nursing Studies*, *39*(8), 773-784.

McCaugherty, D. (1991). The theory-practice gap in nurse education: its causes and possible solutions. Findings from an action research study. *Journal of Advanced Nursing*, *16*(9), 1055-1061.

McCallum, J., Ness, V., & Price, T. (2011). Exploring nursing students' decision-making skills whilst in a Second Life clinical simulation laboratory. *Nurse Education Today*, *31*(7), 699-704.

Michau, R., Roberts, S., Williams, B., & Boyle, M. (2009). An investigation of theory-practice gap in undergraduate paramedic education. *BMC Medical Education*, *9*(23), 1-7.

Pascail, L. (2006). The emergence of the skills approach in industry and its consequences for the training of engineers. *European Journal of Engineering Education*, *31*(01), 55-61.

Roth, W. M., Mavin, T., & Dekker, S. (2014). The theory-practice gap: epistemology, identity, and education. *Education+ Training*, *56*(6), 521-536.

Smith, P. C., & Hamilton, B. K. (2015). The Effects of Virtual Reality Simulation as a Teaching Strategy for Skills Preparation in Nursing Students. *Clinical Simulation in Nursing*, *1*(11), 52-58.

Streveler, M. J. (2013). *Students 'Perception of a Theory-Practice Gap in Athletic Training Education* (Doctoral dissertation, UNIVERSITY OF MINNESOTA).

The Institute of Medicine (2010). Committee on the Robert Wood Johnson Foundation Initiative on the Future of Nursing. The future of nursing: Leading change, advancing health. National Academies Press. Retrieved from: http://iom.nationalacademies.org/Reports/2010/The-Future-of-Nursing-Leading-Change-Advancing-Health/Recommendations.aspx

Waldner, M. H., & Olson, J. K. (2007). Taking the patient to the classroom: Applying theoretical frameworks to simulation in nursing education. *International Journal of Nursing Education Scholarship*, *4*(1), 1-17.

Wayne, D. B., Didwania, A., Feinglass, J., Fudala, M. J., Barsuk, J. H., & McGaghie, W. C. (2008). Simulation-based education improves quality of care during cardiac arrest team responses at an academic teaching hospital: a case-control study. *Chest Journal*, *133*(1), 56-61.

Westbrook, J. I., Duffield, C., Li, L., & Creswick, N. J. (2011). How much time do nurses have for patients? A longitudinal study quantifying hospital nurses' patterns of task time distribution and interactions with health professionals. *BMC Health Services Research*, *11*(1), 319 – 331.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and virtual environments*, *7*(3), 225-240.

Youngblood, P., Harter, P. M., Srivastava, S., Moffett, S., Heinrichs, W. L., & Dev, P. (2008). Design, development, and evaluation of an online virtual emergency department for training trauma teams. *Simulation in Healthcare*, *3*(3), 146-153.

Zhang, A., Hünerbein, M., Dai, Y., Schlag, P. M., & Beller, S. (2008). Construct validity testing of a laparoscopic surgery simulator (Lap Mentor®). *Surgical endoscopy*, *22*(6), 1440-1444.

Appendix A

Example of two questions from MAP questionnaire:

<u>Example 1</u>

In front of you two pictures of medications which responsible for glycemic control.

Compere between the two and then choose the correct answer:

A. These two medications have the same trade name but different generic name.

B. These two medications have the different trade name and different generic name.

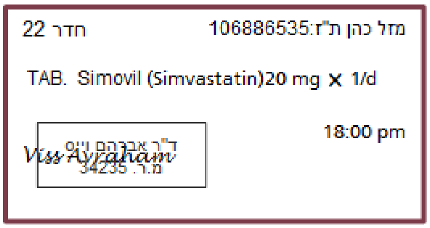
C. These two medications have the same trade name and same generic name.

D. These two medications have the same generic name but different trade name.

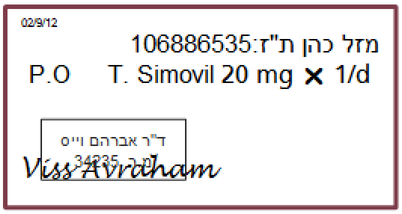
Correct answer: D

<u>Example 2</u>

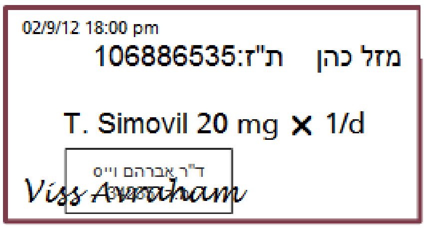
Choose the correct medication order:



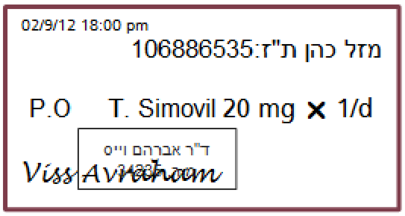
.C



A



D



B

Correct answer: B