Comparing Effectiveness of 3 Learning Strategies
Simulation-Based Learning, Problem-Based Learning, and Standardized Patients

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Introduction: Curricula must not only provide students with knowledge but also foster the development of critical thinking and reasoning skills. Several learning strategies, including problem-based learning (PBL), standardized patients, and high-fidelity human simulation, have been incorporated into courses; however, it is currently unknown which technique is the most effective.

Methods: This is a prospective, randomized, crossover study that was conducted during two 90-minute seizure disorder laboratory sessions for PharmD students in their third professional year. Students rotated between 3 different seizure disorder cases (A, B, and C), with each student experiencing 3 learning strategies including PBL, standardized patients, and high-fidelity human simulation. Evaluation of knowledge consisted of quizzes at the end of each case, and student perception and satisfaction were evaluated by an anonymous survey at the conclusion of the laboratory sessions.

Results: Student quiz scores from the simulation learning strategy were statistically better than those from the standardized interview and modified PBL (mPBL) strategies in cases A and B (P < 0.001). The student quiz scores for the standardized interview were also statistically better than the mPBL scores in case C (P = 0.001). When surveyed, 91% of students agreed or strongly agreed that simulation improved their knowledge, whereas only 69% and 67% of students agreed or strongly agreed that mPBL or standardized patients, respectively, improved their knowledge (P < 0.001).

Conclusions: High-fidelity simulation is an effective learning strategy. When it is compared with standardized patients and mPBL strategies, students performed better on knowledge-based quizzes and had higher levels of satisfaction.

Key Words: Problem-based learning, Simulation-based learning, Standardized patients.

Curricula must not only provide students with background knowledge, but it must also foster the development of clinical and critical thinking skills that are necessary to provide optimal patient care. Several learning strategies, including problem-based learning (PBL), standardized patients, and human patient simulation have been used in curricula.1–4 Accrediting bodies recommend the use of educational technologies and techniques that use different modes of education and evaluation.5 To our knowledge, few trials have been conducted that compare the different learning strategies.6,7 One study uses 2 different learning strategies, simulation and standardized patients, but does not compare the effectiveness of the 2 methods.8 Currently, there have been no studies that have evaluated the 3 different learning modalities. The purpose of this prospective study was to compare the effectiveness and acceptability of 3 different learning strategies: PBL, standardized patient scenarios, and high-fidelity human patient simulation in a seizure laboratory session. This was accomplished by assessing the knowledge and perceptions of students in a professional program.

METHODS

This prospective, randomized study received approval through the University of Pittsburgh institutional review board. This study was conducted during a 3-hour laboratory session that focused on the management of seizure disorders as part of a neurology/psychiatry doctor of pharmacy course (Pharm 5319). This coursework is a requirement in the third professional year of the doctor of pharmacy curriculum at the University of Pittsburgh. The average age of the students enrolled in the Pharm 5319 neurology/psychiatry course was 24 years. Thirty-eight percent of the students were males, and 5% of the class were self-identified as minority students. Before the laboratory session, the students received 4 hours of lecture that included topics of diagnosis, management, and pharmacotherapy for seizure disorders including status epilepticus and refractory status epilepticus. The lectures provided consistent background knowledge for all of the participants in the seizure disorder...
laboratory session that followed. Students were included in the study if they were enrolled in the neurology/psychiatry course and completed the seizure laboratory session. Students were excluded from the study if they did not attend the seizure laboratory session.

The seizure disorder laboratory session consisted of 3 different seizure disorder cases (A, B, and C) that focused on concepts of pharmacotherapy, medication administration, adverse drug events, and monitoring. Before the laboratory session, the 3 cases were evaluated for content validity by 3 independent clinicians not associated with this evaluation. On review, the cases were considered to be equivalent in difficulty and relevance to the lecture material by each of the 3 independent clinicians. Each case, containing the same content, was presented by 3 different learning strategies, which were a modified PBL (mPBL) format, a standardized individual scenario, and a high-fidelity simulation scenario. The study was a crossover design of the 3 learning methods, with every student receiving each learning method during the laboratory session.

Each case was designed with the same learning objectives that were as follows: (1) to identify the major problem occurring with the patient, (2) to develop a pharmacotherapy plan including the correct medication, dose, and route of administration, (3) to explain how to correctly administer the medication chosen for therapy, and (4) to list the necessary monitoring parameters and common adverse effects associated with the medication that is being administered. Although each case addressed the same learning objectives, the problem list, medication to be administered, route, and/or the monitoring parameters were different between the cases. Each case involved different medications and/or patient problems to create independent learning experiences and limit potential recall bias. In case A, the patient develops status epilepticus that is refractory to benzodiazepines. This case necessitates the student to develop a treatment plan using intravenous (IV) phenytoin, administering it at the correct rate, and monitoring for adverse effects of the medication. Case B presents a patient with a medical history of epilepsy. The patient is taking phenytoin on a daily basis but begins to seize because of a subtherapeutic phenytoin level. In this case, the students must identify that the phenytoin level is subtherapeutic because of a new drug interaction. The students must develop a treatment plan to reload the patient with oral phenytoin, due to the inability to achieve IV access in this patient, and monitor for adverse effects. Case C focuses on a child who has an episode of status epilepticus and does not have IV or oral access for medication. The students must identify a medication with an alternative route of administration, describe how to administer the medication, and describe what monitoring parameters and adverse effects should be considered.

Students were randomly assigned to 6 groups consisting of 16 to 18 students. The 3-hour laboratory session was divided into two 90-minute sessions (sessions 1 and 2), to allow for reasonable group sizes. Session 1 included groups 1 to 3, and groups 4 to 6 participated in the second session. The student groups were separated into 3 different rooms with a faculty member in each room who was responsible for facilitating the case. Each faculty member conducted cases with 1 of the 3 teaching strategies. One faculty member presented each of the 3 cases as an mPBL scenario, another conducted each of the 3 cases as a standardized individual, and the third faculty member conducted the 3 cases with a high-fidelity simulation session. The 3 learning methods included in the laboratory session are used regularly in the PharmD curriculum. The faculty members were selected based on their previous experience with the learning method that they used during the laboratory. Faculty experience included training on the theory and implementation techniques of their particular learning method and vast utilization in the classroom for their respective courses.

After the students completed case A, they rotated to a different room where they then completed case B with a different teaching modality. After the completion of case B, the students again rotated to the third room and completed case C with the final teaching modality. At the end of each case, students completed a quiz based on the answers that they formulated during the case. All students received the cases in the same order; however, the mode of instruction differed. For example, group 1 received case A as a standardized patient case, case B as the mPBL, and case C as the high-fidelity simulation, whereas the second group received case A as the mPBL, case B as the high-fidelity simulator, and case C as the standardized patient. The same design and rotation between teaching modalities occurred during the second 90-minute session. Figure 1 displays the rotation of students between cases and the teaching modalities.

For the PBL strategy, the primary learning activity is problem solving, and the student is an active rather than a passive participant. In a classic PBL, students do not receive a didactic session before the PBL session. In our study, we modified this approach by proceeding all sessions, including the PBL with a didactic lecture, therefore making this an mPBL. The primary focus of the mPBL session remained problem solving skills and involved active student participation. For the mPBL scenario, students were provided with the case and were asked to formulate a pharmaceutical plan that included medication administration instructions and monitoring parameters for the patient in the case. These specific leading questions were meant to aid the students in narrowing their focus to meet the learning objectives for the case. They then worked in small groups to develop a problem list and questions to research. The standardized individual scenario was presented by a faculty member acting as another health care provider. Because of the 3 cases involving a patient actively seizing, the faculty member could not act as the patient. Therefore, that faculty member portrayed a health care provider who was able to answer the students’ questions. The students asked questions and interviewed the role-playing health care professional to obtain the needed information. They could ask questions to clarify concepts and assess effectiveness of treatment. The faculty member followed a script throughout the laboratory, so that the students received standardized information and responses. The high-fidelity simulation was conducted with a mannequin that was controlled with SimMan 3G (Laerdal Corporation, Stavanger, Norway) computer program. The human
patient simulators have a palpable pulse; audible heart, lung, and abdominal sounds; and hemodynamic parameters. The simulators are controlled by SimMan software (Laerdal) that can be programmed with physiologic response to different clinical scenarios, including the administration of medications. During this laboratory session, the mannequin was programmed to have visible tonic-clonic seizures, palpable pulses, visible hemodynamics based on the scenario, and physiologic responses to medications that were recommended by the students. Students asked the faculty facilitator questions to obtain the needed information to develop a treatment plan and were able to interact with the simulator to watch the effects of their treatment plan. With all 3 learning strategies, debriefing did not follow the session.

The evaluation of knowledge consisted of quizzes at the end of each case for every student before circulating to the next case. The quiz questions were evaluated before the study by 3 independent reviewers for content validity. The quiz consisted of 3 questions: (1) What is your pharmaceutical plan for this patient’s primary problem? Include drug name, dose, and route of administration. (2) How do you properly administer the drug? (3) What are your monitoring parameters for this medication, including possible adverse effects for the drug that you selected?

On completion and collection of the quiz, students were escorted by a facilitator between rooms to the next case. This was to ensure that no discussion between classmates occurred. On completion of the 3 cases, the students were

Figure 1. Schematic of study design.

Figure 2. Percentage of agree plus strongly agree student responses from survey questions.
then asked to complete an anonymous survey. The survey consisted of 16 questions that assessed the student’s opinions and attitudes to the different teaching modalities that they experienced throughout the laboratory session. Responses were based on a Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree).

The quizzes completed at the conclusion of each case were graded based on a previously established answer rubric. There was only 1 individual grading the quizzes; therefore, interrater reliability was not an issue. The grader was blinded to the assignment of the students and to the different teaching modalities. On completion of the grading of the quizzes, student grades were entered into an Excel (Microsoft Office Professional Edition 2003) spreadsheet with identifying information removed.

Data Analysis

The data were analyzed for differences in learning modalities for each case to meet the primary goal of the study. The mean quiz scores of each learning strategy were calculated within each case (A, B, and C). The mean quiz scores were then compared using analysis of variance (ANOVA). A post hoc test for multiple comparisons, the Bonferroni test, was used to determine the differences between the learning modalities by setting $\alpha$ at a 0.005 level. According to a power calculation performed, a sample of 103 subjects could detect a medium effect size (0.40) significant for a 1-way ANOVA with 3 groups when $\alpha = 0.005$ and power = 0.80. The differences between cases were not an outcome of interest and therefore were not analyzed. Students were randomly assigned to groups before initiation of the study; therefore, groups were assumed to be evenly distributed according to grade, race, and sex and comparable at baseline. Although demographics are provided for the class, an analysis of covariance was not conducted because student data were deidentified and not collected on an individual basis.

The survey contained 5 questions pertaining to each teaching modality ranked on a Likert scale from 1 to 5 (1 = strongly disagree and 5 = strongly agree). The results of the survey were analyzed by first calculating the mean score for each of the 5 survey questions for each learning modality. The survey questions are displayed in Figure 2. For each learning modality, the percentage of agree responses plus the percentage of strongly agree responses were compared for each question using a McNemar test to determine the relative difference in overall percentages. Statistical significance was set at an $\alpha = 0.05$ level. All statistical analyses were performed using SPSS version 16.0 (SPSS, Inc, Chicago, IL).

RESULTS

There were 104 students registered in the Pharm 5319 neurology/psychiatry course, and a convenience sample of the 103 students, who completed the laboratory session, was enrolled in the study.

When evaluating the mean quiz scores for the learning strategies within each case, the results indicate statistically significant differences. The student scores from the simulation learning strategy were statistically better than the
student scores from the standardized interview and mPBL modality in cases A and B ($P < 0.001$). In case C, the student quiz scores for the simulation learning strategy were not higher than the quiz scores of the students who had the standardized interview modality. However, they were statistically higher than the quiz scores for the students who had the mPBL strategy ($P = 0.001$). The student quiz scores for the standardized interview were also statistically better than the mPBL strategy scores in case C ($P = 0.001$). These results are displayed in Table 1.

Of the 103 students who participated, 101 completed the voluntary, anonymous survey. On comparison of the mean scores of the survey question responses, based on the different learning strategies, more students agreed or strongly agreed to the first 4 statements concerning the simulation learning strategy compared with the standardized scenario and mPBL strategies ($P < 0.001$). There was no difference observed between the standardized scenario and mPBL strategies in the first 4 questions on the survey. On review of the mean scores of the agree or strongly agree responses, the fifth question of the survey, “Anxiety affected my ability to solve the scenario presented” showed no statistically significant difference between the simulated learning strategy and the standardized patient ($P = 0.481$) and between the standardized patient and mPBL ($P = 0.332$). There was a statistically significant difference of the mean scores of the agree or strongly agree responses between the simulation-based learning (SBL) and mPBL strategies ($P = 0.003$). These results for high agreement are displayed in Figure 2.

**DISCUSSION**

Educators strive to identify the best methods of teaching and learning to prepare their students to be successful clinical practitioners. Our study demonstrates that student knowledge and perception of learning may be better with SBL compared with mPBL and standardized cases. Simulation-based education has been shown to improve knowledge in both the academic and clinical setting. In a previous study, simulation-based education has demonstrated superiority to mPBL in regard to student knowledge.6 This was thought to be due to the active learning elements associated with simulation-based education. It is also believed that the incorporation of psychomotor activity in combination with cognitive elements improves student performance.6 Other studies in the academic setting have demonstrated significant improvement in clinical skills and knowledge in the area of cardiology through the use of SBL.3,4 The academic setting is not the only environment to use SBL to improve clinical skills. In the clinical setting, SBL has been used to reduce medication errors, improve physician clinical techniques, increase teamwork and leadership skills, and identify deficiencies in conforming to national guidelines.12-15

When evaluating the results of case C, the simulation learning method resulted in statistically significant higher scores than the mPBL strategy but not the standardized patient strategy. Case C presented a concept that was unique with visualizations during the seizure lectures that occurred before the laboratory session. This particular case necessitated the student to recognize that the rectal administration of diazepam was necessary to treat the patient. During the seizure lecture, this administration technique was emphasized through video clips and detailed handouts. We believe that the students collectively remembered this concept from the didactic lecture and applied this knowledge to the case, regardless of the learning strategy that they encountered.

Overall, students also believed that the simulation learning strategy improved their knowledge of seizure disorders and management strategies. When the students were asked on the postpractice survey, 91% of students agreed or strongly agreed that simulation improved their knowledge, whereas significantly fewer students agreed or strongly agreed that mPBL or standardized patients, respectively, improved their knowledge. Students believed that the simulation learning strategy improved their confidence, was a good use of their time, and increased their interest in the topic that was being taught more often than the mPBL or the standardized patient learning method. This result is similar to several other evaluations of student perspective on SBL.3,16 Students surveyed in other studies expressed a positive experience with SBL specifically due to an increase in confidence in clinical skills and problem solving ability, the ability to practice skills in a safe environment, and improvement of knowledge acquisition and retention.3,4,16 Overall, the students reportedly enjoyed the laboratory session and would like to see similar sessions in the future. Although student satisfaction is a minor educational outcome, as an educator, student satisfaction is important when constructing interactive learning experiences that necessitate active student participation.

When evaluating the anxiety associated with each of the learning strategies, it was discovered that the simulation and standardized patient learning scenarios did not differ. However, students reported less anxiety with mPBL than with simulation. Students have been exposed to all 3 learning formats throughout the PharmD curriculum. Throughout the curriculum, the students have many opportunities to experience PBL, standardized patients, and SBL. Therefore, unfamiliarity with one of the learning methods would not explain the development of anxiety in this population. Previous studies cited that the “adrenaline rush” associated with simulation will actually help the learner retain the information being presented.16 This point raises a question for future study: Are the increased quiz scores attained with the simulation and standardized patient learning techniques associated with an increase in the level of student anxiety as compared with mPBL?

Some recommendations for implementation would be to divide the students into groups of 10 or less. Smaller groups allow for more individualized teaching and provide the students with more opportunities to interact with the human simulator. It is also recommended that a debriefing session follow the SBL. This would be to provide immediate feedback and review the important clinical learning points of each case. A debriefing session was not completed in our study as to not create potential bias compared with the other learning modalities. Although we opted for a more conservative approach by not debriefing after simulation,
if implemented, it may further contribute to knowledge gained and retention of knowledge.

There are several challenges with the use of high-fidelity simulation. The cost of the simulators, as well as the need for trained faculty, poses 2 large barriers to SBL implementation. Faculty members could seek relationships with simulation training centers in hospital systems and other schools of the health professions to use and share available resources. Interested faculty members could also become trained in simulator programming and case design. Simulation-based education can also be resource intensive. For example, our study used 4 faculty members and 3 teaching assistants to facilitate the laboratory session. However, if one was to conduct this laboratory session not for research purposes, there would be more flexibility to student group transitions between cases and less time restraints. For example, the laboratory could be held over several days, thereby involving fewer faculty members.

There are some limitations to our study. The seizure module is a mandatory part of the PharmD curriculum; therefore, the students needed to receive a didactic lecture before the laboratory session. Therefore, we used an mPBL instead of a traditional PBL. To facilitate a large class in a limited time through this study design without introducing any confounders (reading outside class, etc), each session lasted for 90 minutes. The period was the same for all of the groups and cases. This time allotment would be reasonable for any class using only 1 simulator having a large number of students outside the confines of a study. A debriefing session was not used after the SBL method, which is a typical component; however, if this was included, it may have further increased the knowledge gained by the SBL session. The generalizability of the results of this study may be difficult because this study was conducted in a defined population, PharmD students, with a specific topic, seizures, and limited cases. Therefore, we suggest that additional larger-scale research that is conducted in a varied population is needed for better generalizability of the results. Another limitation to our study pertains to our clinical assessment test. There are 5 components to validity including content, response process, internal structure, relationship to other variables, and consequences. Although these are important sources of validity evidence, our test was limited to the assessment of content validity. A more rigorous method for test development could be applied to future studies.

Overall, high-fidelity simulation seems to be an effective learning strategy that is well accepted by students. Compared with standardized patients and mPBL strategies, students performed better on the knowledge-based assessment after a simulated patient case scenario. In the future, we plan to increase the use of simulation in our curriculum, expanding its use to other disease states.

REFERENCES