Exploratory Research in Clinical and Social Pharmacy 11 (2023) 100316

Contents lists available at ScienceDirect

Exploratory Research in Clinical and Social Pharmacy

journal homepage: www.elsevier.com/locate/rcsop

A systematic review on the use of virtual patient and computer-based simulation for experiential pharmacy education

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ARTICLE INFO

Keywords:
Virtual patient
Computer-based simulation
Experiential education
Student pharmacists

ABSTRACT

Background: Simulation use is rapidly expanding, with technologies like virtual patients (VPs) and computer-based simulation (CBS) allowing for educators to equip pharmacy students with the necessary skills that are aligned with the demands and expectations of a practicing pharmacy professional. These technologies enable pharmacy students to be exposed to challenging or infrequent patient case scenarios in an authentic pharmacy setting. This allows for the reinforcing of care processes and for techniques and crucial skills to be applied.
Aim of the study: To consolidate the existing evidence regarding the utilization of VPs and CBS in preparing and supporting students in pharmacy experiential education and evaluate the effectiveness of these approaches in enhancing student pharmacists' learning outcomes, including knowledge, skills, confidence, enjoyment, and engagement.
Methods: Five electronic databases were searched using combined keyword and indexing terms (when available) with Boolean operators for the literature search. Studies that reported or investigated the use of VPs and CBS in pharmacy experiential education were included. Data on study design, demographics of participants, information on the interventions, course/skills, primary and secondary outcomes, and qualitative findings were extracted.
Results: A total of 911 unique articles were initially identified and filtered down to 19 articles fitting within the inclusion criteria. The selected 19 articles involved student pharmacists (Y1-Y5) and pre-registered pharmacists from ten countries. Simulation tools were used in various pharmacy courses, including Advanced Pharmacy Practice Experience (APPE), Advanced Pharmaceutical Care II, and Medication Management. Implementing these tools in pharmacy experiential education demonstrated a statistically significant improvement in student knowledge ($p < 0.05$). Most students agreed/strongly agreed that practicing with virtual patient cases enhanced their clinical reasoning, counseling skills, confidence in communication, and attitudes toward the courses.
Conclusions: This systematic review supports the use of VPs and CBS in pharmacy experiential education and provides practical recommendations for educators including selecting suitable tools, implementing them strategically within courses, integrating them with existing activities, and considering financial and IT support.

1. Introduction

The trend in the use of simulation in education continues to expand rapidly. Educational technologies such as virtual patients (VPs) and computer-based simulation (CBS) facilitate educators' provision of experiential opportunities regarding the demands and expectations of the pharmacy profession.[1] A VP is an interactive computer simulation of a computer programmable patient (or avatar) in a real-life clinical scenario for the purpose of medical training, education, or assessment that will respond to learner decisions.[2] Computer-based simulation is defined by the Agency for Healthcare Research and Quality (AHRQ) as, "a simulation-based learning activity designed to provide an experience with inputs and outputs exclusively confined to a computer, usually associated with a monitor and a keyboard or other assistive device".[1]

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https://doi.org/10.1016/j.rcsop.2023.100316
Received 28 June 2023; Received in revised form 5 August 2023; Accepted 5 August 2023
Available online 7 August 2023

Experiential learning is crucial for student pharmacists because it enhances the student-learning experiences and prepares them for success in direct patient care settings.[3] Experiential learning is a philosophy and methodology where educators engage students in direct experiences and reflections to increase knowledge, develop skills, and clarify values. It's also known as learning by doing, learning through experience, and learning through discovery.[4] Typically, several courses in pharmacy curricula provide experiential learning to students - before their advanced pharmacy practice experiences - in order to heighten their professional knowledge, skills, and confidence. However, experiential learning cannot always be provided in-person as university facilities' close during serious pandemics or clinical rotation sites are scarce.[5] The transition to digital delivery of pharmacy education, moreover, has forged new innovations to maintain student engagement and educational mission.[6] Thus, implementing VPs and CBS in experiential learning could address these challenges. These technologies allow students to experience more complex or rare cases that might be difficult to face during their real-world sessions and provide students with opportunities to remind themselves of processes of care, techniques, and essential skills.

Huang and colleagues reported that VPs are well received by students and may improve cognitive and behavioral skills better than traditional methods such as reading articles and applying theory in paper-based case studies.[7] Virtual patients have been used to help learners develop requisite knowledge and skills through independent, practical repetition, and have provided educators with a means of granting learners access to realistic environments.[1] Both VPs and CBS have been implemented in pharmacy education including the provision of medication dispensing and medication therapy management; clinical decision-making in acute care, oncology, and diabetes, and antibiotic administration; patient communication and interprofessional competency; patient assessment and recommendation development; and substance misuse education.[1]

Previous studies have highlighted the diverse range of simulations employed in pharmacy curricula. These simulations aim to enhance student pharmacists' experiences in areas such as basic sciences, dispensing and medication supply, and communication and counseling skills.[2,8,9] A recent review conducted by Beshir and colleagues in United Arab Emirates provided a comprehensive summary of the use of VPs by student pharmacists.[10] The review concluded that VPs not only improve knowledge and clinical decision-making skills but also cater to the needs of students with preferences for active learning.

However, there is a notable gap in the current literature, as there are no studies that explicitly examine the use of VPs and CBS in supporting student pharmacists or pre-registered pharmacists in various aspects. These aspects include their impact on knowledge, skills, satisfaction, confidence, enjoyment, and engagement. This study distinguishes itself by focusing on these areas, particularly during experiential education, pharmacy practice experience, and interprofessional education involving students from other disciplines. Therefore, aims of the study are to consolidate the existing evidence regarding the utilization of VPs and CBS in preparing and supporting students in pharmacy experiential education and evaluate the effectiveness of these approaches in enhancing student pharmacists' learning outcomes, including knowledge, skills, satisfaction, confidence, enjoyment, and engagement.

2. Materials and methods

2.1. Inclusion and exclusion criteria

Articles were included if they were experimental, quasi-experimental, observational, descriptive, qualitative, mixed-methods, cohort, cross-sectional, case-control studies, case reports, case studies, or randomized controlled trials evaluating the effectiveness or benefits of computer-based simulation or virtual patients in helping student pharmacists' learning and skills during their experiential training. Only articles published in English were included. Exclusion criteria are as follows: (1) study with data not reliably extracted, duplicative, or overlapping; (2) abstract-only papers as preceding papers, conference, editorial, and author response theses and books; (3) articles without full text available; (4) articles without population (P), and intervention (I), and outcomes (O) data; and (5) systematic review studies. The informationist (K.V.) performed the literature search from five relevant databases, including Ovid MEDLINE, EMBASE, Scopus, Education Resources Information Center (ERIC), and Education Abstracts (Appendix). The date search was run on September 24, 2021. Deduplication was conducted in EndNote X9 (Clarivate), via a modified version of the Bramer method.[11] Three authors (C.P., S.P., and R.M.) independently screened the titles and abstracts of the studies, and discrepancies were resolved by the three authors. This review followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guideline.

2.2. Data extraction

The retrieved records were exported to Rayyan. A title and abstract screening was conducted and full-text articles that met the inclusion criteria were independently screened by C.P., S.P., and R.M. The information extracted into a Qualtrics survey from the selected articles was the authors' name, published year, study design, study setting, study participant characteristics, intervention characteristics, primary outcomes, and secondary outcomes. Two individuals completed data extraction for each article. Any disagreement was resolved by consensus.

2.3. Quality assessment

The methodological quality of the included studies was independently assessed by three authors (C.P., S.P., and R.M.). To evaluate cross-sectional, quasi-experimental, randomized controlled trial, and qualitative studies, the Joanna Briggs Institute (JBI) checklists[12] were utilized. Mixed-method studies were assessed using the mixed methods appraisal tool (MMAT) version 2018.[13] Studies with percentage scores equal to or exceeding 70 were deemed to be of high quality.

2.4. Outcome measurements

The outcomes of this systematic review included primary outcomes (knowledge, skills, and performance) along with secondary outcomes such as satisfaction, confidence, enjoyment, and engagement.

3. Results

After deduplication, a total of 911 unique articles were identified from the database search. Nineteen studies were included in this systematic review (Fig. 1). Among the included studies, 9 studies were mixed method designs, 5 studies were quasi-experimental designs using before/after with no control, and the rest were quasi-experimental designs using before/after with control ($n = 2$), qualitative (n = 2), and cross-sectional ($n = 1$). The characteristics of the included studies are summarized in Table 1 and Table 2. Student pharmacists included in this systematic review were from Year 1 to Year 5 of their pharmacy program. Thirteen articles ($n = 10$ VPs and $n = 3$ CBS) evaluated both primary outcomes (knowledge, skills, performance) and secondary outcomes (satisfaction, confidence, engagement, etc.) whereas six articles reported either primary outcomes (n = 1 VP and 2 CBS) or secondary outcomes (n = 3 VPs).

3.1. Types and characteristics of VPs and CBS

VPs were implemented in 14 included studies.[14–27] The VPs were designed to mimic patient encounters at hospitals/clinics ($n = 8$), community pharmacies ($n = 1$), and more than one setting/not specific

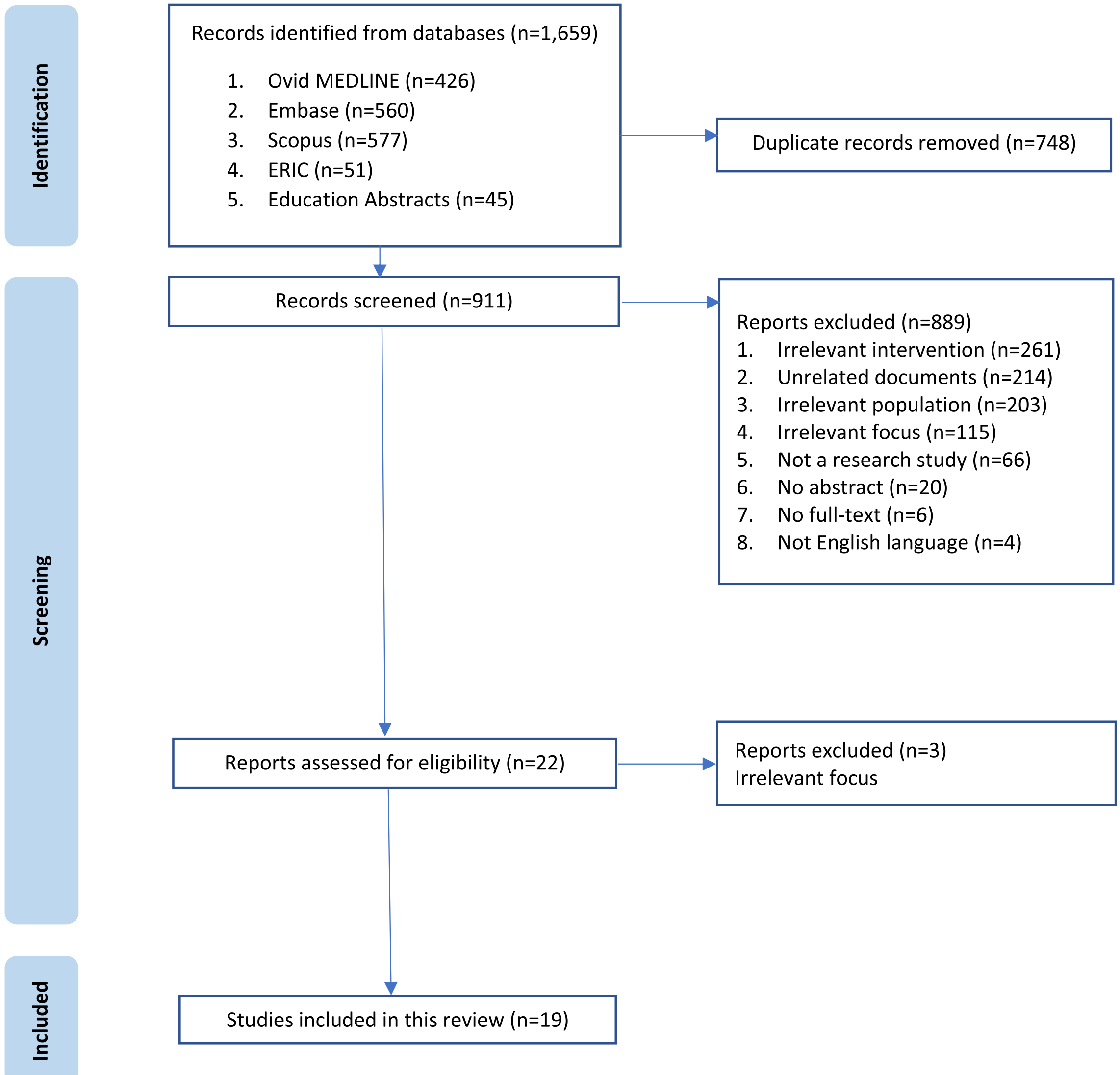

Fig. 1. PRISMA diagram for selection and inclusion of the studies.

setting (n = 5). Student pharmacists were provided opportunities to practice their professional skills including preparing themselves for clinical examinations such as OSCE. The remaining studies (n = 5) implemented CBS and focused on knowledge such as prescription analysis, dose calculation, and specific medication management.28–32

The VPs and CBS were mostly added to existing learning activities (n = 16). Eight programs with no cost were vpSim (n = 2), the Monash OSCE Virtual Experience (MOVE) (n = 1), Simulador de Atendimento Farmaceutico (SAF) (n = 1), Virtual Patient for Geriatric Education (VIPAGE) (n = 1), Interactive Clinical Avatar (n = 1), MyDispense (n = 1), CyberPatient 2007 software and Virtual Organ Bath computer software (n = 1), and Strathclyde Computerized Randomized Interactive Prescription Tutor (SCRIPT) (n = 1).

3.2. *Courses/skills/settings*

VPs and CBS were utilized in various pharmacy courses, including Advanced Pharmacy Practice Experience (APPE)17,31 (n = 1 VP and 1 CBS), Advanced for Pharmaceutical Care II14,15 (n = 2 VPs), and Medication Management18,28 (n = 1 VP and 1 CBS). Additionally, VPs were exclusively mentioned in two interprofessional education courses, Interprofessional Education and Clinical Simulation I (IPECS I),16 and Interprofessional Learning (IPL).22

3.3. *Students' characteristics*

Participants in all included studies were student pharmacists ranging from Year 1 to Year 5 of their pharmacy program or pre-registered pharmacists. The participants were enrolled in a 4-year or 5-year program based on their country, i.e., 4-year PharmD program in USA and Canada; 4-year BPharm program in Australia, Malaysia, New Zealand, and Fiji; 4-year pharmacy degree (MPharm) in Scotland; and 5-year BPharm/Integrated degree in Portugal and Brazil. Two studies19,22 had a combination of student pharmacists and medical students while participants in another study26 was composed of preregistration trainees and first-year qualified pharmacists.

3.4. *Students' learning outcomes and perceptions*

In this study, two considerable outcomes covered student pharmacists' learning outcomes (i.e., primary outcomes), including knowledge, skills, and performance, and the students' perceptions (i.e., secondary outcomes) such as satisfaction, confidence, enjoyment, and engagement. In all ten studies that underwent pre- and post-test measurements, encompassing both VPs and CBS (n = 5 each), statistically significant improvements were observed in both primary and secondary outcomes.

Knowledge was assessed in 12 studies (n = 7 VPs and n = 5 CBS), and

Table 1
Description of the included studies – **Virtual Patients.**

No.	Authors, Year of Publication, Country	Design	Study participants	Course/Skills	Virtual patient information	Outcomes		
						Primary (i.e., knowledge, skills)	Secondary (i.e., satisfaction, confidence, engagement)	Qualitative findings
1	Benedict, Schonder, 2011, USA	Quasi-Before/after with no control	Y3 student pharmacists (n = 142) 4-year program Age: Not available Gender: Not available	Advanced Pharmaceutical Care II	**Name of the program:** The PharmaCAL program **Areas of focus:** Critically ill patients and patients with kidney disease **Setting:** Hospital **Intensity:** integrated throughout one course **Cost:** Not available	Knowledge (pre-post test): Significantly more questions were answered correctly on the post-simulation test than on the pre-simulation test ($p < 0.001$)	Pharmacy Students' Opinions Regarding PharmCal: enjoyable (92%), easy to use (90%), stimulated interest in critically ill patients (82%), and allowed for application of lecture material (91%)	Not available
2	Benedict, Schonder, McGee, 2013, USA	Quasi-Before/after with control	Y3 student pharmacists (n = 213) IV – vpSim(n = 106) C – conventional teaching (n = 107) 4-year program Age: Not available Gender: Not available	Advanced Pharmaceutical Care II	**Name of the program:** vpSim **Areas of focus:** Postoperative nausea and vomiting, chronic kidney disease, and anemia of chronic kidney disease. **Setting:** Hospital **Intensity:** integrated throughout one course **Cost:** No cost	Final exam scores: no difference between intervention and control group.	Students' perceptions and satisfaction: the virtual patient modules/portion of the course to be organized (90%), appropriate in content (88%), enjoyable (82%), intellectually challenging (97%), and contributing to their understanding of course content (91%).	
3	Borja-Hart, Spivey, George, 2019, USA	Mixed-method	Y1 student pharmacists (n = 205) Age: Not available Gender: Female (n = 116), other (n = 89)	the Communications and Interprofessional Education and Clinical Simulation I (IPECS I) courses	**Name of the program:** the Digital Clinical Experience (DCE) **Areas of focus:** Health history taking - foot injury and the comorbidities of diabetes and asthma. **Setting:** Clinics **Intensity:** integrated throughout one course **Cost:** Not available	Performance on assignment (Grade): The mean grade for subjective data was 31.48% (F) and for objective data was 93.66% (A).	Confidence, Impressions toward VPs: pre (n = 203) and post (n = 163) confidence in student abilities related to communication indicated statistically significant improvement ($p < 0.001$). Impressions toward VPs, student responses were improved and statistically significant ($p < 0.001$) for 1 of 4 survey items (tools are easy to use).	Major categories for student self-reflection were related to patient interviewing (41 comments) and assessment (53 comments).
4	Bravo, So, Natsheh, 2019, Canada	Qualitative	Y4 student pharmacists (n = 10) 4-year program Age: Not available Gender: Not available	Advanced Pharmacy Practice Experience (APPE)	**Name of the program:** The Virtual Interactive Case (VIC) **Areas of focus:** Asthma, hypoglycemia, orthopedic surgery, and intra-abdominal infection **Setting:** Hospital **Intensity:** integrated throughout one course **Cost:** Payment required	Not available	Impression	Students' impressions of VIC included information gathering; built-in, real-time, formative feedback; fun and positive experience; realistic; and user-friendly.

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Table 1 (*continued*)

No.	Authors, Year of Publication, Country	Design	Study participants	Course/Skills	Virtual patient information	Outcomes		
						Primary (i.e., knowledge, skills)	Secondary (i.e., satisfaction, confidence, engagement)	Qualitative findings
5	Dahri, MacNeil, Chan, 2019, Canada	Mixed-method	Y1, Y2, and Y3 student pharmacists ($n = 180$) Age: Not available Gender: Not available	Medication management courses	**Name of the program:** the Virtual Interactive Case System **Areas of focus:** *Clostridium difficile* and heart failure **Setting:** Hospital **Intensity:** available for 1–2 months after the content was taught **Cost:** Payment required	Not available	Perception - VPs was a valuable learning experience (agreed/strongly agreed; 94% of participants)	Learning benefits from VP cases were (a) applying and solidifying classroom-based learning; (b) being exposed to, and gaining knowledge about, real-world cases; (c) becoming active decision makers.
6	Gilmartin-Thomas, McNeil, Powell, 2020, Australia	Qualitative study	Y4 student pharmacists ($n = 24$) - 4-year BPharm program Y3 medical students ($n = 29$) - 5-year program Age: Not available Gender: Not available	the hospital/medical practice/community pharmacy professional experience placements. Communication with Dementia patients.	**Name of the program:** the Alzheimer's Australia Vic Virtual Dementia Experience™ **Areas of focus:** dementia **Setting:** hospital/ medical practice/ community pharmacy **Intensity:** integrated throughout one course **Cost:** Not available	Not available	Not available	Knowledge, learning: Medical and pharmacy students found the experience impactful (more lasting memory, engaging, clear understanding). Attitude: Medical and pharmacy students described how they could use their learnings from the experience to become more dementia friendly in the future (more empathy and compassion, be supportive).
7	Lim, Lee, Karunaratne, 2020, Australia and Malaysia	Mixed-method	Y4 student pharmacists ($n = 120$) 4-year BPharm program Age: Not available Gender: Not available	Objective structured clinical examinations (OSCEs)	**Name of the program:** the Monash OSCE Virtual Experience (MOVE) **Areas of focus:** history-taking, identifying medication-related problems, recommending management options and counseling points **Setting:** Hospital, community, prescription, drug chart, product request **Intensity:** integrated throughout one course **Cost:** No cost	User attempt, performance: >99% of all students completed at least one of the online case scenarios, and 81% of students attempted all 20 scenarios. >7000 attempts were documented across both campuses. No direct correlation between students' online practice attempts and final assessment performance.	Perception (Quantitative + Qualitative): 90% of students in Malaysia and 70% of students in Australia reported MOVE to be helpful for their OSCE preparation.	Focus group ($n = 20$): 6 themes emerged (1) MOVE compliments the general OSCE preparation process, (2) MOVE prepares students for the real OSCE, (3) Other methods for OSCE preparation, (4) MOVE helps students with targeted questioning in patient history taking, (5) Difficulty level of MOVE, and (6) The comparison between MOVE and a face to face practice session
8	MacNeil, Varga, Gill, 2021, Canada	Mixed-method	Y3 student pharmacists ($n = 43$) Age: Not available Gender: Not available	Patient assessment and clinical reasoning skills	**Name of the program:** the Virtual Interactive Case System **Areas of focus:** Chronic obstructive pulmonary disease and heart failure **Setting:** Hospital **Intensity:** integrated throughout one	Clinical reasoning skills (agreed/ strongly agreed; 84% of participants) Thought process – NESA: necessary, effective, safe, adherence (agreed/strongly agreed; 51% of participants)	Confidence in assessing patients (agreed/strongly agreed; 49% of participants)	VP cases were helpful and could be improved to enhance student learning forward. However, they had some limitations such as unrealistic VP cases and time pressure.

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Table 1 (*continued*)

No.	Authors, Year of Publication, Country	Design	Study participants	Course/Skills	Virtual patient information	Outcomes		
						Primary (i.e., knowledge, skills)	Secondary (i.e., satisfaction, confidence, engagement)	Qualitative findings
					course **Cost:** Payment required			
9	Martini, Farmer, Patil, 2019, New Zealand	Mixed-method	Y4 student pharmacists (n = 20) and Y3 medical students (n = 20) Age: Not available Gender: Not available	Interprofessional learning (IPL)	**Name of the program:** Ready to Practice (R2P) **Areas of focus:** Renal care **Setting:** Emergency care. **Intensity:** integrated throughout a particular period of data collection **Cost:** Not available	Not available	Attitudes to IPL. increasing from 78.78 (pre-) to 82.25 (post-) on a 95-point scale, $p < 0.0001$	Five main themes emerged from the interviews: (1) confidence in clinical decision making, (2) teamwork-shared decision making, (3) communicating thought processes, (4) appreciation of roles and responsibilities (5) attitudes to the simulation and IPL.
10	Pereira, Cavaco, 2014, Portugal	Cross-sectional	Y3, Y4, and Y5 student pharmacists from 8 Portuguese pharmacy schools (n = 717) 5-year program Age: 21.6 ± 2.69 Gender: Female (n = 567), Male (n = 150)	Pharmacotherapy and Communication Courses OTC patient counseling, self-medication skills	**Name of the program:** Simulador de Atendimento Farmaceutico (SAF) **Areas of focus:** A cold medicine **Setting:** Community pharmacy (Over-the-Counter drug; OTC) **Intensity:** a one-time activity **Cost:** No cost	Counseling skills (patient counseling scores; out of 10; <8 points is considered a bad counseling performance): 8.03 (SD = 1.25)		
11	Silva, Pereira, Santos Silva, 2020, Brazil	Quasi-Before/after with no control	Y2, Y3, Y4, and Y5 student pharmacists (BPharm program) (n = 128) Age: 24 ± 3 Gender: Female (n = 91), Males (n = 37)	Pharmaceutical Care	**Name of the program:** Virtual Patient for Geriatric Education (VIPAGE) **Areas of focus:** Geriatrics - all biopsychosocial aspects of the elderly (physiological, pathological, income, social rights, and psychological health) **Setting:** Not specific **Intensity:** integrated throughout one course **Cost:** No cost	Knowledge: Facts on Aging Quiz (FAQ) Scores (The average score on geriatrics knowledge): pre: 44.7(12.0) vs post: 52.6 (11.9), p = 0.003	Geriatric Attitudes Scale (GAS): Mean GAS score: pre = 3.7(0.8), post = 3.9 (0.7), p = 0.01. The VIPAGE software Satisfaction: Total mean score of satisfaction = 4.2 (0.5) out of 5	Not available
12	Smith, Mohammad, Benedict, 2014, USA	Quasi-Before/after with no control	Y3 student pharmacists (n = 105) 4-year PharmD program Age: Not available Gender: Not available	Advanced Therapeutics Pharmacy Course clinical decision making, communication	**Name of the program:** vpSim **Areas of focus:** Asthma **Setting:** Not specific **Intensity:** integrated throughout one course **Cost:** No cost	Knowledge (pre-post test): the use of virtual patients significantly enhanced student learning for both higher- and lower-level test questions (p < 0.001 and p = 0.01, respectively).	Student Perceptions (n = 51): effective way to learn (72%), were enjoyable (69%), and were appropriate in content (80%), and that more should be incorporated (59%)	Not available

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Table 1 (*continued*)

No.	Authors, Year of Publication, Country	Design	Study participants	Course/Skills	Virtual patient information	Outcomes		
						Primary (i.e., knowledge, skills)	**Secondary** (i.e., satisfaction, confidence, engagement)	**Qualitative findings**
13	Thompson, White, Chapman, 2020, United Kingdom	Mixed-method	Preregistration trainees (n = 4), first-year qualified pharmacists (*n* = 6) Age: 22.5 (mean age) Gender: Female (n = 7), Male (n = 3)	Range of knowledge and skills essential for preregistration training and future practice.	**Name of the program:** Interactive Clinical Avatar **Areas of focus:** Emergency hormonal contraception (EHC), calculation of renal function, and childhood illnesses **Setting:** Hospital and community pharmacy **Intensity:** a one-time activity **Cost:** No cost	Development of knowledge (100%, n = 10/10) Application of knowledge (80%, n = 8/10) Development of skills for future practice (80%, *n* = 8/10) Clinical reasoning skills (90%, n = 9/10)	Confidence in caring for patients (90%, *n* = 9/10), Enjoyable (90%, n = 9/10), Interesting (100%, n = 10/10), The right level for preregistration training (90%, n = 9/10), Adequate for participants' learning needs (100%, *n* = 10/10).	Key themes emerged (1) use of the case studies as learning tools, (2) use of the case studies in the preregistration training year, (3) limitations of the case studies, and (4) suggestions for improvements of the case studies.
14	Wilhite, Jones, Kebodeaux, 2021, USA	Quasi-Before/after with control	Y1 and Y2 student pharmacists (*n* = 264) 4-year program Age: Not available Gender: Not available	Patient-Centered Care Experience (PaCE) - Ambulatory care module simulation covered (1) PY1 Checking station, (2) PY1 MyDispense, (3) PY1 Aliquot, (4) PY1 Compounding, (5) PY1 Geometric Dilution, (6) PY2 Smoking Cessation, (7) PY2 MyDispense, and (8) PY2 Compounding	**Name of the program:** MyDispense **Areas of focus:** Identifying the presence of a technical problem with a prescription and resolving the problem appropriately without introducing new errors **Setting:** Ambulatory care **Intensity:** integrated into a six-semester course **Cost:** No cost	Student remediation rate: There was also no difference between track A (in-person) and track B (on-line) in remediation rates after the first and second attempt	Professionalism scores: average professionalism score for track A students (in-person) in both the PY1 and PY2 courses was 98.03%, compared to track B students (on-line) with an average professionalism score of 97.69%.	

six[14,24,25,28–31] (n = 3 VPs and n = 3 CBS) reported a statistically significant improvement in students' knowledge comparing pre-and post-test ($p < 0.05$) after practicing with VPs or CBS. Two research teams conducted studies comparing the exam scores of two groups of student pharmacists.[15,29] The first group exclusively practiced with a VP named vpSim or a CBS called DecisionSim, while the second group solely participated in a conventional lecture-based teaching approach or traditional problem-based cases in paper format. The study revealed no statistically significant difference in final exam scores between the two groups for vpSim.[15] However, the group of student pharmacists who exclusively participated in the DecisionSim achieved significantly higher scores compared to the group of students who followed the traditional teaching method exclusively.[29] Clinical reasoning skills and counseling skills were common outcomes of VPs (n = 3) in this systematic review. Two studies reported that a majority of student pharmacists (n = 36, 84%[21]; and n = 9, 90%[26]) agreed/strongly agreed that practicing with VP cases helped them develop their clinical reasoning skills. Another study[23] presented that student pharmacists' counseling scores (8.03 (1.25)) were acceptable (above 8 out of 10) after practicing their Over-the-Counter counseling with a VP simulator named Simulador de Atendimeneto Farmaceutico – SAF.

There were several secondary outcomes identified in this systematic review, however; students' confidence, attitudes, and perception were most frequently reported. Three studies (n = 3 VPs) presented confidence as their research outcomes; a study[16] showed a significant improvement in confidence after practicing with the VPs called the Digital Clinical Experience (DCE) ($p < 0.001$) whereas the other two studies[21,26] reported about 50% and 90% agreement that practicing with VPs to increase their confidence in the particular courses or skills. Two notable VPs studies[22,24] underscored the significant positive influence of VPs ($p < 0.05$). These studies revealed a noteworthy impact in enhancing students' attitudes toward a specific course, specifically interprofessional learning ($p < 0.05$), as well as their attitudes toward a specific patient group, namely geriatric patients ($p < 0.05$). This systematic review found various positive perceptions from student pharmacists of VPs and simulation. The positive perceptions covered valuable learning experiences, enjoyment, and helpful programs.

4. Discussion

Despite the fact that VPs and CBS are effective and have been used in various curricula of the healthcare profession including pharmacy education, there is scant evidence summarizing effective VPs and CBS that can be used to support student pharmacists' desirable learning outcomes - knowledge, skills, satisfaction, confidence, enjoyment, and engagement - during their experiential education. Unlike previous studies, this research represents the first comprehensive summary of evidence on the effectiveness of VPs and CBS in shaping student pharmacists' learning outcomes during experiential education, sourced from reputable databases including Ovid MEDLINE, EMBASE, Scopus, Education Resources Information Center (ERIC), and Education Abstracts. The results from this systematic review showed that the VPs and CBS had positive

Table 2
Description of the included studies – **Computer-based simulation.**

No.	Authors, Year of Publication, Country	Design	Study participants	Course/Skills	Computer-based simulation information	Outcomes		
						Primary (i.e., knowledge, skills)	**Secondary** (i.e., satisfaction, confidence, engagement)	**Qualitative findings**
1	Al-Sallami, Loke, 2018, New Zealand	Mixed-method	Y4 student pharmacists (*n* = 115) 4-year BPharm program Age: Not available Gender: Not available	Anticoagulation management	**Name of the program:** CoaguSim **Areas of focus:** Concentration-time profiles of warfarin and the coagulation factors, and the effect-time profile of warfarin after administration of chosen doses of warfarin to virtual patients with variable PK and PD profiles **Setting:** Emergency care **Intensity:** a one-time activity **Cost:** Not available	Learning outcomes: mean scores (pre−/post-test): mean scores improved from 45% pre-workshop to 81% post-workshop	Not available	Focus group (n = 7) found two main points (1) learning outcomes, and (2) learning process
2	Bernaitis, Baumann-Birkbeck, Alcorn, 2018, Australia	Mixed-method	Y4 student pharmacists (*n* = 62) 4-year BPharm program **Intervention** – DecisionSim (*n* = 28) Age: 22.3 ± 4.1 Gender: female (n = 20), male (n = 8) **Control** – traditional teaching (*n* = 34) Age: 23.8 ± 4.3 Gender: female (*n* = 22), male (n = 12)	Integrated Pharmacotherapeutics (IP) oncology Cases assessing the application of knowledge and testing clinical decision-making skills.	**Name of the program:** DecisionSim **Areas of focus:** The management of oncological emergencies. **Setting:** Hospital **Intensity:** integrated into the second half of their course after the mid-semester exam. **Cost:** Not available	Knowledge: end of semester (EOS) exam mark: IV (78.6 ± 8.6 (median − 77.75) vs C (68.7 ± 13.5 (median − 67.75) ($P < 0.01$)	Students perceptions of DecisionSim technology: Students found the simulated oncology cases engaged them in learning (median 1.5), had a role in therapeutics education (median 1), and developed decision making skills (median 1)	Thematic analysis of open comments suggested it was most beneficial as a self-directed study tool.
3	Ezeala, Ram, Vulakouvaki, 2013, Fiji	Quasi-Before/after with no control	Y2 BPharm student pharmacists (*n* = 42) Age: Not available Gender: Not available	Pharmacology course - Pharmacokinetics and pharmacodynamics	**Name of the program:** CyberPatient 2007 software and Virtual Organ Bath computer software **Areas of focus:** Pharmacokinetics and pharmacodynamics problems **Setting:** Not specific **Intensity:** a one-time activity **Cost:** No cost	Mean knowledge score (full score = 10 points) (pre- vs post-): Pharmacokinetics: pre- (5.643 ± 1.322) vs. post- (8.57 ± 1.192) ($p < 0.001$). Pharmacodynamics: pre- (6.24 ± 0.95) vs. post- (8.98 ± 0.92) ($p < 0.001$).	Not available	Not available
4	Isaacs, Walton, Nisly, 2015, USA	Quasi-Before/after with no control	Y4 student pharmacists (*n* = 40) 4-year program Age: Not available Gender: Not available	Advanced Pharmacy Practice Experiences (APPEs)	**Name of the program:** Interactive web-based learning modules **Areas of focus:** Inpatient anticoagulation, pneumonia, and antibiotic pharmacokinetics and pharmacodynamics **Setting:** Hospital - inpatient general medicine **Intensity:** a one-time activity **Cost:** Not available	Assessment scores (Knowledge): post-assessment scores significantly increased compared to preassessment scores ($p < 0.001$).	Perception: 97% of participants (n = 34) reported high rates of agreement with the positive learning experience of WBL.	Not available

(*continued on next page*)

Table 2 (*continued*)

No.	Authors, Year of Publication, Country	Design	Study participants	Course/Skills	Computer-based simulation information	Outcomes		
						Primary (i.e., knowledge, skills)	**Secondary** (i.e., satisfaction, confidence, engagement)	**Qualitative findings**
5	Zlotos, Thompson, Boyter, 2015, Scotland	Mixed-method	Y3 student pharmacists (*n* = 272) IV: the replacement model 2009–2010 (*n* = 145) Age: Not available Gender: Female (n = 89), Male (n = 56) C: the supplemental model 2008–2009 (*n* = 127) Age: N/A Gender: Female (*n* = 88), Male (*n* = 39) 4-year pharmacy degree (MPharm)	Dispensing	**Name of the program:** Strathclyde Computerized Randomized Interactive Prescription Tutor (SCRIPT) **Areas of focus:** Prescription analysis **Setting:** Not specific **Intensity:** one-sixth of the taught component of the class **Cost:** No cost	Test - exemption and degree assessment: no statistical difference between the cohorts for the proportion of students who passed the exemption assessment or the degree assessment	Access: Students in the supplemental cohort [Control] accessed SCRIPT outside teaching time more often than students in the replacement cohort [IV] (*p* = 0.002).	Semi-structured interview (n = 18) and 4 themes emerged (1) in-class and remote use of SCRIPT, (2) use alone or in groups, (3) approaches for targeting prescription scenarios, and (4) facilitators and barriers to engagement with e-learning.

impacts on student pharmacists' knowledge and skills as well as enhanced students' satisfaction, confidence, enjoyment, and engagement.

The present systematic review highlights the effectiveness of both VPs and CBS in enhancing the knowledge of student pharmacists. This finding is in line with previous reviews that have also supported the efficacy of simulation tools in improving students' knowledge.[10,33,34] Notably, in our study, VPs emerged as particularly influential in strengthening students' skills. This observation is consistent with the findings reported by Kononowicz and colleagues and Richardson and team, who identified VPs as effective in improving various skills such as communication, counseling, clinical reasoning, procedural skills, and a combination of procedural and team skills.[2,34] However, it is worth mentioning that a study by Lim and colleagues found no direct correlation between students' online practice attempts with a VP and their performance.[20]

Several secondary outcomes, such as satisfaction, confidence, enjoyment, and engagement were reported as positive effects of both VPs and CBS in this review. These findings align with several studies that have confirmed the enhancement of these learning outcomes through the use of these learning tools.[16,35,36] Of particular note, VPs emerged as particularly influential in supporting students' perception. Researchers have explained that the virtual learning environment provided by VPs offers students opportunities to observe, participate in, and practice techniques and skills in an authentic and safe learning and teaching environment.[37,38] Furthermore, VPs contribute to creating engaging and enjoyable environments, which are key components of the learning process.[39] Additionally, the use of VPs has been found to improve students' attitudes toward courses, interprofessional teams, and patients.[19,22,24]

Our study also observed that the effective utilization of VPs and CBS primarily involved incorporating them as additions or complements to existing activities. Plackett and team supported this finding that VP tools could be considered effective complements to current teaching especially if opportunities for face-to-face teaching or other methods are limited.[40] Other scholars echoed this concept that using VPs in blended learning has been found to be effective at improving knowledge and skills.[34,41]

Other findings identified as results of this systematic review were implementing time and students' opinions. VPs and CBS were mostly implemented into pharmacy courses that were in the last half of their curriculum (i.e., Y3, Y4), especially in courses that required hands-on activities including practicing learning experiences such as Advanced Pharmacy Practice Experience (APPE), Advanced Pharmaceutical Care, and Advanced Therapeutics Pharmacy. General opinions and comments from student pharmacists regarding their experiences in practicing with VPs and CBS during their experiential education are benefits/impressions (self-directed, impactful, and user-friendly), limitations of the case studies (unrealistic cases, and time pressure), and suggestions for improvements of the case studies (providing an example simulation, including a help button, and including key learning points).

Apart from the evidence of effective VPs and CBS for student pharmacists to practice enhancing their experiential education, this systematic review provides valuable recommendations for educators on the implementation of these learning simulation tools in their students' experiential courses. To begin with, educators should carefully consider selecting VPs or CBS that align with their students' desired learning outcomes. If the intended outcomes primarily focus on developing professional or practical skills, building confidence, enhancing perception, fostering engagement, or shaping attitudes toward courses or patients, VPs would be the preferred choice. Moreover, these learning tools, whether VPs or CBS, can be incorporated throughout the duration of the courses or introduced periodically. By adopting a strategic approach to their implementation, educators can ensure maximum effectiveness and relevance. Furthermore, it is important to note that these tools yield the greatest benefits when integrated alongside existing learning activities. By complementing and augmenting traditional educational methods, VPs and CBS can enhance the overall learning experience for student pharmacists. Lastly, educators are encouraged to take into account their institution's financial considerations and available resources when implementing these tools.

Further research is recommended to compare the effectiveness of using solely VPs or CBS versus traditional teaching methods in improving professional skills of student pharmacists. It is also important to investigate the correlation between students' learning outcomes and their perception of using VPs and CBS in practice. Additionally, exploring faculty members' perspectives on implementing these tools to enhance pharmacy experiential education, with a specific focus on the functions and applications of the tools, is crucial.

The primary limitation of this study is that no studies included subsequent data about student performance during real-world patient care interactions in traditional experiential education experiences after VPs or CBS. Only articles written in English and focusing on experiential education were included in this systematic review. However, how and when experiential education is included in pharmacy programs varies by institution and country and as a result, it is possible that we may have accidentally included studies not in experiential education or missed some that were in experiential education. Furthermore, this review did not include unpublished literature.

5. Conclusion

In summary, this systematic review highlights the effectiveness of VPs and CBS in enhancing the experiential education of student pharmacists. It provides practical recommendations for educators, including selecting suitable tools that align with desired learning outcomes, implementing them strategically within courses, integrating them with existing activities, and considering financial and IT support. By following these guidelines, educators can maximize the impact of these learning simulations and enhance the educational experience for student pharmacists.

Author contribution

This review was conceptualized by CP, KF, and SV. CP planned the search strategy, analyzed and interpreted the studies, curated the findings and wrote the manuscript with assistance and editing from SV. KV planned and conducted the search strategy, and compiled the studies. SP acted as a second reviewer for the selection of papers, RM acted as the third reviewer to resolve any discrepancies.

Financial disclosure

None.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical disclosure

No ethical approval was required for this article.

Data sharing statement

Data were collected from already published articles.

Declaration of Competing Interest

All authors declare no conflict of interests.

Appendix

Search strategies

We used both keyword and indexing terms (when available), combined with Boolean operators. No limits were applied in any database.

Ovid MEDLINE:

Platform details: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexing Citations, Daily and Versions(R) 1946 to September 23, 2021.

426 results

(exp "Students, Pharmacy"/ OR exp. "Schools, Pharmacy"/ OR exp. "Education, Pharmacy"/ OR PharmD.mp. OR ((exp "Pharmacy"/ OR "Pharmacists"/ OR (pharmacy OR pharmacist*).mp.) AND ("Students"/ OR "Education"/ OR exp. "Teaching"/ OR (student* OR trainee* OR "pre-regist*" OR preregist* OR learn* OR pedagog*).mp.))) AND ((("Computer-Assisted Instruction"/ OR (virtual OR computer* OR online OR Zoom* OR distance OR remote).mp.) AND (exp "Simulation Training"/ OR (simulat* OR interactive).mp.)) OR ((patient* adj3 virtual).mp.) OR (((virtual OR online OR remote OR distance OR Zoom*) AND experiential).mp.))

Embase:

Platform details: Embase.com via Elsevier.

560 results

('pharmacy student'/de OR 'pharmacy education'/exp. OR PharmD:ti,ab,kw OR (('pharmacist'/exp. OR (pharmacist OR pharmacists):ti,ab,kw) AND ('student'/de OR 'education'/de OR 'virtual learning environment'/de OR 'teaching'/de OR (student* OR trainee* OR "pre-regist*" OR preregist* OR learn* OR pedagog*):ti,ab,kw))) AND (('computer simulation'/exp. OR ((virtual OR computer* OR online OR Zoom* OR distance OR remote):ti,ab,kw AND ('simulation training'/exp. OR 'patient simulation'/exp. OR 'patient simulator'/exp. OR (simulat* OR interactive):ti,ab,kw))) OR ((patient* NEAR/3 virtual):ti,ab,kw) OR (((virtual OR online OR remote OR distance OR Zoom*):ti,ab,kw AND ('experiential learning'/de OR experiential:ti,ab,kw))))

Scopus:

Platform details: Scopus.com via Elsevier.

577 results

TITLE-ABS-KEY((PharmD OR ((pharmacy OR pharmacist*) AND (student* OR trainee* OR "pre-regist*" OR preregist* OR learn* OR pedagog*))) AND (((virtual OR computer* OR online OR Zoom* OR distance OR remote) AND (simulat* OR interactive)) OR (patient* W/3 virtual) OR ((virtual OR online OR remote OR distance OR Zoom*) AND experiential))).

ERIC (Education Resource Information Center):

Platform details: ERIC via ProQuest.

51 results

NOFT((PharmD OR ((pharmacy OR pharmacist*) AND (student* OR trainee* OR "pre-regist*" OR preregist* OR learn* OR pedagog*))) AND (((virtual OR computer* OR online OR Zoom* OR distance OR remote) AND (simulat* OR interactive)) OR (patient* NEAR/3 virtual) OR ((virtual OR online OR remote OR distance OR Zoom*) AND experiential))).

Education Abstracts:

Platform details: Education Abstracts (H.H. Wilson) via EBSCOHost.

45 results

TX((PharmD OR ((pharmacy OR pharmacist*) AND (student* OR trainee* OR "pre-regist*" OR preregist* OR learn* OR pedagog*))) AND (((virtual OR computer* OR online OR Zoom* OR distance OR remote) AND (simulat* OR interactive)) OR (patient* N3 virtual) OR ((virtual OR online OR remote OR distance OR Zoom*) AND experiential))).

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