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Implementing and Evaluating Virtual Patient Cases within a Team-Based Learning Pedagogy in a Therapeutics Course Sequence

Running Title: Implementing Virtual Patient Cases within TBL

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Abstract

Introduction: Accreditation Council for Pharmacy Education (ACPE) requires that pharmacy curriculum stresses active learning. This allows students to listen, read, write, discuss, and reflect on their approach to course content through various methods. ACPE advocates use of innovative, active learning teaching methods to develop necessary skills students need to problem-solve, think critically, and effectively work as a team. We have successfully implemented team-based learning (TBL) throughout therapeutics curriculum; however, there is still a critical need for students to practice what they have learned through an interactive fashion. Use of virtual patients has been previously evaluated in non-TBL courses and has resulted in improved student learning. Thus, using virtual technology could bridge the gap between TBL and providing "real-life" patient-centered care.

Objectives: To evaluate short-term learning outcomes and student perception of implementing virtual simulation within a TBL therapeutics course series. We expect that virtual simulation will add another unique action-based learning experience within TBL.

Methods: Faculty developed virtual patient cases using branched-outcome decision-making processes and integrated them into six TBL sessions throughout the therapeutic courses in the second (two sessions) and third years (four sessions) of pharmacy school. Students completed virtual patient cases in groups and pre-simulation/post-simulation assessments were completed. Assessments and activity evaluation were used to measure student learning and perceptions. Pre-simulation/post-simulation assessments included 12 lower-level and 9 higher-level learning questions.

Results: Use of virtual patient cases resulted in significantly higher post-simulation scores compared with pre-simulation scores (p<.001). Increases in student's learning of lower- and higher-level domains (p=.02 and p=.11, respectively) were observed. Seventy-four percent of students agreed that virtual cases were effective in learning therapeutic clinical application, and 80% believed these cases stimulated their critical thinking.

Conclusion: Integrating virtual patient cases into curriculum may enhance student's ability to critically think and apply their knowledge to real health care world.

Keywords: education technology; pharmacy education; critical thinking

The 2016 Accreditation Council for Pharmacy Education (ACPE) standards require that graduates from pharmacy schools have "knowledge, skills, abilities, behaviors, and attitudes necessary to provide patient-centered care."[1] Graduates are expected to provide this care as the medication expert through effectively collecting and interpreting evidence, formulating their assessments and recommendations, implementing those recommendations, monitoring patient's status, and documenting activities appropriately. The Center for the Advancement of Pharmacy Education (CAPE) 2013 educational outcomes constructed domains to guide pharmacy schools in providing graduates the knowledge and skills for patient-centered care, the ability to work with and educate other health care professionals, and the problem-solving skills necessary to effectively care for patients.[2] ACPE requires that pharmacy curriculum stresses an active learning pedagogy, which actively engages learners during teaching. This allows pharmacy students to listen, read, write, discuss, and reflect on their approach to course content through various methods. ACPE advocates the use of innovative, active learning teaching methods in schools curricula to develop necessary skills students need to problem-solve, think critically, and effectively work in an interprofessional environment.[1] Some of these teaching methods include patient simulation utilizing educational technologies or actors, problem-based learning (PBL), or team-based learning (TBL).

The University of Michigan College of Pharmacy has been a leader in the TBL implementation, which is a teaching pedagogy that "flips the classroom".[3,4,5,6] This active learning instruction was implemented to improve long-term learning outcomes (e.g., performance during experiential rotations, clinical exams, and board exams) by utilizing engaged, action-based learning experiences for students prior to their advanced pharmacy practice experiences where they interact with real-life patients. There have been several studies that support using TBL in therapeutics. Students reported in a recent study that TBL improves teamwork skills, learning both knowledge- and application-based course content, and lifelong learning skills.[4] Another study randomized students to receive lecture- versus TBL activities focused on six therapeutic topics.[5] Results showed that there were significantly higher exam scores and student survey scores focused on critical thinking and therapeutic knowledge favoring TBL compared with lecture format. While TBL implementation has been very successful within our curriculum and has allowed us to measure some outcomes (e.g., knowledge scores, student confidence assessment, and satisfaction survey of the activity), there is still a critical educational need for our students to actually practice what they have learned through TBL in an interactive fashion before directly working with real patients within the health care system.[4] Virtual patient technology could be used to bridge the gap between TBL and providing "real-life" patient-centered care as this technology simulates "real-life" clinical scenarios for students to utilize their critical thinking skills. Virtual patient simulation is defined by the American

Association of Medical Colleges (AAMC) as, "a specific type of computer-based program that simulates real-life clinical scenarios; learners emulate the roles of health care providers to obtain a history, conduct a physical exam, and make diagnostic and therapeutic decisions".[7] Use of virtual patients allows students to provide patient-centered care and to take on the pharmacist role on a team by obtaining the necessary patient information and making appropriate diagnosis and therapeutic recommendations.[8]

TBL provides an interactive approach for teaching curriculum and material; however, we believe that virtual patient simulation implementation will add another significant and unique action-based learning experience in a TBL-based curriculum.   The purpose of our study is to evaluate short-term learning outcomes and student perception of implementing virtual patient simulation activities within a TBL therapeutics curriculum.

Methods

Description of the Curricular Activity

At University of Michigan College of Pharmacy our therapeutics course sequence began the second semester of first year of pharmacy school (P1) and continued through the end of the third year of pharmacy school (P3). Throughout the course sequence, TBL was the only method used during the recitation sessions. As part of the TBL process, students were required to complete pre-work (a guided self-study or Microsoft® PowerPoint® recorded lectures) before class. During the recitation class session, students conducted readiness assurance assessments (individual and team-based readiness assessments) to evaluate knowledge and basic application of pre-work material. After the assessments were completed, students worked in teams to apply knowledge obtained through pre-work on application-based activities (e.g., patient cases, role playing). In addition to recitations, laboratory activities occurred throughout the semester once weekly. The laboratory sessions included application-based and clinical skills activities and were focused on key curricular threads (e.g., communication and physical assessments) with current content taught during the recitation session. Some of these laboratory activities included standardized patient interactions, virtual patient simulation, skill assessments, and case presentation. Virtual patient simulation was a method to provide more real-life patient scenarios and critical-thinking based activities.

Virtual patient cases were integrated into six TBL sessions throughout the therapeutic courses in the second (P2) and third years (P3) of pharmacy school over four semesters. Two sessions were in the P2 year and four sessions were in the P3 year. Implementation of virtual simulation and activities were standardized regardless of topic area or timing of session. Cases

were not used to teach new material, but to supplement and reinforce material presented in the pre-work material and prior TBL sessions. DecisionSim™ technology (Chadds Ford, PA [www.kynectiv.com]) was used to introduce virtual patient simulation to students during select sessions, which previously had been discussed using paper-based cases. The sessions, which replaced other teaching methods (e.g., paper-based cases, role playing) with virtual patient simulation, included pharmacokinetics, hepatology, transplant, oncology, and two cardiology sessions. The virtual patient case content were written by content experts and reviewed by virtual simulation experts. The virtual patient cases were then reviewed and tested by pharmacy students, faculty, or residents prior to the class session. A consultant was available to answer any question regarding the DecisionSim™ technology, as they had previous experience using this program. Before faculty developed virtual simulation cases, all faculty involved received both group training provided by the DecisionSim™ trainer and one-on-one training by virtual simulation experts.

During the virtual patient simulation activity, students worked on cases as a team of five or six students and they were given between one and two hours to complete the cases. Immediately after students completed the virtual patient cases, the instructors discussed their findings and key points in a large classroom setting and individual assessments were completed. Following the activity, students had open access to the virtual patient cases.

Virtual patient cases were developed using DecisionSim™ technology, and several faculty members created and implemented the cases. Faculty developed the virtual patient cases and used a branched-outcome decision-making process, in which students were given patient case scenarios and were to choose the best choice that could lead them to the right or wrong path. Students received immediate feedback of their choice and any consequences associated with those choices. Immediate feedback was to mimic a situation in which a student was making clinical recommendations to other health care professionals for patient issues and for the student to see the clinical outcome of that recommendation. An example of a virtual patient case is presented in **Figure 1**.. Additionally, virtual patient cases were developed from the learning objectives of the course section. Overall, the purpose of using virtual patient cases was to provide a safe environment for students to practice critical thinking skills, allow students to apply the course content to these cases, provide instant feedback to students as they progress through the cases, and provide a discussion with the faculty after completion of the activity.

Study Design and Assessments

This was a retrospective study to evaluate the impact of virtual simulation cases on knowledge retention in a TBL therapeutics course sequence. Knowledge retention was assessed by evaluating pre- and post-simulation assessment scores of all pharmacy students included in the study.   This study included P2 and P3 students (from September 2015 to April 2016) who took part in the virtual simulation cases and completed the pre- and post-assessments. The primary end point of this study was change in pre- and post-assessment scores. A secondary end point included student satisfaction of the activity. The study was approved as exempt status by the University of Michigan investigational review board and student consent was not required to participate in the simulation activity and study. We obtained funding through the University of Michigan Third Century Initiative to support our study. The funds allowed us to secure the virtual simulation software program, DecisionSim™..

This study utilized both quantitative and student evaluation data to evaluate the effectiveness of a virtual simulation software program, DecisionSim™, on students. Pre- and post-simulation assessments (quizzes) and an evaluation of the activity were used to assess student learning and perceptions. The students were given a five or six question (depending on the session) pre-simulation assessment prior to the DecisionSim™ activity, followed by the same number of post-simulation assessment questions and an evaluation survey after the activity. All except one post-simulation assessment question were created to be similar but not identical to the pre-simulation assessment questions. The purpose of making the assessments different was to prevent recall bias. Only five sessions (out of the six sessions) were included in the data analysis of the pre- and post-simulation assessment scores. Pre- and post-assessment scores of one of the sessions were removed from the analysis due to the assessments being identical. Peer review of the assessment questions were conducted by the course faculty members who were the content experts of the specific virtual patient case activities. Additionally, course teaching assistants (e.g., pharmacy residents) reviewed some of the questions to assess appropriateness. All pre- and post-simulation assessments were developed from the learning objectives of the course section. The course faculty based the level of difficulty of the questions based on the Bloom's taxonomy of learning activity levels[9]. We only included the TBL sessions in the P3 year (four sessions) to evaluate lower-level (e.g., knowledge) and higher-level learning (e.g., application). Out of all of the questions included in the four sessions, a total of 12 lower-level learning (pre- or post-assessment) and nine higher-level learning (pre- or post-assessment) questions were evaluated. The evaluation survey was developed by the study investigators and included 13 questions using a 5-point Likert scale and two questions using free text responses. The survey was adapted from a survey used in a previous study on virtual patients.[10] Additional questions were included in the survey to compare the use of traditional TBL activities compared with virtual simulation cases. The evaluation survey was administered to individual students

after the activity to evaluate student perceptions of, and satisfaction with, the teaching strategy. The students were required to complete pre- and post-simulation assessments and were strongly encouraged to complete the evaluation survey. Statistical analysis was conducted using IBM SPSS® Software (version 22). Pre- and post-simulation assessments were analyzed using paired student's t-tests. A p value of less than 0.05 indicates a statistically significant difference. The results from the evaluation survey were presented as descriptive data.

Results

Overall, 156 students (n =82 [P2], n = 74 [P3]) were participants in the study. **Table 1** summarizes the pre- and post-simulation assessment results. Out of the 368 assessments (individual assessment of student pre and post-scores) from five of the sessions, virtual patient simulation significantly increased the students' overall learning by 13.3% when comparing pre- and post-simulation assessment scores (p<0.001). A subgroup analysis was conducted to compare pre and post-simulation assessment scores between Fall (two sessions) and Spring (three sessions) semesters. In the Fall semester, pre- and post-simulation assessment scores were similar (72% vs. 69.5%, respectively; p=.17). However, in the Spring semester, post-simulation assessment scores were significantly higher by 25% compared with the pre-simulation assessment scores (p<.001). The virtual patient simulation significantly increased the students' learning of lower-level domains by 25.2% (p=.02). The difference in pre- and post-simulation scores in learning of higher-level domains was 14.7%; however, it did not increase significantly (p=.11). Lower- and higher-level domains were evaluated in the sessions in the Spring semester. Virtual patient simulation significantly increased the students' learning of lower-level domains by 18.1% when comparing pre- and post-simulation scores (p=.019). The difference in pre- and post-simulation scores in learning of higher-level domains was 15.7%; however, it did not increase (p=.26).

After the virtual patient simulation, students were provided a link to complete an evaluation survey related to the virtual patient cases as a teaching tool in the course. Two hundred and forty-eight surveys were completed by the students (average response rate of 49.2% per session). The students could have filled out a survey for each of the sessions; therefore, there were more surveys completed compared with the number of students that were involved in the activity. **Table 2** summarizes the student perceptions and results from the evaluation survey. Seventy-four percent of 248 students agreed or strongly agreed that the virtual patient cases were an effective way to learn clinical applications of therapeutics, 67% wanted more of these cases incorporated into the therapeutic course sequence, 80% believed that these cases stimulated their critical-thinking during the recitation session, 72% agreed or

strongly agreed that both TBL and virtual patient cases should be utilized for therapeutic topics, and 60.5% enjoyed these cases. Additionally, 72% of students strongly disagreed or disagreed that virtual patient cases should only be used for recitation sessions; however, students were indifferent when asked if they prefer learning with the typical TBL recitation session instead of learning with a virtual patient case (40% selected undecided).

Discussion

Incorporation of virtual patient simulation technology within an embedded active learning pedagogy (TBL) in a core curricular class sequence had a positive effect on learning outcomes on both student learning and perceptions. There was significant improvement in overall post-simulation test scores with significantly higher scores observed for knowledge-based questions. There were higher scores seen for application-based questions; however, the difference was not statistically significant. Additionally, the post-simulation test scores were significantly higher in the Spring semester compared with pre-simulation scores; however, there was no significant difference in pre- and post-simulation test scores in the Fall semester. These results could be due to students already having multiple exposures to the virtual simulation technology prior to the Spring semester. Therefore, these students would be expected to score better compared with the Fall semester. In addition, approximately 80% of students agreed or strongly agreed that critical thinking skills were stimulated using virtual patient simulation technology. Overwhelmingly, the majority of students (72%) also believed that both TBL and virtual patient technology should be used to teach therapeutic topics. Utilizing both virtual patient simulation technology and TBL was well accepted by students.

A novel aspect of this study is the evaluation of virtual patient simulation technology embedded within an established active learning pedagogy – TBL. Because TBL is the core pedagogy for our five semester therapeutics sequence, our students are well versed in this pedagogy which makes for an ideal setting to add a different active learning strategy. Our findings suggest over 70% of students value the use of virtual patient simulation technology in addition to TBL. Importantly, the virtual patient simulation technology helped students (approximately 71%) to understand the pre-work that is associated with TBL. However, the data suggests that students do not believe that virtual patient simulation technology should replace TBL. Specifically, only 20% of students disagreed with the statement "I prefer learning with the TBL recitation session instead of learning with a DecisionSim™ case". Further, only 10% of students agreed that "Only DecisionSim™ cases should be used for recitation sessions".

Overall, our study results, especially pre- and post-simulation test scores and student survey results, were consistent with a prior study that evaluated the use of DecisionSim™ to develop and implement a patient case activity.[10] A few schools implemented and evaluated the effectiveness and student satisfaction in utilizing virtual patient simulation technology in the pharmacy curriculum. One study evaluated the use of a virtual patient system to create real clinical cases to teach pharmaceutical care and communication skills to pharmacy students.[11] The results demonstrated that students strongly agreed that they found the cases realistic and

that they learned from using the system. Another study evaluated the use of virtual patient cases in an advanced therapeutics pharmacy course to promote active, patient-centered learning.[10] Cases were developed that incorporated a branched-narrative, decision-making teaching model and pre-simulation/post-simulation tests were used to assess student learning. The use of virtual patient cases resulted in significant improvement in student learning for both high-level and low-level test questions. Additionally, students were satisfied with using virtual patient simulation and agreed/strongly agreed that the cases were enjoyable (69%), content was appropriate (80%), and cases were an effective way to learn (72%). Fifty-nine percent of students also wanted to see more cases incorporated throughout the course. A recent study evaluated the use of one virtual patient case in one required therapeutics course using a flipped-classroom teaching format.[12] Similar to the previous study,[10] the case incorporated a branched-narrative, decision-making teaching model and pre-simulation/post-simulation tests were used. The results showed that median post-simulation test scores were 17% higher than pre-simulation test scores (50% vs 33%, p=.01; respectively). Students scored significantly higher on the post-simulation test questions compared with pre-simulation test questions assessing high-level learning (83% vs 67%, p=.003; respectively). Median exam scores were also evaluated and were higher compared with historical control scores (80% vs 70%, p=.025; respectively). Additionally, 67.6% of students agreed or strongly agreed that the virtual patient case helped them apply knowledge gained in video pre-work.[12] More recently, a study compared the use of a virtual simulated patient case versus a paper-based case on a subjective objective assessment plan (SOAP) and 13 student-perceived confidence items in medication management.[13] Results showed that there was a significant increase in all confidence items; however, there was no difference in total SOAP note scores between groups. Overall, the studies showed that virtual patient simulation is a useful teaching tool. However, key strengths of our study were that this study included more virtual patient cases throughout a therapeutics course sequence, including content in P2 and P3 years, and the activities were incorporated into a curriculum with TBL.

Limitations of our study included that administration of the survey immediately after the activity may not capture students' feedback on exam preparation, and a lack of a comparative group that included a pre-implementation group with a similar activity without the use of virtual patient simulation. Other limitations we have learned from this study included the use of non-validated assessments, and obstacles to consider when using a virtual simulation platform and when developing virtual patient cases. In regards to using non-validated assessments, we conducted a review of the assessments to ensure assessments were linked to learning objectives of the course section and that the level of difficulty was appropriate for students. However, it was difficult for us to validate the assessment due to the variation of topics covered

in the six sessions. A second limitation to consider before implementation of virtual simulation was the costs associated with using a virtual simulation platform. Additionally, there are significant resources, specifically faculty time that is required to develop these virtual patient cases. One study reported that approximately 50 hours was dedicated to developing and implementing virtual patient cases.[10]   However, with future use of these cases, it is expected that there would be minimal time needed to update and implement these cases. Additionally, virtual patient case sharing across schools may allow universities to overcome barriers, such as faculty time and resources, that may prevent implementation of virtual patient simulation activities in the classroom.[14] Schools may not have the resources to utilize a virtual simulation program; however, simulation could be done using other techniques but must maintain key elements of a virtual simulation approach: 1. Cases must use a branched-outcome decision making process, in which the students are given patient case scenarios and are to choose the best choice that could lead them to the wrong or right path, and 2. Students receive immediate feedback of their choice and any consequences associated with those choices.

Conclusion

Overall, incorporating virtual patient simulation within TBL had a positive effect on learning outcomes for both student learning and perceptions. We believe that this type of simulation program is optimal for student learning, especially in P2 and P3 students, because as already stated, they will be able to immediately see the impact of their decisions related to medication therapy and how patient outcomes are directly related to these recommendations. Implementation of virtual patient simulations may have significant potential to create sustainable change in how our students are educated, as faculty can easily adapt and create new cases as new medications become available or as treatment guidelines change. Virtual simulation allows for critical reinforcement of the application principals taught within our TBL pedagogy and creates a necessary intermediate step between classroom and clinic that our curriculum is currently lacking. We feel that this one relatively simple change in how we teach our students will greatly enhance their ability to critically think and apply their knowledge to the real health care world. Future studies are needed to compare the effectiveness of virtual simulation and traditional teaching (e.g., lecture) in student learning in the TBL setting.

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Table 1. Results from the Pre-Simulation and Post-Simulation Quizzes (N=368, individual assessment of student pre- and post-scores; 5 team-based learning (TBL) sessions)

	Pre-Simulation Question Answered Correctly	Post-Simulation Question Answered Correctly	p value
All questions	59.1%	72.4%	< .001
Fall semester (n=212); 2 TBL sessions	72%	69.5%	.17
Spring semester (n=156); 3 TBL sessions	49.5%	74.5%	<.001
Knowledge-based questions (n=286, individual assessments of student pre and post-scores; 12 individual questions compared)	58.5%	83.7%	.02
Application-based questions (n=286, individual assessments of student pre and post-scores; 9 individual questions compared)	55.9%	70.6%	.11

Table 2. Results from the Post-Virtual Patient Case Evaluation Survey and Student Perceptions of the Teaching Tool

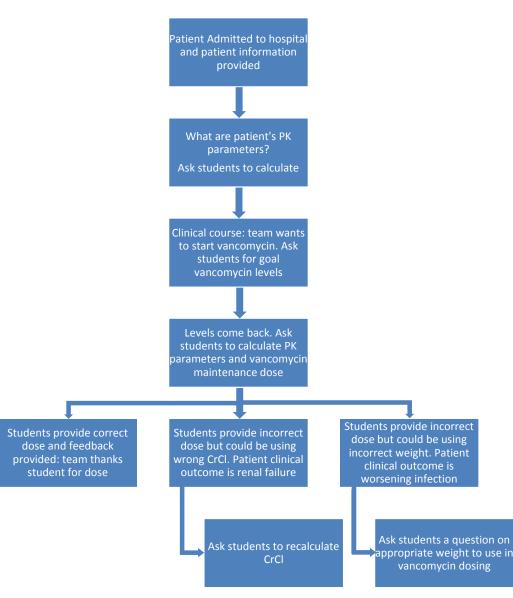| Question	Student Responses (N=248; 6 TBL sessions)					
	Strongly Agree n (%)	Agree n (%)	Undecided n (%)	Disagree n (%)	Strongly Disagree n (%)	N/A n (%)
The DecisionSim™ case was an effective way to learn the clinical application of therapeutics	34 (13.7)	149 (60.1)	36 (14.5)	18 (7.3)	11 (4.4)	0
More DecisionSim™ cases should be incorporated into the therapeutic course sequence	37 (14.9)	129 (52)	42 (16.9)	28 (11.3)	12 (4.8)	0
DecisionSim™ stimulated my critical thinking during the recitation session	50 (20.2)	149 (60.1)	28 (11.3)	11 (4.4)	10 (4)	0
I enjoyed using DecisionSim™ for the recitation session	36 (14.5)	114 (46)	50 (20.2)	31 (12.5)	17 (6.9)	0
I learned more using the DecisionSim™ case as compared with a typical TBL recitation period	17 (6.9)	52 (21)	90 (36.3)	63 (25.4)	25 (10.1)	1 (0.4)
Only DecisionSim™ cases should be used for recitation sessions	5 (2)	22 (8.9)	43 (17.3)	96 (38.7)	82 (33.1)	0
I accessed the DecisionSim™ case after the recitation session to help study for the exam	27 (10.9)	61 (24.6)	21 (8.5)	82 (33.1)	52 (21)	5 (2)
The degree of difficulty in the DecisionSim™ case helped me to prepare for the exam	16 (6.5)	115 (46.4)	80 (32.3)	25 (10.1)	11 (4.4)	1 (0.4)

questions						
The content on the DecisionSim™ case was appropriate for the therapeutic area	42 (16.9)	165 (66.5)	27 (10.9)	10 (4)	4 (1.6)	0
The learning objectives for the recitation period were met during the DecisionSim™ case	20 (8.1)	150 (60.5)	39 (15.7)	28 (11.3)	10 (4)	1 (0.4)
The DecisionSim case contributed to my understanding of the material from the pre-work	33 (13.3)	144 (58.1)	38 (15.4)	16 (6.4)	16 (6.4)	1 (0.4)
I prefer learning with the TBL recitation session instead of learning with a DecisionSim™ case	41 (16.5)	55 (22.2)	99 (39.9)	46 (18.6)	5 (2)	2 (0.8)
For a therapeutic topic (e.g., solid organ transplant) both a typical TBL recitation session and a DecisionSim™ case should be utilized	74 (29.9)	105 (42.3)	47 (19)	12 (4.8)	10 (4)	0

TBL = team-based learning.

Figure 1. Example of a virtual patient case. CrCL = creatinine clearance; PK = pharmacokinetics.