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Overview of implementation and learning outcomes of simulation in pharmacy education

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Abstract

Simulation, an educational, assessment, and research technique used to mimic real-world situations, is increasingly used in pharmacy education. The most-used simulation methods include high-fidelity simulation (HFS), low-fidelity simulation (LFS), standardized patients, and game-based simulation. A common element of simulation is its ability to offer learners the chance to practice a skill or acquire knowledge in a safe and accessible space. Simulation methods differ in key aspects, including cost and other resource investment as well as ideal venue for use in education. HFS provides a more realistic simulation environment than LFS but is typically more expensive. Standardized patients offer learners the opportunity to engage with a live person but may elicit greater variability in responses to learners' input than HFS. Computer-based simulation uses technology to supply a wide variety of learning opportunities; however, it may require the use of proprietary software and devices. Despite widespread use, literature describing learning outcomes of simulation in pharmacy education is limited. Some existing reports with positive findings have focused on learner satisfaction with or perceived benefit of simulation activities. The

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few existing publications summarizing changes in skills or knowledge demonstrate a positive impact. Simulation is a promising modality for educating pharmacy students and residents; however, more data summarizing the benefit of learning outcomes are needed.

KEYWORDS
learning outcomes, pharmacy education, simulation

1 | INTRODUCTION

Simulation is a technique typically used for education, assessment, and research in which participants apply knowledge, skills, and attitudes in a scenario that simulates the real world.[1] The Agency for Healthcare Research and Quality defines simulation as "a technique that creates a situation or environment to allow persons to experience a representation of a real event for the purpose of practice, learning, evaluation, testing, or to gain understanding of systems or human actions."[2] Although the history of simulation has roots in the aviation and military industries, the medicine and nursing professions have adopted many simulation principles with the goal of improving patient outcomes and safety in the complex health care system. Other health professions have incorporated simulation over time.[3]

The Accreditation Council for Pharmacy Education Standards 2016 supports the use of simulation-based education to "mimic actual or realistic pharmacist-delivered patient care situations," to fulfill certain introductory pharmacy practice experiences (IPPEs) and provide opportunities for interprofessional team education.[4] Use of simulation is not limited to pharmacy students and may also be incorporated into pharmacy residency curricula. However, the American Society of Health-System Pharmacists Accreditation Standards for Postgraduate Year One (PGY1) Pharmacy Residency Programs do not explicitly require or limit its use.[5]

The most common simulation modalities in health professions education include standardized patients (SPs), task trainers, manikins, and games. Overall, simulation affords a standardized environment where learners can practice applying the knowledge, skills, and attitudes learned in didactics without the risk of patient harm.[6,7] In essence, simulation provides learners authenticity with a safety net to try new approaches, slow down patient scenarios, and build self-confidence.[6,8] Debriefing through guided reflection is a vital step within simulation-based activities as participants learn to make sense of what they have experienced.[9] Incorporating simulation into curricula allows educators to assess clinical practice skills and ensure learners are prepared for the next stage of training.[10] Simulations have been used to assess communication, interprofessional dynamics, care plan development, compounding, medication errors, and cultural competency, among many other skills.[7,8,11,12] The knowledge and skills acquired in simulation scenarios have been shown to translate into and affect real-world practice.[8]

Contemporary simulations incorporate various technologies, including electronic health records (EHRs), patient manikins, and task trainers.[13–17] Simulations have also forged into the gaming and virtual worlds to allow for immersive experiences in a familiar and safe environment.[6,18–25] Virtual simulations allow for remote participation, bringing together learners from various disciplines and locales into one simulated healthcare environment.[26–32] In fact, during the COVID-19 pandemic, simulations in the remote setting became necessary to meet curricular outcomes.[33,34]

Overall, use of simulations in health professions education is widespread and has positively affected learner satisfaction, knowledge, skills, and behaviors.[35,36] In pharmacy education, the incorporation of simulation has grown over the past 20 years. A decade ago, most colleges/schools of pharmacy reported incorporating simulations into their curriculum.[37] This white paper addresses the impact of various simulation modalities on learning outcomes within the pharmacy professional degree curricula and residency training programs.

2 | HIGH-FIDELITY SIMULATION

To define high-fidelity simulation (HFS), one must start with the concept of fidelity. Simply stated, fidelity is the extent to which an experience is true to reality.[2] It follows that HFS in pharmacy education is the extent to which the experience represents what learners will encounter in clinical practice. HFS is a broad term that encompasses any experience mimicking reality. In this paper, HFS refers to sophisticated manikins that can be programmed to exhibit realistic vital signs, physical examination findings, and responses to interventions and medications and their use in pharmacy education.[38,39]

2.1 | Examples of HFS in pharmacy education and training

Almost 85% of colleges/schools in the United States have access to high-fidelity manikins or SPs.[37] Much of the published literature with high-fidelity manikins involves pharmacy students only or pharmacy students in conjunction with interprofessional teams. A common use of HFS is in the setting of cardiovascular emergencies, particularly education, and training for advanced cardiac life support (ACLS).[26,40–44] In this exercise, learners care for a patient as part of a team during a simulated cardiac arrest, allowing for practice of resuscitation fundamentals such as chest compressions, ventilations, defibrillation, medication administration, and exposure to a stressful situation.[40] High-fidelity manikins have also been incorporated throughout pharmacy curricula to teach about a variety of acute care clinical topics, including anaphylaxis, endocrine emergencies, seizures, arrhythmias, asthma, heart failure, and toxic exposures.[44–50]

The most common interprofessional dynamics described in the HFS literature include teams of students from pharmacy, nursing, and medicine, with others including social work, respiratory therapy, and physician assistants. Many of the published reports outline single interprofessional events such as caring for a patient with anaphylaxis, drug toxicity, end-of-life needs, stroke, or heart failure exacerbation.[51–55] Reports also contain examples of several HFS scenarios or repeated events throughout a course, but these are less common.[56–58]

Use of HFS in the training of pharmacy residents is less common. Literature describing pharmacy resident involvement in HFS experiences has primarily included high-risk scenarios, such as medical emergencies and ACLS.[59–62] Simulation activities in medical emergencies have covered a wide array of patient scenarios, including the management of hyperkalemia, ischemic stroke, anaphylaxis, rapid sequence intubation, ST-segment elevation myocardial infarction, sepsis, status epilepticus, intracranial hemorrhage, bleeding reversal, malignant hyperthermia, ventricular arrhythmia, supraventricular tachycardia, and symptomatic bradycardia.[59,62]

2.2 | Learning outcomes assessed using HFS and evidence supporting use in education and training

Learning outcomes associated with HFS have been described for pharmacy students,[15,26,40–44,48–50,63–66] pharmacy residents,[59–62] and interprofessional learners[51–58,67–72] (Table 1).

Knowledge as assessed by quizzes and examinations is the most commonly described learning outcome for pharmacy students participating in HFS.[15,40,42–44,46–50,63,66] Students' knowledge improves with HFS in a variety of clinical content areas.[15,40,43,46–50,63,66] Beyond knowledge acquisition, knowledge retention has also been evaluated for durations of 25 days to 3 months after HFS.[46,49,50] Knowledge was retained in the settings of acute care medical emergencies and when supplementing IPPEs.[46,50]

HFS is a practical and commonly used method for teaching skills performance.[15,26,41,48,65] All instances of skills performance assessment with HFS in the pharmacy education literature are associated with statistical or numerical improvements.[15,26,41,45,48,63,65] Publications from one institution describe increased basic life support (BLS) and ACLS skills retention as well as simulated patient survival.[26,41,65] BLS skills were retained within 120 days of training.[65] After a one-time exposure in an elective course, there was a numerical, but not statistically superior, retention in students' ACLS skills at 120 days compared with students without previous training.[41] After a 10-h ACLS certification course with HFS within the previous year, BLS and ACLS skills were retained.[26] Although simulated patient survival increased after previous exposure to HFS in an elective (37%) or certification (86%) course, the outcome was statistically superior only after the certification course.[26,41] Other supplementary outcomes routinely assessed include attitudes, perceptions, confidence, and satisfaction related to HFS.[15,26,40–47,49,50] Increased learner confidence and satisfaction with HFS are routinely described.[15,26,40–47,50,63]

Learning outcomes for pharmacy residents participating in HFS experiences of medical emergencies or ACLS focuses on global cognitive skills over discrete tasks and include outcomes such as confidence, knowledge, competency, satisfaction with the simulation, preparedness, and sustainability of preparedness.[59–62] These learning outcomes are typically evaluated using quantitative methods in the form of Likert scale surveys administered to participants either before and after or just after the simulation.[59–62] One paper described a more positive impact on self-reported competence with cardiovascular emergencies such as cardiac arrest or arrhythmias at the end of PGY1 training in students participating in these exercises than in those not exposed to simulation.[59] Another report detailed the use of high-fidelity manikins to train PGY1 residents on managing cardiopulmonary arrest using three distinct scenarios. The authors reported improvement in knowledge, confidence, and competence after simulation compared with baseline.[60] Other published reports have focused on perceived confidence and preparedness for managing medical emergencies after taking part in HFS exercises.[61,62]

The outcomes described for interprofessional HFS experiences with pharmacy students have focused on attitudes or perceptions toward collaborating as a team rather than clinical management or outcomes. The emphasized outcomes align with the Interprofessional Education Collaborative core competencies, including values/ethics, teamwork, communication, and understanding of the roles and responsibilities of team members.[67,70,72] Many validated survey instruments have been incorporated into the literature for evaluating learning outcomes in interprofessional HFS.[51–53,55–57,67,68,70,71]

The most frequently reported survey instrument is the Readiness for Interprofessional Learning Scale, which assesses the attitudes of health and social work students toward interprofessional learning by assessing domains such as teamwork and collaboration, professional identity, and roles and responsibilities.[51,53,55,68] After participating in interprofessional HFS, participating students have shown improved attitudes and readiness for interprofessional learning.[51,55,68] Attitudes and perceptions of teamwork can also be evaluated in HFS using a modified version of the TeamSTEPPS Teamwork Perceptions Questionnaire and Teamwork Attitudes Questionnaire to target healthcare professional students instead of clinical practitioners to assess effective communication, value as team members, collaboration, and recognition of the expertise of members of the interprofessional team.[67]

The change in perceptions toward interprofessional health care teams has been evaluated using the Students' Perceptions of Physician-Pharmacist Interprofessional Clinical Education Revised (SPICE-R) and Attitudes Toward Health Care Teams Scale (ATHCT) tools. Third-year pharmacy and senior nursing students' perceptions of interprofessional healthcare teams as assessed by SPICE-R improved after completion of two hospital-based HFSs.[56] Evaluations of participants using the ATHCT showed improved student perception of interprofessional after completing interprofessional HFS on pharmacology topics.[52] Other

TABLE 1 Learning outcomes associated with HFS activities.

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Student pharmacists				
Bingham (2015)	ACLS Two groups: Teams with previous ACLS simulation training 120 days earlier and teams without	194 pharmacy students (third year)	• Skills retention 120 days after HFS (BLS, ACLS) • Simulated patient survival (i.e., correct performance of all ACLS skills) • Attitudes and perceptions regarding ACLS response and simulation	For 75% of ACLS skills observed (e.g., time calculating correct vasopressor infusion rate [83 s vs. 113 s, $p = 0.01$]), teams with previous simulation training showed numerical superiority Simulated patient survival was 37% higher for teams with previous simulation training (70% vs. 33%, $p = 0.2$)
Bingham (2020)	ACLS Two groups: Teams with ACLS-certified students and teams without	184 pharmacy students (third year)	• Skills performance (BLS, ACLS) • Simulated patient survival (i.e., correct performance of all BLS and ACLS skills) • Attitudes and perceptions regarding BLS/ACLS response	All BLS skills (100% vs. 60%, $p = 0.02$) and ACLS skills (86% vs. 20%, $p < 0.001$) observed were superior for teams with ACLS-certified members Simulated patient survival was 86% higher for teams with ACLS-certified members (86% vs. 0%, $p < 0.001$) Qualitative themes regarding participation included leadership/teamwork skills developed, confidence increased, content knowledge increased, prepared by previous exposure and repetition, and calculation skills not developed
Branch (2013)	Drug-induced dyspepsia with GI bleeding	123 pharmacy students (second year)	• Knowledge (pre/post-simulation test) • Clinical competence (application of knowledge and communication, problem-solving, clinical skills, professionalism) • Satisfaction with simulation technology	Scores improved on eight of nine knowledge questions ($p < 0.001$). No difference in knowledge of "alarm signs" for dyspepsia ($p > 0.05$) Elements of performance assessed included patient interaction, problem identification, and problem-solving on an eight-item formative assessment rubric. Average performance was 59.5% of the maximum score Satisfaction scores were statistically different between the two cohorts of students but were generally positive. Average scores were aligned with the "agree" response for satisfaction statements
Davis (2013)	ACLS Two groups: Classroom-based lecture first followed by hands-on HFS exercise or vice versa	135 pharmacy students (second year of an accelerated 3-year program)	• Knowledge (test scores on a written exam of 13 questions at baseline and after each teaching technique) • Learner confidence (self-assessed; two Likert scale questions on ACLS knowledge and skills) • Overall satisfaction (one question)	Knowledge scores based on sequencing of the teaching method did not differ ($p = 0.114$). Students reported similar levels of confidence with drug knowledge after lecture and simulation ($p = 0.795$). More students strongly agreed simulation provided greater confidence with ACLS skills ($p = 0.009$)
Gilliland (2012)	End-of-life care (end-stage renal disease) with a focus on 15 min premortem and 15 min postmortem	30 pharmacy students	• Attitudes and perceived competencies (pre/post-simulation surveys: Attitudes Toward Death Survey, End-of-Life Competency Survey) • Satisfaction with simulation	Attitudes toward death and competency on the end-of-life experience improved from pre-simulation to post-simulation ($p = 0.011$ and $p < 0.001$, respectively). Student perceptions regarding teaching methods and self-assessment of their own behavior were positive (average scores were 4.3 and 4.4, respectively, on a five-point Likert scale)

(Continues)

TABLE 1 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Lee Chin (2014)	Human patient simulation versus case-based learning for diabetic ketoacidosis (DKA) and thyroid storm	174 pharmacy students (final-year undergraduate pharmacy students)	• Knowledge (pre/posttest) • Knowledge retention (test) • Satisfaction with human patient simulation	Posttest scores did not differ between case-based learning and human patient simulation for the DKA material ($p = 0.28$). Students performed better on the thyroid storm posttest when randomized to the simulation arm (78.5% vs. 75.1%, $p = 0.033$). Participants had high levels of agreement for all 10 statements related to simulation (range 84.7%–98.1% for those who selected agree or strongly agree)
Maxwell (2016)	ACLS	177 pharmacy students (third year)	• Knowledge (pre/post-knowledge assessment) • Confidence (pre/post-survey)	Knowledge assessment (80% vs. 76.3%, $p = 0.005$) and confidence ($p < 0.0001$) scores improved significantly Knowledge and confidence changes from baseline were not correlated Weak positive correlation was identified between pre-simulation studying and pre-simulation knowledge ($r = 0.22$, $p = 0.004$) and confidence ($r = 0.26$, $p = 0.005$)
Mieure (2010)	ACLS Pre-session lecture, calculation exercise, and a 40-min human patient simulator session	119 pharmacy students (third year)	• Perception (self-assessment of understanding/willingness to repeat experience; no baseline assessment) • Knowledge retention (post-quiz; completed at end of semester)	Most students agreed or strongly agreed they had an improved understanding of ACLS and the roles of a pharmacist (99.2% and 98.3%, respectively). Dose calculations and medication preparation during cardiac arrest were rated high (79% and 88.2%, respectively). Median score on the five-item knowledge assessment was 25%
Priftanji (2018)	BLS with rapid response team Two groups: Previous peer-led BLS training and historical controls	148 pharmacy students (third year)	• Skills performance and retention 120 days after peer-led BLS training program	Teams with peer-led BLS training showed retention of BLS skills 120 days after the training program and significant improvement in certain skills assessed compared with pre-implementation: assessed for responsiveness (96% vs. 41%, $p < 0.001$), assessed for breathing (100% vs. 32%, $p < 0.001$), administered appropriate rescue breaths (100% vs. 32%, $p < 0.001$)
Ray (2012)	Opioid and acetaminophen overdose Two groups: HFS and written patient case	26 pharmacy students (fourth year)	• Knowledge retention (multiple-choice test pre/post-retention [25 days later])	Knowledge scores did not differ between the group completing a written case and the group completing a simulation with the same content ($p = 0.85$). Knowledge scores for each group improved when comparing pretest with posttest and pretest with the retention time point
Seybert (2007)	Blood pressure assessment	95 pharmacy students (second year)	• Skills performance • Knowledge (objective written examination) • Attitudes regarding learning experience	Accuracy of blood pressure measurement improved from 21.5% in the first session to 97.6% in the third ($p < 0.05$). Knowledge significantly improved on all five knowledge questions (range: 14.3%–88.3% correct on the pre-simulation knowledge quiz to 95.8%–97.9% correct on the post-simulation quiz). Attitudes regarding simulation were relatively unchanged after the experience

TABLE 1 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Seybert (2011a)	Acute care simulation (design of a pharmacotherapeutic plan) Self-study via online learning modules followed by simulation activity	13 pharmacy students	• Performance/critical thinking skills (pharmacotherapy plan rubric administered at midpoint and final) • Knowledge (weekly pre/posttests) • Satisfaction (online survey)	Average post-test knowledge scores improved on all clinical areas except for sedation ($p < 0.05$). Simulation performance (patient introduction, pharmacotherapy plan, verbal communication, and data collection and interpretation) numerically improved from midpoint to the final; only data collection and interpretation were statistically significant
Seybert (2012)	Management of dysrhythmias and heart failure Randomized, crossover study with two learning strategies (HFS and problem-based learning)	29 pharmacy students	• Knowledge (pre/post-quizzes for each learning strategy) • Clinical assessment (evaluation for introduction to the patient, data collection and interpretations, patient problem list, pharmacotherapy plan, monitoring, verbal communication)	Average scores on a pre-assessment quiz were similar between the simulation and problem-based learning groups ($p = 0.704$). Average scores on the post-assessment quiz and clinical evaluation were higher for the simulation group than for the problem-based learning group (68.7% vs. 59.3%, $p = 0.013$ and 78.8% vs. 63.1%, $p < 0.001$, respectively)
Smithburger (2012)	Seizure disorders laboratory Randomized, crossover study with three learning strategies (HFS, problem-based learning, and SPs)	103 pharmacy students (third year)	• Knowledge (quizzes after each learning strategy) • Satisfaction with learning strategy	Quiz scores from HFS were higher than those from the SPs and problem-based learning in cases A and B ($p < 0.001$); quiz scores for SPs were higher than those for problem-based learning in case C ($p = 0.001$) More students agreed or strongly agreed HFS (91%) improved their knowledge compared with problem-based learning (69%) and SPs (67%) ($p < 0.001$)
Thomas (2018)	Simulation-based emergency medicine elective course	24 pharmacy students	• Knowledge (performance on examination) • Student satisfaction with elective course	Midterm and final examination performance did not differ between groups that took an active part in simulation and groups that observed over a 2-year span ($p > 0.05$ for all comparisons). There were very high levels of agreement (agree or strongly agree) for simulation as being valuable to learning (100%), application of classroom learning (100%), critical thinking skills (95.5%), and skills transferrable to APPEs gained (100%)
Vyas (2010)	HFS series (6 week) as a supplement to IPPEs Two groups: Simulation series participation or no participation	27 pharmacy students (fourth year)	• Knowledge (post-simulation quiz) • Clinical confidence	Post-simulation knowledge scores statistically improved for the three clinical areas (asthma, heart failure, and endocarditis; $p < 0.01$ for each comparison). Confidence improved from 48% to 78% on each of the 10 self-reported domains that rated confidence ($p < 0.05$)
Pharmacy residents				
Bartel (2014)	ACLS	PGY1 pharmacy residents ($n = 8$)	• Confidence and comfort • Perception of value	ACLS didactic and simulation training requirements increased resident confidence and comfort levels Residents perceived that didactic and simulation training better prepared them to function as a pharmacist on the ACLS team

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TABLE 1 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Eng (2014)	ACLS	PGY1 pharmacy residents ($n = 12$)	• Knowledge, confidence, and competency via written exam, survey, and simulated exercise	HFS training improved resident knowledge (written examination: from 65% to 88%, $p = 0.001$), confidence (confidence score on a five-point Likert scale: from 3.2 to 4.0, $p = 001$), and competency (competency evaluation: from 64% to 77%, $p = 0009$)
Morris (2019)	Medical emergencies	PGY1 pharmacy residents ($n = 33$)	• Perceived competence • Overall experience and satisfaction with each simulation	Perceived competence of simulation-trained versus non-simulation-trained controls was significantly greater for 5 of 12 medical emergency scenarios (acute coronary syndromes, symptomatic bradycardia, supraventricular tachycardia, ventricular tachycardia, cardiac arrest) Perceived the simulation curriculum would improve their performance as a clinical pharmacist
Thompson Bastin (2017)	Medical emergencies	PGY1 ($n = 9$) and PGY2 ($n = 4$) pharmacy residents	• Self-reported perception of preparedness and sustainability of preparedness (measured pre, post, and 6 months post)	Residents reported that simulations met their expectations (scores: 71.5–81.5 on a 100-point scale) and that PGY2 residents facilitated the simulations fairly well (scores: 68.5–80 on a 100-point scale) Residents reported benefits of simulation training persisted at 6 months
Interprofessional learners				
Bolesta (2014)	Acute care (cardiovascular patient care)	Pharmacy ($n = 48$) and nursing ($n = 7$) students	• Readiness for interprofessional learning with addition of questions to assess IPE effect on discipline-specific abilities, attitude toward IPE, and communication (pre/post; modified RIPLS)	Improved student attitudes toward and readiness to participate in IPE after the experience, specifically improved positive thoughts about other professionals, desire for collaboration with other health care students, ability to be team members, and understanding of their team roles ($p < 0.05$ for each)
Clark (2015)	Semester-long class with HFS on critical illness (also included medium- and low-fidelity technologies, paper-based case studies, debriefings, quizzes, and reflections) TeamSTEPPS	Pharmacy, nursing, social work, respiratory therapy students (total: $n = 45$ pre; $n = 37$ posts)	• Changes in student perceptions in collaboration, communication, and value as team members (pre/post; modified TeamSTEPPS TTPQ and TTAQ)	Significant increase in perceived understanding of scope of practice of other disciplines (24.4%–60% strongly agreed/agreed) Students also gained appreciation for working with an interprofessional team, with an increased number agreeing/strongly agreeing that working on an interdisciplinary team was challenging (66.7% vs. 81%)
Frenzel (2019)	Adult cardiac arrest	Pharmacy ($n = 83$) and nursing ($n = 57$) students	• Teamwork and collaboration, professional identity, team skills, competence (pre/post; RIPLS, TSS)	Post-simulation scores were improved in teamwork and collaboration, professional identity, team skills, and competence in managing adult cardiac arrest ($p < 0.001$)

TABLE 1 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Fusco (2018)	Hospital-based scenarios (ED: adolescent acute asthma exacerbation, adult GI bleed)	Pharmacy ($n = 104$) and nursing ($n = 93$) students	• Perceptions of interprofessional collaborative practice (pre/post; SPICE-R assesses attitudes toward interprofessional health care teams and the team approach to patient care) • Satisfaction and self-confidence (post; SSSCL)	Overall positive impact on perceptions of interprofessional health care teams, with median score increases in all SPICE-R items ($p < 0.01$) for pharmacy students and 9 of 10 items ($p < 0.01$) for nursing students regarding questions pertaining to teams and teamwork, roles and responsibilities, and patient outcomes Students overall rated the experience and their confidence highly on the SSSCL, with nursing student scores higher than pharmacy student scores for 7 of 13 items ($p < 0.05$)
Gannon (2017)	End-of-life care Paper case scenarios (pharmacy students only) versus IPE simulation of same scenarios	Pharmacy students ($n = 158$) Advanced practice nursing ($n = 8$) and pharmacy ($n = 37$) students	• Attitudes toward end-of-life care (pre/post both groups; Lazenby's EPCS—used to identify learning needs) • Readiness for interprofessional learning (pre/post-simulation group only; RIPLS)	Perceived improvement in end-of-life care as shown by greater changes in pre/post scores in the EPCS in all but two areas than in the paper-based group in areas ranging from cultural and ethical values to patient and family-centered communication to effective care delivery After adjustment, six items remained significant in the subdomains of patient and family communication and culture and ethical values in the simulation group compared with the paper-based group. RIPLS scores pre- and post-simulation did not differ significantly, potentially because only a few post-surveys were completed
Kim (2017)	Critical event/disaster response Online didactic course followed by a 4-h HFS TeamSTEPPS	Allied health ($n = 8$), medicine ($n = 156$), nursing ($n = 160$), and pharmacy ($n = 79$) students	• Course impact on learning performance, leadership, team development, communication, and training satisfaction (pre/post: UW Macy Teams Assessment—Items address course impact on training benefits, learning, and performance, learning environments, skills, team structure, leadership, situation monitoring, mutual supports, communication, training satisfaction, frequency the scenarios allowed practice or observation of various team functions)	Simulation training resulted in improvement in team participation values, critical event knowledge, and reported learning of useful skills (94% of participants) Simulation training resulted in self-reported improvement in team contribution (24%; $p < 0.01$), communication facilitation (18%; $p < 0.001$), and working with teams (15%; $p = 0.01$); delegation, planning, leadership, and conflict resolution were not statistically significant ($p = 0.3$, 0.74, 0.14, and 0.12, respectively)
Lucas (2020) a	Stroke management RIPE model	Pharmacy ($n = 56$) and nursing ($n = 8$) students	• Perception of interprofessional collaboration (pre/post, student perceptions of their role and responsibilities, working collaboratively to enhance clinical decision-making, and the roles and responsibilities related to other health care members of the team-based care; quantitative and qualitative portions)	Pharmacy students had a positive increase in perceptions for all six items ($p < 0.05$), ranging from awareness of the roles and responsibilities of their own profession and that of the nurses in team-based care to clinical decision-making to communication to teamwork Findings were supported in thematic analysis, which showed that the simulation activity helped develop appreciation and respect for healthcare team members, particularly with respect to enhanced decision-making, communication, collaboration, and new understandings of roles and responsibilities

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TABLE 1 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Lucas (2020a)	Acute care (acute stroke) Seven focus group sessions lasting 18–28 min composed of six to eight participants RIPE model	Pharmacy students ($n = 55$), nursing students, practicing licensed nurses	• Interprofessional collaboration and communication (emerging themes: time management, patient-centered care, communication, and teamwork [qualitative focus groups])	Four key themes emerged from thematic analysis of participant responses: time management with managing interruptions in a time-pressured acute care environment, patient-centered communication and engaging patients and family in care, communication as a vital skill, and recognizing the importance of teamwork, relationships, and respect
Marshall (2020)	Medical error disclosure	Medicine ($n = 85$), pharmacy ($n = 50$), nursing ($n = 36$), and physician assistant ($n = 15$) students	• Targeted IPEC core domain competencies (values and ethics for interprofessional practice, roles and responsibilities, interprofessional communication, teams, and teamwork) • Attitudes toward IPE and medical error disclosure plus IPAS—Subscales included teamwork, roles/responsibilities, patient-centeredness, diversity and ethics, community-centeredness (mixed-methods: pre/post-survey and focus groups)	A positive change was shown by the survey analysis, which was confirmed in focus groups in teamwork, roles, and responsibilities and all four domains of IPEC core competencies with persistent profession-specific impacts of the simulation on interprofessional skills, attitudes, and behaviors Pharmacy students experienced positive change across a wider range of interprofessional attitudes, including teamwork, roles, responsibilities ($p = 0.038$), patient-centeredness ($p = 0.005$), community-centeredness ($p = 0.047$), and importance of healthcare professionals disclosing medical errors as a team ($p < 0.001$)
Meyer (2017)	Pharmacology (digoxin toxicity, management of changes in blood pressure and heart rate, management of heart failure)	Pharmacy ($n = 77$) and nursing ($n = 69$) students	• Perceptions of interprofessionalism (pre/post; ATHCT) • Perception of impact on pharmacology knowledge and professionalism (post; self-assessment, included a combination of Likert-type questions and open-ended questions)	HFS in pharmacology can positively affect students' perceptions of interprofessionalism, as shown by improved ATHCT scores (from 4.55 to 4.75; $p = 0.005$), and most students (> 90%) reported that pharmacology knowledge and the simulation improved their ability to apply pharmacology knowledge
Smithburger (2013)	Acute care (hypertensive crisis and bacteremia) Once weekly for 4 week	Medical ($n = 1$), pharmacy ($n = 2$), nursing ($n = 2$), physician assistant ($n = 2$), social work ($n = 1$) students	• Student perception • CATS—assesses coordination of care, situational awareness, and interprofessional communication	Students perceived that the HFS improved their ability to communicate with other professionals, confidence in patient care in an inpatient team, and interest in inpatient work and that it was an efficient use of student time CATS scores improved weekly over the month (sessions 1 to 2 [$p = 0.01$]; 2 to 3 [$p = 0.035$]; 1 to 4 [$p = 0.001$]) except sessions 3 to 4 ($p = 0.07$)
Southall (2021)	Acute anaphylaxis	Medicine ($n = 9$), nursing ($n = 11$), and pharmacy ($n = 4$) students	• Readiness for interprofessional learning (pre/post-RIPLS; includes domains such as teamwork and collaboration, professional identity or roles of the team, professional responsibilities, and readiness for interprofessional learning)	After participating in the simulation, the mean scores of 10 of the 19 groups showed significant improvement in positive attitudes toward teamwork and collaboration, a better understanding of clinical problems, enhanced communication skills, increased understanding of professional limitations, more trust and respect for team members, and the benefits of interprofessional learning opportunities

TABLE 1 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Tilley (2021)	Chronic cardiovascular disease	Pharmacy and advanced practice nursing students ($n = 96$)	• Perception of interprofessional competency (pre/post; ICCAS—six domains: communication, collaboration, roles and responsibilities, collaborative patient/family approach, conflict resolution, and team function) • Satisfaction (post; 5-point Likert scale survey; 1 = excellent, 5 = poor)	Students perceived improvements in communication, collaboration, roles and responsibilities, collaborative patient/family approach, conflict resolution, and team function after the simulation activity ($p < 0.001$) Students rated the IPE simulations as a positive experience that allowed them to appreciate other healthcare team members roles, was well organized, and had highly engaged faculty
Wilson (2016)	Acute care (managing dyspnea) TeamSTEPPS	Medical, physician assistant, nursing, and pharmacy students ($n = 1475$ over 5 year)	• Based on IPEC: Collaboration, professional roles, communication, team performance (i.e., team skills over clinical management) • Perception of experience, qualitative comments	From 2013 to 2015, most students rated the workshop highly for being useful and practical, helping to learn new skills, providing sufficient orientation to the experience, and enhancing their understanding of other professions' roles and responsibilities; they found scenarios appropriate to level of training and considered the faculty excellent Qualitative comments focused on the importance of TeamSTEPPS skills and communication between professionals; qualitative comment themes included the value of the experience, desire for additional simulation opportunities during professional training, and importance of teamwork and communication skills

Abbreviations: ACLS = advanced cardiac life support; ATHCT = Attitudes Toward Health Care Teams Scale; BLS = basic life support; CATS = Communication and Teamwork Skills; EPCS = End-of-Life Professional Caregiver Survey; HFS = high-fidelity simulation; ICCAS = Interprofessional Collaborative Competencies Attainment Survey; IPAS = Interprofessional Attitudes Scale; IPE = interprofessional education; IPEC = Interprofessional Education Collaborative; IPPE = introductory pharmacy practice experience; RIPE = Reflective Interprofessional Education Model; RIPLS = Readiness for Interprofessional Learning Scale; SP = standardized patient; SPICE-R = Students' Perceptions of Physician-Pharmacist Interprofessional Clinical Education Revised; SSSCL = Student Satisfaction and Self-Confidence in Learning; TSS = Team Skills Scale; TTAQ = Teamwork Attitudes Questionnaire; TTPQ = Teamwork Perceptions Questionnaire.

studies have also found that interprofessional HFS improves participants' perception of interprofessional collaboration.[54,58,69]

Improved interprofessional competency of pharmacy students has been shown using the Interprofessional Collaborative Competencies Attainment Survey (ICCAS) to assess self-reported communication, collaboration, roles and responsibilities, collaborative patient/family approach, conflict resolution, and team functioning.[71] Improved team communication between medical, pharmacy, nursing, physician assistant, and social work students was shown using the Communication and Teamwork Skills (CATS) assessment after four HFS sessions of once-weekly management of acute care.[57]

3 | LOW-FIDELITY SIMULATION

Unlike HFS, low-fidelity simulation (LFS) models do not need to be controlled or programmed externally for learner participation in the activity.[73] LFS mirrors the actual action or scenario closely but omits some elements of the real-life experience, thus enabling the learner to grasp smaller concepts more easily as building blocks of a larger concept. Therefore, LFS is often used to build knowledge and provide a more suitable scenario for initial practice than HFS. LFS may be particularly useful in settings that lack resources to support HFS and can also play a key role in helping learners accrue knowledge and skills over time. By leaving out certain elements of the actual situation, LFS creates a less-distracting opportunity for learners to focus on basic knowledge and skills.[74] In this paper, LFS is defined as activities that are not fully reflective of real-world interactions, including case studies, task trainers, and role-playing.

3.1 | Examples of LFS in pharmacy education and training

Although LFS will feel the least real to the learner, it is useful to build knowledge and develop basic skills. Task trainers, one common form of LFS, are models or manikins that represent a body part, such as an extremity or anatomic structure. Such devices allow the learner to focus on an isolated task. Examples of task trainers are intravenous (IV) arms and injection pads, which can allow students to practice IV insertion and injection techniques without feedback. One publication compared two forms of LFS to train and assess pharmacy students' injection techniques: injection pads and patient simulator injection arms. Students' ability to administer an injection and their self-perceived levels of confidence, proficiency, and anxiety did not depend on the type of simulation training used.[74] Case studies are another example of LFS and may be delivered via interactive fiction or eCases. Interactive fiction is a digital media for delivering computer-based "choose-your-own-adventure" stories and can be used to assess clinical decision-making. This low-fidelity approach requires significantly less time and fewer resources to develop and deploy than high-fidelity options such as virtual patients.[75] Role-playing is another example of LFS in which role-players assume the attitudes of another to understand a different point of view. Role-playing differs from standardized or virtual patients because players are not coached to perform similarly to an actual patient (e.g., symptoms or diseases); hence, a student's performance can be determined by an evaluator or another student.[2] Overall, LFS modalities are relatively easy to implement and less expensive than HFS techniques. Although LFS does not provide learners with the most authentic experience, learning outcomes can still be assessed with this method.

3.2 | Learning outcomes assessed using LFS and evidence supporting use in education and training

Simulations are meant to support learning objectives and outcomes; however, data are limited regarding the impact of LFS on learning outcomes. Learning outcomes typically assessed via LFS include interprofessional education outcomes, noncognitive skills, and certain discrete tasks (Table 2). With the use of LFS to teach the medication use process among pharmacy and nursing students, students reported increased confidence and satisfaction with accurately calling in, retrieving, and filling a prescription.[76] Noncognitive skills assessed using LFS are critical thinking, problem-solving, communication, and interpersonal interaction. A simulator of any level of fidelity can be incorporated into activities to increase student confidence and competence in technical skills.[77] A low-fidelity heart and breath sounds simulator used in a didactic pediatric elective showed that LFS increased student confidence, knowledge, and interest in pediatrics.[78]

Each simulation technique has the potential to provide different learning and development opportunities for learners, depending on the intended learning outcome and required fidelity. Michael et al. outline how simulation-based training in pharmacy school can support skills acquisition and pharmacist development. The article gives the example of using an artificial arm or medication chart as LFS to teach discrete tasks such as blood pressure monitoring and medication reconciliation, respectively.[79] Another discrete task that can be assessed using LFS is physical assessment.

HFSs are not required for a simulation to be successful. In a study comparing the high-fidelity human patient manikin SimMan with student peer role-players, student outcomes did not differ with respect to the type of simulated patient used.[80] Several studies in medical education have found no distinct advantage of HFS over LFS with respect to improvement in knowledge or skills.[81] The appropriate level of fidelity depends on the intended learning goals. Different levels of fidelity may be needed for different objectives and levels of trainees, and literature is limited on the impact of using low-fidelity measures among pharmacy residents.[82] Future research should include the types of LFS used to facilitate knowledge and skills delivery in residents and evaluate the changes in learning outcomes.

4 | STANDARDIZED PATIENTS

SPs have widely been used to simulate clinical settings in the education and training of health professionals of various types for almost

TABLE 2 Learning outcomes associated with low-fidelity simulation activities.

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Student pharmacists				
Eiland (2021)	Physical assessment of heart and lung sounds	106 pharmacy students (second year)	• Confidence in performing a physical assessment • Knowledge of pediatric vital signs	All post-simulation confidence scores improved ($p < 0.001$), and 98% of students showed competency on the final assessment
Morningstar-Kywi (2021)	Interactive digital patient cases on several topics	~500 students (cases were used in multiple classes)	• Confidence in the topic and understanding of material	> 90 of students reported that cases helped them learn
Perea (2020)	Physical assessment Two groups: SimMan versus student peer SPs	139 pharmacy students (first year)	• Pharmacists' Patient Care Process: Physical assessment technique • Student preference for SP or manikin	95% of students practicing on a live patient and 88% of students practicing on a manikin agreed their physical assessment skills improved
Skoy (2013)	Immunization training Two groups: Using injection pad and using injection arm simulator	78 pharmacy students (third year)	• Self-assessed proficiency, confidence, and anxiety in administering immunizations	Self-rated proficiency of administering an injection increased from no proficiency to somewhat proficient, confidence increased from low to somewhat confident, and anxiety decreased from some to low anxiety
Interprofessional learners				
Bartlett (2020)	Asynchronous medication administration safety activity	126 nursing students (first year) 152 pharmacy students (first year)	• Confidence in performing the activity • Satisfaction with the activity	> 80% of students expressed satisfaction and confidence after learning

Abbreviation: SP = standardized patient.

60 years. However, like many other aspects of clinical education and practice developed decades ago, the evidentiary base supporting the use of SPs in health professions education is relatively weak and includes several observational and anecdotal reports and few rigorous studies.[83,84]

By definition, SPs are trained to play the role of a patient or other character consistently across student encounters in a scripted case scenario to provide a safe, standard learning environment.[84] In some instances, the terms SP and *simulated patient* are used interchangeably; however, a simulated patient more commonly refers to the types of HFS mentioned earlier, such as manikins capable of programmable physiologic responses to interventions.[66,85] *Standardized colleagues* portray physicians or other healthcare professionals to be on the receiving end of recommendations and interact in a simulated interprofessional healthcare environment. In an ideal setting, standardized colleagues are played by a healthcare professional because a background that includes clinical training generally produces more realistic encounters.[86,87]

Developing scripts for objective structured clinical examinations (OSCEs) and training a wide variety of actors, students, other health professionals, educators, and retirees (including retired physicians, nurses, and other health professionals) to consistently and uniformly portray the desired patient is expensive and labor-intensive over the long term. However, these initial expenses are low compared with HFS or interactive human or animated videos. Use of live SPs provides greater fidelity in portraying simulation scenarios for teaching and evaluating physical assessment, communication, empathy, motivational interviewing, and other skills requiring human interactions. SPs can simulate illnesses and clinical situations not commonly encountered in the actual care setting. In high-risk scenarios, SPs provide the learner with a safe environment for acquiring new knowledge and developing advanced skills.[84]

4.1 | Examples of SPs in pharmacy education and training

Use of SPs is a widespread practice in pharmacy education to develop both communication and clinical skill sets among pharmacy students and sometimes for pharmacy residents. Incorporating SPs into pharmacy curricula allows students to build confidence in their patient communication skills in a safe, controlled environment and has been shown to improve empathy as well as cultural and emotional competence.[84,88] The teaching of physical assessment skills, such as cardiac, pulmonary, and dermatologic assessments, can be augmented with the use of SPs.[89,90]

In a senior-year clinical skills course at one university, use of SPs was transitioned to more than 40 “simulated patients” portrayed by actors and representing members of an elaborate, multigenerational family tree. With input from practicing community pharmacists, the SPs were encouraged to be creative while adhering to the outlines of a plot, history, and outcome for each “patient.” Students completing this clinical skills course had high pass rates on the licensing board's OSCE. Positive feedback was collected from randomly selected students during qualitative interviews 3 years after graduation and licensure.[91]

SPs have been used for simulating interprofessional activities among medical, nursing, dental, physical therapy, and pharmacy students in both ambulatory care and high-stress emergency department simulations.[11,92] Use of SPs in pharmacy residency training has not been extensively explored. However, one study using mixed simulation modalities, including SPs, positioned PGY1 residents as a benchmark for pharmacy students in their first and third professional years to strive for as they compared clinical skills between learner levels.[7]

4.2 | Learning outcomes assessed using SPs

SPs can be used to teach and assess a variety of outcomes (Table 3). Outcomes may be assessed by the SPs themselves, a third-party observer, such as a faculty member or preceptor (who sometimes use video to observe several interactions of learners and SPs), self-assessment by a student, or a combination of these.[96]

Use of SPs to assess entrustable professional activities (EPAs) in medical schools and physician residency programs is well-established in the literature.[97–100] Although little has been published specifically about using SPs to assess EPAs in pharmacy curricula, SPs have been used to assess students' core domain abilities before they begin advanced pharmacy practice experiences (APPEs).[10] SPs may be used to assess specific tasks in the Pharmacists' Patient Care Process (PPCP), such as collecting information via patient interview and developing and implementing a plan in collaboration with the “patient.”[101,102] SPs are particularly helpful for teaching and assessing directly observable tasks such as physical assessment, with some students indicating a preference for SPs over manikins for learning physical assessment and examinations.[89]

The most commonly documented use of SPs in pharmacy curricula is for teaching and assessing interpersonal skills such as communication, motivational interviewing, and counseling skills, including the ability to show empathy during patient encounters.[88,103–107] Students may report improved confidence in their communication skills after interacting with SPs.[86,108] In one study, mock patient interactions were more effective at teaching motivational interviewing skills to pharmacy students than peer role-play or written dialogue.[109] In a learning activity, a standardized colleague was used to assess students' ability to admit uncertainty to a healthcare provider.[110]

4.3 | Evidence supporting use of SPs in education and training

Evidence for the reliability, validity, and replicability of the use of SPs in health professions education and postgraduate training is more from experiential and observational reports than from rigorous, well-controlled, comparative studies. Pharmacy education has increased the incorporation of SPs as expectations for effective direct patient communication have increased, competition for training sites has grown with the increased number of pharmacy schools and residency training programs, and shorter hospital stays have reduced patient access during acute care-based APPEs.

Four themes have been identified from the literature on the use of SPs in pharmacy education: student satisfaction; effectiveness in imparting knowledge, skills, and interprofessional practices; use in assessment; and cost of the educational activity. In addition, student acceptance of SPs as a teaching tool is high, and evidence supports the benefit of SPs in teaching pharmacy-related knowledge and skills.[84]

Use of SPs in education and training has some degree of external validity because the student or resident encounters a live person describing symptoms or displaying emotions, just as patients do when talking with health professionals. However, internal and construct validity are not ensured, and differences among SPs' and learners' reactions are difficult to predict, measure, or control. SPs are real people, and differences in personality, as well as interpersonal skills, can affect their interaction with the learner. How well the actors are trained and scripted may affect replicability. Similarly, students and residents may react differently to SPs depending on congruence or incongruence of age, gender, race, ethnicity, and other factors influencing human behavior. How closely the interactions match those in the real world affects construct validity when SPs are used in teaching. The reliability of SP-based education for achieving stated learning objectives is often unstudied and not compared with the efficacy or costs of other forms of simulation and pedagogical methods.[84,86]

In nursing education, SPs are used frequently, and many studies have been published. A 2019 systematic review analyzed 65 studies on the use of SPs in nursing education. The authors concluded that more randomized controlled trials were needed as well as studies with power analyses and validated measurement instruments. The dearth of comparisons of SPs with HFS was also noted, which are needed to “determine optimal student learning outcomes and standardize best practices in simulation,” the authors concluded.[111]

A scoping review examined the templates and protocols used to direct actors in SP roles. From 2746 published reports of quasi-experimental, mixed-methods, and qualitative studies of the use of SPs in health professional education, 17 met the study criteria and were analyzed in detail. Educational settings included medical, nursing, allied health professional, and veterinary medical schools, including one study of pharmacy students.[86,112] Only one of these studies clearly validated the cases used by SPs, and two studies evaluated the authenticity of the SP portrayal. Accuracy and consistency of SP portrayals, consistency among actors when more than one was used, and

TABLE 3 Learning outcomes associated with SP simulation activities.

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Student pharmacists				
Austin (2006)	OSCE: Switching from standardized to simulated patients Two nonindependent groups: Learner surveys and postgraduate interviews	114 and 14 pharmacy students (fourth year)	• Licensing exam pass rates • Learner satisfaction and perceptions about score fairness	98% of learners passed their licensing exam on the first attempt Students expressed concern about assessment methods regarding the switch from standardized to simulated
Bradley (2021)	Case scenario: Communicating uncertainty, in-person standardized client versus virtual written case Two cohorts, third-year pharmacy students (2019, 2020): Survey; qualitative free-form response	50 pharmacy students (third year, spring 2019); 46 pharmacy students (third year, spring 2020)	• Reflection on ability to say "I don't know" • Reflection on ability to interact with a busy/distracted provider	Both the SP and the virtual written case groups felt more confident in saying "I don't know," with no differences between groups Students in the written case-cohort often desired more practice opportunities than those in the SP group
Cho (2019)	Two OSCEs with internal SPs (faculty/staff) and trained actor SPs P3 pharmacy students and faculty: Electronic survey	54 pharmacy students (third year)	• Perceptions regarding internal SPs (faculty/staff) versus trained actor SPs	Most students reported that actor-SPs more realistically played patients (77.8%) and created a more comfortable environment (75.9%) than faculty-SPs
Davies (2015)[93]	SP and standardized colleague One cohort: Pre- and post-surveys	107 pharmacy students (third year)	• Change in performance on SP and standardized colleague interviews and SOAP notes • Student confidence in performance • Attitudes and perceptions about SPs and standardized colleagues	Students showed more improvement between practice and final activities when using SPs than when using standardized colleagues ($p < 0.0001$ vs. 0.58, respectively) 83.5% of students agreed this activity strengthened their communication skills, and was beneficial for future experiences; recommended continuing this activity
ElGeed (2021)	Not specified Survey	133 pharmacy students and recent graduates (second, third, and fourth year and two graduating classes)	• Perceptions regarding SPs for professional skills, patient assessments, and practical examinations	52.4% of patients disagreed that interactions with standardized colleagues were preferred to SPs > 90% of students reported that interactions with SPs improved their communication and counseling skills
Galal (2018)	Motivational interviewing with SPs Evaluator rubric and student self-assessment scores	205 pharmacy students (first year)	• TA and SP scores via rubric • Student self-assessment of verbal/nonverbal communication, social-emotional competence, and motivational interviewing skills	Students showed significant improvement in both TA ($p < 0.001$) and SP ($p = 0.002$) scored assessments between weeks 1 and 2 Students also gained significant self-confidence in all areas assessed ($p < 0.001$)
Gillette (2017)	Drug information and communications course incorporating SPs Three cohorts: Case studies, discussion, peer role-play (2013, 2014 offering); case studies, discussion, peer role-play; and SPs (2015 offering)	220 pharmacy students (second year)	• First-time pass rate and scores for high-stakes communications exam	Students who were taught using SPs were significantly more likely to pass the exam on the first attempt than were those taught using peer role-play (90.79% vs. 61.6%, $p < 0.0001$). Use of SPs was associated with a 3.45-point increase (11.3%) in student scores on the assessment

(Continues)

TABLE 3 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Grice (2013)	Physical assessment skills: Cardiac and pulmonary Two groups: One with a manikin and one with an SP	154 pharmacy students (third year)	• Difference in performance by learning modality • Levels of comfort, confidence, and accuracy • Modality preference and satisfaction	No difference in performance scores between students using manikins and students using SPs ($p = 0.81$) Students reported more dissatisfaction with manikins than with SPs ($p = 0.004$)
Lempicki (2021)	SP: Communication skills Rubrics (SPs, evaluators) and self-evaluations (students)	206 pharmacy students (midpoint assessment); 208 pharmacy students (final assessment (first and third year)	• Agreement between student self-evaluation via a rubric, SP evaluations, and evaluator (pharmacist, pharmacy resident, and community pharmacist) evaluations	Between the midpoint and final communication evaluations, agreement between SP and students improved from 62.9% to 83.7%, respectively
Lupu (2012)	Three strategies for motivational interviewing skills Three groups: Written dialogue, peer role-play, or mock-patient counseling activities; post-activity summative assessment and survey	143 pharmacy students (first year)	• Student knowledge of motivational interviewing techniques • Student confidence in motivational interviewing skills	Mean change in knowledge scores was significantly greater in the SP group than in the written dialogue group ($p < 0.01$)
Mafinejad (2017)	Validation and training of SPs for a communication assessment SP performance on three scenarios: Correlation of scores; observer rating	12 pharmacy students (fourth year) interacting with four SPs	• Correlation between SP and rater scores on assessment checklist • Observer rating of SPs case portrayal	Correlation of scoring between raters with SPs was 0.75 Interrater reliability between observers and SPs was 0.75 ($p = 0.01$)
Murry (2022)	SP interview One group: Communication rubrics	141 pharmacy students (third year)	• Level of empathy and communication scores	Found a positive association between students' communication and empathy scores ($p < 0.05$)
Rickles (2009)	Lecture-laboratory course including SPs for communication activities Students: Performance scores, survey SPs: Survey	127 pharmacy students (second year of 6-year program)	• Student performance measured by scores on videotaped counseling encounters • SP and student attitudes about SP program and lab sessions	Students' communications scores significantly increased from baseline at both the midpoint and final evaluations ($p < 0.001$)
Shrader (2015)	Standardized colleague One cohort: Pre- and post-survey	171 pharmacy students (fourth year)	• Student performance of SBAR presentations • Self-confidence in interprofessional communication	Students' communication scores improved significantly for both inpatient and outpatient SBARs ($p < 0.0001$) Student self-confidence significantly increased in all five survey items
Vyas (2019)	Simulated colleagues One group: Performance scores and pre- and post-attitudes surveys	182 pharmacy students (second year)	• Performance scores • Attitudes about simulated EHRs and colleagues	> 90% of students reported the simulation increased their understanding of professional roles and importance of interprofessional communication

TABLE 3 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Wallman (2013)	Systematic review of communications in pharmacy education, 1995–2010	Pharmacy students	N/A	61 articles were included Of the studies included, 39 were from the United States. Learning activities described included simulated and SP interactions; interdisciplinary activities; seminars, courses, and pharmacy practice experiences; and computer-based activities Patient-focused simulation activities included interviewing, patient education or public health promotion, and consulting
Yuksel (2011)	Development of a pharmacy course, including assessment of PPCP with SPs Four-course offerings: Course evaluation survey	508 pharmacy students (undergraduate, Canada)	• Student perceptions of the course	Of the 508 students who completed the course, 60% completed evaluations. Student feedback was positive overall
Pharmacy residents				
Benedict (2017)	Blended simulations, including SPs Three groups: P1 and P3 students, PGY1 residents	18 pharmacy residents, 108 third-year pharmacy students, and 106 first-year pharmacy students	• Learner performance and competence regarding virtual patients, decision-making, attitudes, interprofessionalism, and patient communication • Learner attitudes about assessment	N/A
Interprofessional learners				
Smith (2020)	Development of interprofessional capstone experience	230 pharmacy students (second year), 68 dental students (D4) in 2017; 265 pharmacy students (second year) and 90 dental students (D3) in 2018	• Attitudes toward teamwork survey on the Jefferson Scale of Attitudes Toward Interprofessional Collaboration (JeffSATIC) and roles and responsibilities quiz • Pre- and post-assessment scores	There was no statistically significant change in attitudes toward interprofessional collaboration. There was no statistically significant change in knowledge of roles and responsibilities of dental or pharmacy professions
Wamsley (2012)	Clinical skills examination Two groups: One with pre- and post-activity survey and one of nonparticipating students	101 participating students (23 dental, 26 medicine, 21 nursing, 24 pharmacies, and 7 physical therapy) versus 152 nonparticipating (19 dental, 47 medicine, 27 nursing, 50 pharmacy, and 9 physical therapy)	• Attitudes toward health care teams survey	Among all participants, 83% completed the pre- and post-surveys. "Team value" significantly increased for all professions ($p < 0.001$), as did "team efficiency" ($p = 0.014$)

(Continues)

TABLE 3 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Non-pharmacy learners				
CarlLee (2019)	OSCE administered during internship orientation One group	33 internal medicine interns	• Faculty ratings of learner performance for eight EPAs • Post-OSCE survey completed by interns	All 33 participants completed the survey. 79% of interns viewed the skills assessments as helpful Immediate faculty feedback was the most beneficial part of the exercise (94%)
Davies (2021)	Scoping review of use of templates and protocols in SPs in a variety of health professional education programs	Several types of health professional students	• N/A	17 articles were included Of the included studies, five provided protocols or templates for developing/working with SPs. Seven of the studies described using SPs in the development of clinical skills, and 10 described using SPs in the assessment of clinical performance. The included studies indicated that SPs were used in multiple diverse roles in health education
Dwyer (2016)[94]	OSCE Two groups: PGY1 and PGY4 orthopedic residents; evaluation via a checklist and global rating score from a content expert evaluator	Nine PGY1 residents and nine PGY4 residents	• Evaluator ratings of resident performance at stations for three EPAs	N/A—SPs were used in the assessment, but the study was not designed to evaluate the use of SPs
Herrigel (2020)	Development of a simulation-based curriculum	> 450 medical students (third and fourth year)	• Student perception of learning for EPAs mapped to various simulation modalities	Student feedback was "overwhelmingly positive"
Kempner (2016)	Case with SPs: Obtaining informed consent Three cohorts of fourth-year medical students (over 3 year), evaluation via a checklist	251 medical students (fourth year)	• Formative assessment with feedback • 43-point checklist	The case was well received, with "almost universally positive" comments from first-year residents about the SPs. Residents felt that SPs provided helpful feedback
Pritchard (2016)[95]	Systematic review of use in physical therapy education	Physical therapy students	• N/A	14 articles were included Of the included studies, seven used single-cohort study design with pre- and/or post-test evaluations. Three articles reported on five randomized controlled trials, one reported on a nonrandomized controlled trial, and three reported on qualitative studies. Overall, the authors concluded that SPs were similar to other educational strategies for physical therapy competencies

TABLE 3 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Rutherford-Hemming (2019)	Systematic review of use in nursing education – 65 studies	Student nurses	• N/A	Of the 65 studies included, 29 were quantitative, 15 were qualitative, 14 were mixed-method, 5 were literature or systematic reviews, and 2 were meta-analyses. Of note, 27 studies were conducted outside the United States Overall, the authors concluded that rigorous research was lacking regarding the use of SPs in nursing simulations
Wijnen-Meijer (2015)	Performance assessment, including SP interaction Two cohorts (Germany, Netherlands): Evaluation via scoring forms	59 "near-graduate" medical students (Germany, Netherlands)	• Performance of EPAs	N/A—SPs were used in the assessment, but the study was not designed to evaluate the use of SPs

Abbreviations: EHR = electronic health record; EPA = entrustable professional activity; N/A = not applicable; OSCE = objective structured clinical examination; PPCP = Pharmacists' Patient Care Process; SBAR = situation, background, assessment, and recommendation; SOAP = subjective, objective, assessment, and plan; SP = standardized patient; TA = teaching assistant.

documentation of the affect, behaviors, and tone of voice were studied inconsistently in the 17 reports. The authors recommended more consistent inclusion of several categories of information in cases used by SPs: demographics (name, age, and gender), background and situation (including medications), psychosocial information, symptoms, and findings, and instructions to actors (opening statement, conversation starters or extenders, and what to expect with respect to setting, number of students and others present, and time interval).[86]

Use of SPs in pharmacy (and other health professions) education and training is common and perceived as useful; however, extensive evidence is lacking to support its effectiveness, validity, reliability, consistency, lack of bias, and cost. More robust studies could inform pharmacy educators on best practices for SP use.

5 | COMPUTER-BASED SIMULATION

Computer-based simulation (CBS), sometimes called software- or screen-based simulation, replicates real-time decision-making processes in a virtual learning environment, including virtual patients, virtual reality (VR) task trainers, computer-generated game simulators, and VR simulation.[2,113] In pharmacy education, CBS also encompasses mock EHR systems, interactive game-based learning (GBL), and simulations based in extended reality (XR). Although CBS is sometimes considered part of LFS, this paper separates CBS to expand on the use of modern technologies in pharmacy education.

5.1 | Examples of CBS in pharmacy education and training

Pharmacy curricula are increasingly using simulated EHRs to better prepare students for practice. In 2020, 37 of 59 responding colleges/schools of pharmacy reported use of a simulated EHR in their curriculum.[114] Colleges/schools of pharmacy commonly use simulated EHRs to afford learners the ability to practice and perform discrete tasks such as data collection, documentation, medication reconciliation, order entry, and order verification.[114–120] Respondents also commented on the simulated EHR's ability to practice and/or assess various steps of the PPCP and specific Center for the Advancement of Pharmacy Education outcomes.[114] Several other skills and competencies to teach and/or assess in the EHR have been suggested, such as communication, interprofessional collaboration, and data analysis.[13]

Interactive GBL is a type of "serious gaming" in which interactive computer applications are used for training or educational purposes.[121] Game-based learning methods may be more advantageous than traditional methods of instruction, given that they emphasize an incorporation of compelling or competitive elements throughout the game to maintain the learner's interest. In pharmacy education, GBL varies in the types of content explored, game genres, and degree of immersion and scalability.[32] Common uses of GBL include provision of immersive learning experiences in pharmacotherapy, drug information, leadership, entrepreneurship, management, and direct patient

TABLE 4 Learning outcomes associated with CBS activities.

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Student pharmacists				
Ambroziak (2018)	Medication dispensing via computer simulation program	85 Pharm.D. students (first year)	• Skills assessment on final exam (medication dispensing) • Perceptions of simulation program	No relationship established between test score and number of practice exercises completed in the simulation "Majority of students" found the simulation helpful for learning
Bernaitis (2018)	Oncology cases via computer simulation program Two groups: Course taught with simulation and course taught without	62 BPharm students in Australia (final year)	• Knowledge of oncology pharmacotherapy on mid-semester and end-of-semester exams • Perceptions of simulation program	"Majority of students" agreed the technology was engaging, helpful for applying concepts, and helpful for decision-making skills Higher exam scores than a similar course without simulation ($p < 0.05$)
Bushell (2020)	Vaccination training via role-playing, manikins, standardized patients, and MR	37 BPharm and MPharm students in Australia (final year)	• Skills assessment on adult and pediatric manikins • Knowledge via pre- and posttests • Perceptions of learning experience	Improved post-scores (22/30 vs. 14/30, $p < 0.001$) Students indicated satisfaction and value in the MR training
Coons (2018)	Case-based learning using a simulated EHR	115 Pharm.D. students (second year)	• Learning efficiency (i.e., time to optimal recommendation) • Perceptions of clinical skills, communication, and satisfaction	Use of the virtual EHR decreased the time needed to provide the optimal treatment recommendations by 25% compared with control (median of 2.5 min saved during a 10-min patient encounter) Use of the virtual EHR significantly improved students' perceptions of their clinical skills, communication, and satisfaction compared with control 95% of students agreed that use of the EHR contributed positively to their learning
Coyne (2019)	TBL via VR	18 random participants (16 Pharm.D. students)	• Level of immersion and perceived engagement, comfort, and desirability of VR-TBL activities	94% agreed they learned in the VR environment 72% found the environment immersive 68% stated they would choose a VR environment over a current online method for team activities 78% agreed the VR environment was comfortable 11% experienced vertigo
Curtin (2011)	ACLS Two groups, crossover design: Computer-based versus manikin-based sessions	200 Pharm.D. students (unknown year)	• Simulated patient survival for manikin-based sessions (i.e., correct performance of selected ACLS skills) • Percentage score for computer-based sessions • Student satisfaction of learning activities	Higher rate of simulated patient survival if CBS completed first (41.2% vs. 5.6%, $p = 0.018$), but manikin patient survival did not differ between groups Number of teams with BLS in proper sequence (52.9% vs. 0%, $p < 0.001$) > 90% students agreed they enjoyed the CBS and manikin simulations
Fens (2020)	Management of a community pharmacy practice via a simulated multiplayer game-based environment	MPharm students (Netherlands)	• Evaluation of student attitudes toward the game-based platform	Student attitudes from 2011 to 2020 showed that students valued the course with an average grade of 7.8/10

TABLE 4 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Frenzel (2010)	Case-based learning using a simulated EHR	89 Pharm.D. students (third year)	• Perceived gains in knowledge • Perceptions and attitudes related to simulated EHR use	Responses on nine post-survey questions showed significant gains in perceived knowledge 88% of students agreed that pharmacists have the knowledge and resources to positively affect patients' drug therapy problems 97% of students agreed that access to a patient EHR would be useful for documentation
Gibson (2019)[140]	Case-based learning using a simulated EHR	162 Pharm.D. students (second year)	• Perceptions related to simulated EHR use	Perceived efficiency in finding patient information using an EHR and perceived confidence in students' abilities to find patient information in the EHR increased from pre- to post-survey
Gilmartin-Thomas (2020)	Patient experience with dementia via MR	24 BPharm students in Australia (fourth year)	• Qualitative perceptions of learning experience	Student responses included that the AR experience was "thought-provoking, impressive, enjoyable, immersive, educational, interactive, distressing, memorable, confronting, and emotional" Pharmacy student responses included "majority of pharmacies and pharmacists are not currently dementia-friendly"
Gustafsson (2017)	Ward rounds and patient meetings via 3D virtual world	42 MPharm students in Sweden (fourth year)	• Perceptions via course evaluations	Most students agreed the 3D world was helpful 83% of students stated they were able to adopt a clinical pharmacist's role in the 3D world
Ives (2020)	Inpatient medication order processing within a simulated EHR	158 Pharm.D. students (second year)	• Level of confidence • Practical examination performance (skills related to medication order processing) • Perceptions related to simulated EHR use	Student confidence in verifying medication orders increased significantly Practical exam performance improved significantly for students using the simulated EHR compared with students completing the activity using a paper-based medication form the year prior (83% vs. 69%, $p < 0.05$) Student perceptions on the importance of EHRs were high at baseline and did not change significantly
Kirwin (2013)	Common hospital pharmacy tasks (e.g., data retrieval, medication reconciliation) using a simulated EHR	135 Pharm.D. students (third year)	• Confidence • Performance on various skills assessments	Confidence with performing hospital pharmacist tasks increased significantly All average pass rates for the learning objectives assessed were > 85%
Korenoski (2021)	Case-based learning of toxicology topics via a virtual "escape room" game	22 Pharm.D. students	• Knowledge via pre- and posttest scores • Confidence in toxicology topics pre- and post-activity	For case 1, 18% of students received a passing grade on the pretest and 22% on the posttest For case 2, 0% of students received a passing grade on the pretest and 68% on the posttest On a Likert scale, all students ranked their confidence in managing a toxicology case as ≤2; however, after the simulation activity, 95.4% of students reported ≥3

(Continues)

TABLE 4 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Lam (2019)	Case-based learning via a multiplayer online role-playing game	79 Pharm.D. students	• Self-reported familiarity with educational game terms • Attitudes toward virtual learning experience	24.1% and 15% of the students, respectively, indicated quests 1 and 2 were fun and interactive 63.6% and 47.0% of the students completing quests 1 and 2, respectively, stated the simulation exercise should be used in selected courses
Metzger (2015)[141]	Order verification and medication reconciliation using a simulated EHR	83 Pharm.D. students (third year)	• Attitudes and perceptions regarding order verification, medication reconciliation, and other institutional pharmacist roles	95% of students agreed the simulation enhanced their learning 75% of students agreed the simulation increased their interest in institutional pharmacy 96% of students agreed the simulation exercise taught valuable decision-making skills
Oestreich (2022)	GBL and pharmacy	Literature review of 31 articles	• GBL content areas, design, and assessment	Activities depicted in the selected articles showed high engagement in the activities despite high variance in the level of technology used
Patel (2011)[142]	USP 797 standards via a virtual clean room environment	150 Pharm.D. students (third year)	• Pre- and post-assessment knowledge via exam scores	Correct responses improved after the simulation, with 44% correct before the simulation and 74% afterward ($p < 0.01$)
Richardson (2013)	Drug-receptor interactions via MR Two groups, crossover design: Instruction with 2D versus 3D presentations	89 MPharm students in the United Kingdom (second year)	• Medicinal chemistry/ pharmacology knowledge • Perceptions of the interactive 3D learning experience	Improved test scores with 3D learning compared with 2D (63% vs. 72%, $p < 0.05$) 81% students perceived a better understanding with 3D learning
Roosan (2022)	Pharmacogenomics via AR	11 Pharm.D. students (unknown year)	• Usability scale of AR program	Mean final system usability scale score of 83, indicating high usability
Salem (2020)	Contraception and hormone replacement therapy via AR	37 undergraduate pharmacy students in Australia (third year)	• Perceptions of AR learning experience	> 75% agreed AR motivated them to learn, was a more useful learning resource than lectures, and improved their knowledge
Schneider (2020)	Naloxone via AR	25 undergraduate pharmacy students in Australia (all 4 year)	• Knowledge via pre- and posttests • Perceptions of learning experience	Improved post-test scores ($p < 0.001$) "High degree" of user acceptance noted
Sera (2017)	Digital GBL modalities in health professional education	Review article	• Applicability of GBL modalities to various aspects of pharmacy education	N/A
Skelley (2018)[143]	Application of the PPCP with an EHR simulation activity	18 Pharm.D. students (third year)	• Attitudes and confidence regarding EHR use and the PPCP	Statistically significant changes on three post-survey questions related to pharmacist skills and knowledge, benefits of an EHR in didactic coursework, and confidence in documenting clinical activities 94% of students reported feeling confident in their ability to implement the PPCP after the activity (vs. 77% at baseline)

TABLE 4 (Continued)

Author (year)	Simulation activity	Learner	Learning outcomes	Results
Smith (2018)	Case-based learning using a simulated EHR	363 Pharm.D. students (third year)	• Performance on acute care and ambulatory care APPEs • Perceptions of preparedness to use EHRs	No significant differences in acute patient care or ambulatory care APPE performance after simulated EHR implementation Mean ranks increased from baseline on post-survey questions related to knowledge of EHRs, perceived value of EHRs, and confidence levels in effectively using an EHR
Smith (2021)	Medicinal chemistry via AR	179 Pharm.D. students (first and second year)	• Perceptions of AR learning experience	69%–88% of students agreed the AR environment was easy to use
Veronin (2012)	Pharmacy case studies in an elective course via a 3D virtual world	24 Pharm.D. students (second and third year)	• Knowledge and skills via essay-type exam performance (patient therapy cases) • Perceptions via course evaluations	Exam scores ranged from 67% to 94.9% Course evaluations noted comfort and familiarity with using the simulation for communication
Wang (2016)	GBL in training health care professionals	Systematic review of 48 articles	• Assessment of training outcomes used in articles reviewed	42 articles were included, with 33 (79%) including a study design for evaluating the serious game as a teaching intervention 19 studies tried to evaluate their games for improving skill or knowledge, and only 2 (11%) found no significant difference between the intervention and comparison groups when assessed
Zhao (2020)	Human anatomy via VR VR versus other instructional methods	Meta-analysis	• Knowledge via exam scores	Test scores improved with VR ($p < 0.05$) Five studies failed to show statistically significant improvement in test scores

Abbreviations: ACLS = advanced cardiac life support; APPE = advanced pharmacy practice experience; AR = augmented reality; BPharm = bachelor of pharmacy; CBS = computer-based simulation; EHR = electronic health record; GBL = game-based learning; MPharm = master of pharmacy; MR = mixed reality; N/A = not applicable; Pharm.D. = doctor of pharmacy; PPCP = Pharmacists' Patient Care Process; TBL = team-based learning; 2D = two-dimensional; 3D = three-dimensional; VR = virtual reality.

care skills.[21,22,31,32,121–123] Further examples include managing virtual pharmacies, clean room evaluation, clinical problem solving, and clinical concepts in toxicology.[21,22,122,123]

Simulations based on XR, which includes VR, augmented reality (AR), and mixed reality (MR), aim to provide an immersive, realistic experience in which participants' actions affect their experience within the simulated environment.[20] Learning benefits from XR simulations include improved content understanding of spatial structure and function, long-term memory retention, physical task performance, collaboration, and student motivation.[124] In pharmacy education, these simulation types have been suggested to be helpful when teaching visual learners and providing practice in difficult-to-simulate or resource-intensive scenarios.[125,126] Pharmacy topics suitable for XR simulations include pharmacology, anatomy/physiology, compounding, patient safety, and medication errors, critical care, difficult conversations, pharmacy work processes, and memorization gamification.[20,125,126]

Virtual worlds and computer software simulations are the earliest forms and least-immersive versions of XR. Second Life, a virtual world developed for non-pharmacy purposes, has been used to simulate a hospital ward where students attend rounds and patient meetings and host virtual presentations and patient case discussions.[127,128] Computer software simulations, such as MicroSim Inhospital, MyDispense, DecisionSim, CyberPatient, Organ Bath Pharmacology Simulation, AutonomiCAL, Virtual Cat, and Virtual Rat, have been used to develop BLS and ACLS skills, medication dispensing skills, critical evaluation of patient medication regimens, clinical decision-making in oncology patient cases, and pharmacology concept understanding.[19,34,129–131]

More immersive XR simulations with VR, AR, and MR are relatively new to pharmacy education. VR has been used to visualize three-dimensional (3D) representations of human anatomy and as an application for distance team-based learning.[20,132] AR and MR simulations have been used to provide 3D models of drug-receptor interactions and biomolecular structure, additional learning resources for medication information and pharmacogenomics, vaccination training, and immersion in patient experiences of dementia.[133–139]

5.2 | Learning outcomes assessed using CBS

Many of the reported outcomes with CBS focus on student satisfaction, perceptions, and/or attitudes (Table 4). One study found that for students randomized to use a virtual EHR in addition to patient simulation, compared with patient simulation alone, the time needed to provide optimal treatment recommendations decreased by 25%.[16] Conversely, another report described that pharmacy students exposed to a simulated EHR in their third professional year performed no better on acute care and ambulatory care APPEs than previous cohorts not exposed to simulated EHRs.[116]

Published GBL literature primarily assesses student satisfaction, participation, and attitudes toward topic understanding before and after implementation.[32] Students also support the use of GBL in future courses. One study found that students felt more confident in clinical topics after completing the game.[21] Although GBL activities are increasingly being investigated in pharmacy school curricula, current literature lacks descriptions of GBL in pharmacy resident and interprofessional education.

Studies of virtual world and computer software simulations have mainly evaluated students' perspectives.[19,127,128,130] One study reported improved BLS and ACLS performance when CBS was used before manikin simulation.[129] Studies of AR and MR simulations have shown improvement in global learning objectives and qualitative positive student feedback on learning.[133,136,138,139] However, other studies have only described student perceptions of the activities.[134,135,137] Literature describing or evaluating the use of XR simulations in educating pharmacy residents are lacking. Use of VR has improved test scores in anatomy and physiology courses and has been perceived to provide a better environment than other online methods for team learning.[20,132]

In summary, the CBS teaching method generally requires fewer resources than other simulation modalities. Limitations to uptake may include insufficient technological support, preconceived faculty and student attitudes, and time limitations to implementation in the classroom with traditional didactic learning.[117] More studies are needed to show the effectiveness of CBS specific to desired learning outcomes for pharmacy students. In addition, studies using CBS to teach skills to pharmacy residents are completely lacking from the current literature. Because VR simulations require the most development and resources, they are not widely used in pharmacy education, and literature evaluating specific learning outcomes affected by VR simulations has not yet been published.

6 | CONCLUSION

Exciting progress has been made in simulation education in pharmacy over the past 2 decades. Most publications to date have focused on HFS across a variety of pharmacy education settings ranging from didactic to experiential, and most evidence is concentrated in Pharm.D. programs. More publications evaluating various forms of simulation across learner groups are needed. There is growing evidence regarding the impact of simulation on learning outcomes within pharmacy education as well as in interprofessional healthcare education. With the evolving landscape of health professions education and practice, it is important to purposefully align the intended learning outcome with the appropriate simulation modality. Although resource availability is a key component in strategic planning for robust education, there is a significant opportunity for collaboration across all health professions. Simulation has significant potential to continue to advance practice-based learning outcomes for a variety of pharmacy learners.

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