INSTRUCTIONAL DESIGN AND ASSESSMENT

Patient Simulation Software to Augment an Advanced Pharmaceutics Course

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Objective. To implement and assess the effectiveness of adding a pharmaceutical care simulation program to an advanced therapeutics course.

Design. PharmaCAL (University of Pittsburgh), a software program that uses a branched-outcome decision making model, was used to create patient simulations to augment lectures given in the course. In each simulation, students were presented with a challenge, given choices, and then provided with consequences specific to their choices.

Assessments. A survey was administered at the end of the course and students indicated the simulations were enjoyable (92%), easy to use (90%), stimulated interest in critically ill patients (82%), and allowed for application of lecture material (91%). A 5-item presimulation and postsimulation test on the anemia simulation was administered to assess learning. Students answered significantly more questions correctly on the postsimulation test than on the presimulation test ($p < 0.001$). Seventy-eight percent of students answered the same 5 questions correctly on the final examination.

Conclusion. Patient simulation software that used a branched-outcome decision model was an effective supplement to class lectures in an advanced pharmaceutics course and was well-received by pharmacy students.

Keywords: virtual patients, active learning, clinical decision making, critical thinking, simulation

INTRODUCTION

Today's scholars are digital natives, and consequently, more acclimated to learning in a technology-enhanced environment.¹ Advances in educational technologies have led to the development of computer-based, instructional tools that promote active learning and allow students to apply knowledge and skills to simulated "real-life" situations" in a protected environment.

These tools offer advantages over traditional teaching delivery methods (eg, lectures).¹ The phrase "anytime-anywhere" reflects the ease of accessibility of these educational technologies, which not only allow students to participate in structured learning at their convenience, but also to investigate and explore independently. These innovative teaching methods allow for repetition that reinforces the knowledge gained. Moreover, practicing in authentic simulated environments may impart a sense of responsibility to a patient's care and stimulate interest or enthusiasm for the subject matter.

Educational technologies allow educators to assess student comprehension of course content in realistic settings,

without risk of harm to patients or students. The capability to manipulate and control the learning environment gives educators the opportunity to standardize learning and assessment. Technology in the classroom also may empower students to be self-directed learners by engaging them in the learning process.

However, educational technologies are not without limitations.^{1,2} Physical interaction between faculty members and students can be diminished. High costs can be overwhelming obstacles to colleges and schools incorporating technology into the curriculum. Faculty time commitments to develop, implement, and maintain educational technologies also can be extensive.³

The Association of American Medical Colleges (AAMC) classifies these numerous educational technologies into 3 broad categories: computer-aided instruction, human patient simulation, and virtual patients.¹ Computer-aided instruction is defined as any computer-based package aimed at providing interactive instruction in a specific subject area. Also known as computer-assisted learning (CAL), computer-aided instruction replaces human instructors to some extent. Human patient simulation makes use of mannequins or models to simulate patient care environments for instructional or assessment purposes. Virtual patient programs simulate actual clinical scenarios and

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allow learners to emulate the roles of health care providers by obtaining patient information and making diagnostic or therapeutic decisions. Unlike other forms of computer-based learning, virtual patient programs allow patient cases to unfold in response to learner input and do not require specialized equipment, like human patient simulation.⁴

In pharmacy education, these technologies offer practical learning applications that align with the Center for the Advancement of Pharmaceutical Education (CAPE) Outcomes⁵ and Accreditation Council for Pharmacy Education (ACPE) Accreditation Standards,⁶ which stress the importance of graduating pharmacy students with competence in providing independent, patient-centered, evidence-based pharmaceutical care. Pharmacy educators are encouraged to incorporate these innovative teaching methods into their curriculums to develop students' critical thinking and problem-solving skills. ACPE has acknowledged that simulation provides a learning experience for students in the early pharmacy curriculum that is comparable to direct patient contact. In June 2010, the ACPE's board approved a policy to allow simulations to account for up to 20% of the introductory pharmacy practice experience (IPPE) time. By the ACPE definition, simulations include experiences that replicate pharmacy practice activities and medication delivery to the patient, using simulated, standardized, and virtual patients.⁷

Issenberg and colleagues reviewed the literature to identify those features of high-fidelity simulation that are thought to lead to effective learning.⁸ The study concluded that simulations facilitate learning under the following conditions: *formative feedback* is provided, *repetitive practice* opportunities are present, simulation-based exercises are *curriculum integrated*, opportunity exists to engage in a *range of difficulty levels*, *multiple learning strategies* are employed, *clinical variation* is captured, practice occurs in a *controlled environment*, *individualized learning* where the student is the active participant is witnessed, *outcomes are clearly defined* for learner achievement, and simula-

tions possess a high degree of *simulator validity* or realism.⁸ These 10 conditions represent the ideal educational circumstances for effective simulation training, and although they rarely can be satisfied fully, should act as goals to reach maximal impact in simulation-based training.

This manuscript details the design and assessment of an educational technology and instructional tool integrated into an advanced therapeutics course within a pharmacy curriculum. The tool complies with CAPE outcomes and ACPE standards and satisfies all 10 of Issenberg's principles.⁸ It merges computer-aided instruction and virtual patient technologies and has the capacity for knowledge acquisition and application, student assessment, and immediate feedback delivery.

DESIGN

Advanced Pharmaceutical Care II is a required 2-credit advanced therapeutics course for third-year doctor of pharmacy (PharmD) students at the University of Pittsburgh School of Pharmacy. The course provides students with an understanding and appreciation of the challenges of delivering pharmaceutical care to critically ill patients and patients with kidney disease. Key ability outcomes for the course can be found in Table 1. Lectures are used to introduce concepts and principles in the course. Students then are expected to apply their knowledge through a variety of activities including problem-based learning (PBL) practicums, discussion boards, multiple-choice examinations, and a capstone case. Prior to the start of the pharmaceutical care course, students have completed basic pharmaceutical science (Anatomy & Physiology, Biochemistry I – II) and therapeutic courses (Infectious Disease I-II, Cardiovascular Disease, Gastroenterology, Endocrinology, Immunology, Pulmonology/Rheumatology).

In 2007, the school incorporated PharmaCAL, a pharmaceutical care simulation program, into the course curriculum. The PharmaCAL program consisted of an assortment of Web-based, virtual patient sessions designed to augment

Table 1. Key Ability Outcomes for the Advanced Pharmaceutical Care II Course

Identify knowledge deficits and formulate directed questions to guide research into ill-defined problems.
Identify, retrieve and evaluate drug information to resolve ill-defined problems.
Create a patient database using information obtained from the medical record and/or direct patient assessment.
Create a prioritized drug-related problem list.
Formulate appropriate patient-specific treatment regimens with goals of therapy and monitoring plans for complex patients with multiple medical conditions.
Evaluate the success of an original plan and modify to achieve patient goals.
Communicate and document effective and concise pharmaceutical care plans.
Defend recommendations using evidence-based reasoning, knowledge of science, clinical skills and other characteristics of critical thinking.

student learning of lecture objectives. An educational award through the university's Provost's Advisory Council on Instructional Excellence covered much of the production costs, ie, faculty time and resources necessary to design and program each simulation.

Pedagogically, the intent of combining PharmaCAL with lectures was to improve students' knowledge acquisition and application of difficult core concepts encountered in the course. PharmaCAL simulation sessions were designed to accompany each lecture and provide students hands-on, realistic, repetitive practice in applying specific learning objectives in a protected environment. APCII is the only course combining these teaching methods in the curriculum.

In PharmaCAL, students assumed the role of healthcare providers, making recommendations in an array of online, simulation sessions based on a branched-outcome decision-making model. This model made PharmaCAL sessions unique compared to other computer-aided instruction and virtual patient technologies. In this branched-outcome model, learners were presented with a *challenge*, given *choices*, and then provided with a *consequence* specific to their choice. The application allowed students to encounter a simulated clinical scenario, choose a recommendation from a list of possibilities, and receive a realistic patient outcome directly related to their recommendation. As a result, success through the simulation session was defined by the student's recommendations in aggregate, since each recommendation option for a given clinical scenario was linked with a distinct "branching" of the session.

Figure 1 is a schematic representation of a "branching" simulation in PharmaCAL, created in Microsoft Visio (Microsoft Corporation, Redmond, WA), a professional diagramming program. The figure illustrates the 4 recommendation options associated with a clinical scenario, along with corresponding consequences. Branching is the hallmark of PharmaCAL simulations because it allows for individualized student experiences. This individualized experience stems from the sequential recommendations made by the student or the student's "learning path" through the simulation, outlined in red in Figure 1. Recommendation options were developed to be as realistic as possible for each scenario in order to enhance simulation fidelity. Clinical scenarios unfold from the student's previous recommendation and the outcome of the patient changes with each decision.

Branching throughout the simulation culminates at an endpoint unique to the student's learning path. These session endpoints reflect both the positive and negative patient outcomes that would have likely resulted from the collective decisions made by the student. Faculty members had the ability to trace individual student learning paths from

Figure 1. Example of branched-outcome decision making model depicting the start of a simulation, corresponding recommendation options, and the "branches" linked to each recommendation.

opening recommendations to session endpoints within a simulation to approximate content comprehension.

Information about PharmaCAL's design, purpose, accessibility, and functionality was presented to students during course orientation. Students were then directed by the syllabus to a secure password protected Web site to access the program. Although students were required to complete all of the simulation sessions, they were not graded on their ability to successfully navigate through the simulations.

To begin the PharmaCAL simulation, students were given a complex patient case designed by faculty members. Students then were asked to begin making recommendations for clinical scenarios arising from the patient case. Recommendation options were presented to the students in a multiple-choice format, with typically 4 options from which to choose. With each recommendation made, the patient "responded" and the clinical condition of the patient changed. The patient response was unique to each recommendation such that every potential recommendation in the simulation led to a different response. Upon reaching the session endpoint, each student received a summary report of their virtual patient's likely status based on the learning path the student had chosen.

In addition to receiving these summary reports, preprogrammed feedback was provided to the student via e-mail addressing the appropriateness of each recommendation (Table 2). This feedback was designed by faculty members to provide a detailed explanation as to the appropriateness of

Table 2. Example of Feedback Provided to Students Following Completion of PharmaCAL Simulation Session^a

Case Scenario: Ginny, a 61-year-old female with CKD, is being seen for a follow-up appointment 1 month after starting darbepoetin.

User Id	Date Time	Question	Student Answer	Faculty Feedback/References
2487	3/1/2007 17:16	A medical student comes along and sees you studying Ginny's chart and asks you what you think is causing her fatigue. You confidently reply that she has anemia, which you can tell because her Hgb and Hct are low. Eager to learn something new, the medical student asks you what the goal hemoglobin value is for Ginny. What answer do you give him?	12 - 16 g/dL, the normal Hgb level for women	The goal Hgb for anemia associated with CKD is to maintain Hgb between 11 and 13 g/dL. Maintaining levels >13 g/dL has been shown to increase the risk of death, MI, CHF, and stroke in CKD patients who are not receiving dialysis. (Singh et al. NEJM 2006; 355:2085-98.)
2487	3/1/2007 17:16	The medical student doesn't think this sounds right and decides to check it out for himself. Sure enough, his gut feeling was right - you are incorrect.	Please continue.	Anemia associated with CKD is usually a normochromic, normocytic anemia.
2487	3/1/2007 17:16	"So," the medical student asks, "what should we do now?"	Check erythropoietin level.	Incorrect. Erythropoietin levels are of little value when monitoring the response to erythropoietin replacement.
2487	3/1/2007 17:17	The medical student is still doubting you, so he goes off to find some guidelines while you delve farther into the chart. He returns, guidelines in hand, and rather smugly states that you are incorrect. He tells you that the guidelines recommend that you check iron stores first.	Please continue.	The iron stores should be assessed within 1 month of starting erythropoietin replacement to ensure that adequate iron is available for RBC production. This is the most common reason for lack of response to erythropoietin replacement.
2487	3/1/2007 17:17	Iron studies were ordered and the following results are reported: Iron 34 mcg/dL; TIBC 200 mcg/dL; Ferritin 14 ng/mL; TSAT 16%. The medical student wants to know what the goal is for iron studies for Ginny?	Serum ferritin 100 - 500 ng/dL; TSAT 20 - 50%	Correct! These are the proper parameters to evaluate for iron status and the correct goal levels for someone who is not receiving dialysis.

Abbreviations: Hgb = hemoglobin; Hct = hematocrit; CKD = chronic kidney disease; MI = myocardial infarction; CHF = congestive heart failure; NEJM = New England Journal of Medicine; RBC = red blood cells; TIBC = total iron binding capacity; TSAT = transferrin saturation.

^a Feedback was sent to students via e-mail so that they were able to see the question and their answer, as well as faculty responses and references from the literature

each recommendation, along with supporting evidence from the literature. Feedback was essential in granting students a degree of closure regarding their decision-making abilities. Without the feedback, students potentially could have misunderstood the connection between their decisions and the treatment outcomes of their virtual patient.

Additional features of PharmaCAL sessions included "I Need Help" links built into every clinical scenario. When students selected this feature, they were given targeted questions or directed to clinical trials, reviews, and/or consensus

guidelines related to the scenario. The help links further enhanced student learning of the subject matter and promoted life-long learning principles by providing the student with insight and references that would be used by a practitioner in the same setting. To further enhance the realistic nature of the simulated scenario, images from actual practice settings were uploaded into each session as well.

To ensure simulation content was aligned with lecture material, learning objectives created for each simulation session (Table 3) mirrored corresponding lecture objectives.

Table 3. Learning Objectives for PharmaCAL Simulations

A. Renal Failure: 3 sessions	
1.	Evaluate anemia associated with chronic kidney disease, then formulate a patient specific regimen for treatment.
2.	Assess calcium and phosphorous levels associated with secondary hyperparathyroidism.
3.	Develop a patient specific regimen to control hyperphosphatemia.
4.	Evaluate hyperparathyroidism, then formulate a patient specific regimen for treatment.
5.	Weigh the pros and cons of different renal replacement therapies for a specific patient.
6.	Formulate a patient specific plan to manage the complications of dialysis.
7.	Determine the dose adjustments of medications for renal dysfunction given a patient case.
8.	Identify preventative measures for acute renal failure
B. The Surgical Patient: 3 sessions	
1.	Assess the bleeding risk of specific home medications for a pre-operative patient.
2.	Develop a patient specific antibiotic prophylaxis plan prior to surgery.
3.	Assess the appropriateness of specific agents used to prevent perioperative cardiac complications given a patient case.
4.	Evaluate risk factors for venous thromboembolism (VTE) given a patient case, then formulate a patient specific VTE prophylaxis regimen along with monitoring parameters.
5.	Determine an appropriate post-splenectomy vaccination regimen.
6.	Evaluate risk factors for post-operative nausea and vomiting (PONV) given a patient case, then formulate a patient specific PONV prophylactic regimen along with monitoring parameters.
7.	Evaluate a patient's risk factors for stress related mucosal damage, then formulate a patient specific prophylactic regimen.
8.	Weigh the pros and cons of available agents used in the management of alcohol withdrawal, then formulate a patient specific regimen.
9.	Propose a treatment strategy for traumatic brain injury (TBI) seizure prophylaxis
10.	Identify objective indices of pain, then develop a treatment strategy for pain in an ICU patient along with monitoring parameters
C. Septic Shock: 3 sessions	
1.	Prioritize fluid resuscitation and appropriate vasopressor use using an "Early Goal Directed Therapy Model" for septic shock.
2.	Explain mechanism of action for select vasopressor agents, as well as mechanisms for adverse events.
3.	Develop a patient specific empiric antibiotic regimen, then reassess regimen to fit pathogen susceptibilities
4.	Evaluate risk factors for critical illness related corticosteroid insufficiency (CIRCI) given a patient case, then formulate a patient specific treatment regimen.
5.	Grade the severity of hyperglycemia in an ICU patient with septic shock, then formulate a treatment strategy along with monitoring parameters
6.	Evaluate drotrecogin alpha usage (via APACHEII scores) given a patient case

Developing simulations around predefined learning objectives exposed all students to equivalent experiences within a simulation session, despite the learning path the student chose to follow. For example, in a particular simulation, all students encountered scenarios dealing with hyperglycemia in an intensive care unit, fluid resuscitation in septic shock, and surgical site infection prophylaxis, but each student could choose to manage each scenario differently. Therefore, individual management decisions regarding the simulation's learning objectives created individual learning paths and experiences. Although developing simulations from predefined learning objectives reduced simulation fidelity to some extent, it was a necessary strategy when using the simulation as a supplemental teaching tool.

PharmaCAL granted students independent, repetitive practice at the design, implementation, monitoring, and evaluation of patient-specific recommendations in a realistic but controlled environment. The goal of this innovation was to enhance the students' ability to learn and apply learning objectives from lectures given in an advanced therapeutics course. At the completion of the PharmaCAL simulations, students were expected to have enhanced critical thinking and analytical skills as they retrieved, comprehended, interpreted, applied, analyzed, and evaluated information to solve patient problems. Through clinical scenarios based on specific learning objectives, simulations were expected to strengthen the development of requisite knowledge and skills necessary to successfully complete the course. Given that each recommendation

Table 4. Pharmacy Students' Opinions Regarding Computer Learning Prior to Participating in a PharmCAL Simulation (N = 190)

Question	Student Responses, No. (%)			
I feel apprehensive at the thought of using computers for learning.	Strongly disagree, 81 (42.6)	Disagree, 87 (45.8)	Agree, 14 (7.4)	Strongly agree, 8 (4.2)
How would you rate your past experience with computer assisted learning?	None, 32 (16.8)	Minimal, 90 (47.4)	Moderate, 60 (31.6)	Extensive, 8 (4.2)
Which of the following would best describe your ideal method of learning?	Read on my own, 25 (13.1)	Lecture, 52 (27.4)	Small Group Discussion, 94 (49.5)	Computerized Tutorial, 19 (10)

the student made was associated with specific patient outcomes, simulations were expected to bolster the student's sense of professional responsibility to a patient's care. Finally, students were expected to gain skills as a life-long learner by recognizing knowledge and skill deficits, formulating learning strategies, interpreting credible resources, implementing patient care plans, and assessing patient progress.

A protocol was submitted to the investigational review board (IRB) regarding research into PharmaCAL simulations. The protocol was determined to be exempt from review but required investigators to obtain student consent prior to initiation.

EVALUATION AND ASSESSMENT

Students' satisfaction with the technology as a teaching tool was assessed through surveys, while evidence of student learning was assessed through pre- and post-simulation tests. At no point did students' willingness to participate or survey or test results affect their overall grade in this course. Students were mandated to complete all simulations for the course, however, could withdraw from the research (surveys, pre-tests, post-tests) at any time.

Over academic years 2007 and 2008, 190 third-year pharmacy students who enrolled in the Advanced Pharmaceutical Care II course participated in the evaluation of PharmaCAL. All students completed the 3-question pre-simulation satisfaction survey instrument, and 188 of 190 (98%) students completed the postsimulation survey instrument. Tables 4 and 5 summarize students' responses.

Although 64% of students had little or no experience with CAL formats, 88% had no apprehension over using this type of learning method. Most students enjoyed PharmaCAL (92%) and considered it easy to use (90%), believed it stimulated interest in critically ill patients (82%), allowed for application of material learned through course lectures (91%), was an acceptable teaching tool (92%), and should be further incorporated into the pharmacy curriculum (86%). Eighty-two percent of the students confirmed that the feedback delivered upon completion of each simulation was a useful learning tool in this course. Student time commitment was minimal, with 87% of students investing less than 3 hours on the first 3 PharmaCAL simulations. Forty percent of students were either neutral or in agreement with the statement "PharmaCAL requires considerable improvement in order to be usable in the future."

Table 5. Pharmacy Students' Opinions Regarding PharmCAL After Participating in a Patient Simulation, N=188

Question	Student Responses, No. (%)				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
PharmaCAL was easy to use	2 (1.1)	1 (0.5)	16 (8.5)	83 (44.2)	86 (45.7)
PharmaCAL allowed me to apply the knowledge that I have learned in APCII	2 (1.1)	3 (1.6)	12 (6.4)	103 (54.8)	68 (36.1)
PharmaCAL stimulated my interest in critical ill patients	2 (1.1)	3 (1.6)	29 (15.4)	99 (52.7)	55 (29.2)
The degree of difficulty of questions encountered in PharmaCAL was greater than I expected	3 (1.6)	39 (20.7)	91 (48.4)	55 (29.3)	0
Simulation should be further incorporated into the pharmacy curriculum	3 (1.6)	6 (3.2)	17 (9.0)	63 (33.5)	99 (52.7)
The feedback generated with each PharmaCAL simulation was a useful learning tool	1 (0.5)	8 (4.3)	25 (13.3)	83 (44.1)	71 (37.8)
PharmaCAL requires considerable improvement in order to be usable in the future	25 (13.3)	87 (46.3)	44 (23.4)	28 (14.9)	4 (2.1)
PharmaCAL is an acceptable teaching tool for this course	2 (1.1)	2 (1.1)	11 (5.9)	69 (36.6)	104 (55.3)
I have enjoyed PharmaCAL	1 (0.6)	2 (1.1)	12 (6.4)	86 (45.7)	87 (46.2)

Evidence of student learning was evaluated by comparing their performance on a pretest and posttest regarding the anemia simulation in PharmaCAL (Table 6). Students were required to complete the anemia simulation before the accompanying lecture to make certain knowledge was gained only from the simulation. The pretest was built into the PharmaCAL program such that students completed the pretest before they were given access to the simulation. Thus, the pretest was a true assessment of the student's baseline knowledge without prior instruction. The pretest consisted of 5 questions that aligned with learning objectives for the case, which covered the basic principles of anemia management. Students did not receive feedback for the pretest questions and did not know whether their answers were correct prior to the simulation. At the completion of the simulation, the same questions were administered to students in a posttest given in class prior to the lecture on anemia. The same 5 questions were repeated on the final examination following the lecture.

One hundred forty-two students completed both the pretest and posttest. Of these, 116 (82%) improved by at least 1 question from the pretest to the posttest, while 103 (73%) students improved by 2 or more questions on the posttest. One hundred eleven (78%) students answered all 5 questions correctly on the final examination. Twenty-nine of the remaining 31 students answered 4 of the 5 questions correctly.

Statistical analysis using a McNemar test was conducted to compare the number of questions students answered correctly on the presimulation test to the number answered correctly on the postsimulation test and the examination (Table 6). Significantly more questions were answered correctly on the postsimulation test than on the presimulation test ($p < 0.001$). In addition, significantly more questions were answered correctly on the examination than on the presimulation and postsimulation tests ($p < 0.001$).

DISCUSSION

PharmaCAL is, at its core, another step in the continual evolution of case-based learning, giving students the opportunity to apply their knowledge through clinical decision making in a simulated environment. The goal of instituting this virtual patient program at the University of Pittsburgh School of Pharmacy was to augment student learning of course learning objectives through high-fidelity, branched-outcome decision-making virtual patient simulations. PharmaCAL accomplished this goal and demonstrated its effectiveness as a learning tool with more than 80% of students demonstrating improvements in knowledge after completing the simulation prior to the lecture. Improvements also were observed in critical thinking and analytical skills, as well as in the development of requisite knowledge and skills necessary in practice. This was evidenced by the majority of students improving on the posttest by 2 or more questions, and in the significant proportion of students answering correctly on the postsimulation test compared to the presimulation test.

Additional objectives of incorporating PharmaCAL were to bolster students' sense of professional responsibility to a patient's care and highlight the importance of lifelong learning. Evidence of meeting these objectives can be found in the students' survey responses where a majority indicated that PharmaCAL stimulated their interest in critical ill patients and advocated further incorporation of PharmaCAL into the pharmacy curriculum.

In addition to meeting predefined goals and objectives, PharmaCAL was successful in its adherence to published principles of effective learning through high-fidelity simulation.⁸ The program was integrated into the curriculum, incorporated formative feedback, and allowed for individualized learning in a controlled, but realistic environment. Moreover, PharmaCAL simulations offer repetition, with

Table 6. Student Responses to Pretest, Posttest, and Examination Questions

Question	Percentage Who Answered the Question Correctly			Difference in Percentages of Students Who Answered the Question Correctly, p		
	Pre	Post	Exam	Pre vs. Post	Pre vs. Exam	Post vs. Exam
What is the best laboratory parameter to use to assess anemia? (n=139)	61.9	82.0	95.0	<0.001	<0.001	0.001
What is the cause of anemia associated with CKD? (n=142)	33.8	41.5	86.6	0.09	<0.001	<0.001
What is the goal Hgb level for anemia associated with CKD? (n=142)	26.1	74.6	97.2	<0.001	<0.001	<0.001
What is the goal for iron studies? (n=140)	30.0	59.3	97.9	<0.001	<0.001	<0.001
When should you recheck the Hgb after starting erythropoietin replacement? (n=142)	55.6	85.2	100	<0.001	<0.001	<0.001

Abbreviations: Pre = Presimulation; Post = Postsimulation; Exam = Examination; CKD = chronic kidney disease; Hgb = hemoglobin.

active-learning opportunities for students in a variety of clinical settings. Finally, simulations varied in their degree of difficulty and teaching approaches.

Despite its advantages, PharmaCAL is not without limitations. One obstacle for faculty members was the extensive time commitment necessary to design and program each simulation. Initial faculty time commitment in courses employing virtual patients can be considerably more than in courses that do not. We estimated the time for developing the initial simulation sessions within PharmaCAL was approximately 50 hours, including simulation creation, mapping in Microsoft Visio, and software programming. The majority of the time was spent on the latter step, programming content into PharmaCAL. As the comfort level with the program increased, preparation time decreased dramatically, but still remained substantial at approximately 25 hours per session.

Another limitation involved the high production costs and technical support associated with attaining and maintaining the software. Initial construction costs associated with the design and programming of PharmaCAL, along with obtaining electronic graphics, were substantial. The educational grant described above provided funds to cover development costs.

However, the greatest challenge was securing an experienced computer programmer to maintain the software. A loss in technological support during the program's first year greatly inhibited our ability to maintain the system and create new simulations. Shortcomings within the program resulted and are reflected in students' survey comments that the program required considerable improvement to be usable in the future. This was likely due to a recurring transmission error that made feedback difficult for students to follow. The error caused feedback for question 1 to be delivered as feedback for question 2. This glitch was corrected in 2008, but never completely fixed. However, even with this minor fix, the proportion of the 2008 class that stated the program required considerable improvements decreased (27% vs 7%; for 2007 and 2008 classes, respectively).

Another programming criticism common among students was that once a simulation session began, it was not possible to go back and view the patient case associated with the simulation. This issue could not be corrected and students were encouraged to print the patient case prior to session commencement.

In a search for new sources of technological support for the simulations, a collaboration with faculty members from the University of Pittsburgh School of Medicine was developed. School of Medicine faculty members had created a commercial platform for virtual patients (VPSim - Decision Simulation). From a programming and design perspective, VPSim is more sophisticated than PharmaCAL. It allows

faculty members to map cases directly into the simulator, which automatically updates the session and eliminates the need for separate programming software like Microsoft Visio. Mapping within the simulator allows for faster session construction times, as well as more convenient simulation editing. The collaboration has allowed for the incorporation of some of the best features of PharmaCAL, which has resulted in a more advanced platform for virtual patient simulations. (vpSim has recently been commercially licensed. For more information, visit <http://vpsim.pitt.edu/>.)

Technology in the classroom continues to advance, offering students and faculty members innovative educational opportunities. Virtual patient simulations represent one such advancement in educational technology. Even though the use of simulation in higher education remains in the "innovators and early adopters" stage, its use likely will increase over time.⁹ This will especially hold true if education accreditation organizations continue to grant simulations "curricular parity" with real-life clinical experiences.¹⁰

SUMMARY

The addition of PharmaCAL, a branched-outcome decision making, virtual patient simulation software program to an advanced pharmaceuticals course at the University of Pittsburgh School of pharmacy has allowed students to apply course learning objectives and hone clinical decision-making skills in a realistic but protected clinical environment. Features of the instructional tool include "anytime-anywhere" learning, individualized learning experiences, and formative feedback. In addition, simulation repetition allows students to strengthen their knowledge and skills.

The simulations were overwhelmingly supported by students and proved to be effective teaching tools when used to supplement more traditional instructional formats (ie, lecture). Based on these positive findings, strategies to further incorporate these simulations into the curriculum are being supported.

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