Pharmacy Education (2022) 22(1) 954 - 970
https://doi.org/10.46542/pe.2022.221.954970

RESEARCH ARTICLE

Virtual patient simulation in pharmacy education: A systematic review

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Keywords
Active learning
Knowledge
Pharmacy education
Skill
Virtual patient simulation

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Abstract

Background: This review summarises the impact of virtual patient simulation (VPS) on pharmacy students' knowledge, skills, and perceptions. **Methods:** The PubMed, Cochrane Library, and Web of Science databases were searched using relevant keywords. Full-text articles in English, published between 2010 and August 2021, were retrieved if they evaluate the impact of web-based interactive VPS in pharmacy education. **Results:** This review included 19 studies, 9 of which were comparative. VPS was used to develop or assess different pharmacy-related skills. In general, post-VPS exposure test scores were better than the pre-VPS test scores in 12 studies. VPS significantly improved higher-level learning, counselling, and decision-making skills more than paper-based cases. The favourable impact of VPS on learners' confidence, student engagement, and satisfaction was noted. **Conclusion:** VPS enhances knowledge and clinical decision-making skills. It can also address the needs of pharmacy students with active learning preferences.

Introduction

Pharmacists are specially trained to optimise medication use among the population (Toklu & Hussain, 2013). Leading organisations of pharmacy education have recommended that graduating pharmacy students be equipped with the competencies (knowledge, skills, behaviours, or attitudes) needed to provide adequate, individualised, evidence-based pharmaceutical care through education (International Pharmaceutical Federation, 2012; Medina *et al.,* 2013; ACPE, 2016). Traditional teacher-centred didactic education may not fully equip students with all the required competencies. In addition, an increased understanding of experiential learning theories transformed healthcare delivery systems, and the rise in medical errors necessitates a redesign of educational strategy (Okuda *et al.,* 2009). Virtual patient simulations may serve as a tool to develop or assess the relevant competencies by pharmacy educators (Crea, 2011; Seybert *et al.,* 2019).

Simulation-based education creates a situation resembling real-world circumstances where learners must use their knowledge and skills to solve problems. Several industries, such as aviation (Bernard *et al.*, 2022; Filazoğlu, Ateş & Kafali, 2021), engineering (Mare, 2019; Solmaz *et al.,* 2021), and healthcare (Mahdy et al., 2020), have used simulation to train, evaluate, and support decision-making. Simulation improves patient safety by enhancing healthcare education, evaluation, research, and inter-professional collaboration. The Accreditation Council for Pharmacy Education (ACPE) defines simulation as "an activity or event replicating pharmacy practice" (ACPE, 2022). According to Kononowicz and colleagues (2015), a Virtual Patient (VP) is "a standardised computer software, which allows simulation of real clinical scenarios that encompass the most frequent clinical cases up to critical situations" (Kononowicz *et al.,* 2015). This definition does not reflect the complexity associated with the design of VPS. Simulations can be high-fidelity or low-fidelity, based on how closely they resemble the real-life situation (Aggarwal *et al.,* 2010; Isaza-Restrepo *et al.,* 2018). Moreover, VPS models can be linear, semi-linear, or branched based on the extent to which the decision taken by the learner influences the learning pathway (Kononowicz *et al.,* 2015). VPS allows learners to practice higher-level cognitive skills, acquire knowledge, develop better understanding, critical thinking, and problem-solving skills (Ambroziak *et al.,* 2018; Martini *et al.,* 2019; Newsome, Wallace-Gay & Shoair, 2020). The ACPE recognised that simulated, standardised, and virtual patients could be used to mimic real-world pharmacy practice activities (ACPE, 2022).

Several active learning strategies, such as problem-based learning (PBL) (Smith, Mohammad & Benedict, 2014; Smith & Benedict, 2015; Taglieri *et al.,* 2017), team-based learning (Lang *et al.,* 2019; Eksteen, Reitsma & Fourie, 2021), flipped classroom (McCabe, Smith & Ferreri, 2017; Goh & Ong, 2019), process-oriented guided inquiry learning (POGIL) (Pierce & Fox, 2012), reflection (Miller & Lundquist, 2020), and class assessment techniques (muddiest point) (Bullock *et al.,* 2018), have been used in pharmacy education.

In line with the experiential theory of learning and constructivism, effective VPS must have clear outcomes, replicate real-world experiences, and enable learners to have deliberate practice, reflection or debriefing, and feedback (Gunduz & Hursen, 2015; Hepps, Yu & Calaman, 2019). The experiential learning theory states that adults learn best when provided with a deliberately structured opportunity to learn from a relevant situation that enables them to reflect on their learning (Schön, 2017), develop meaningful connections, and identify points of improvement (Kolb, 2014). According to the constructivist theory, learners actively construct new knowledge when they interact to share their feelings, knowledge, and experience (Brown & King, 2003). Similarly, adult learning theories also emphasise that adult learners need to engage in self-directed, problem-centred learning (Knowles, 1978).

Although VPS has been used in health education, none of the systematic reviews evaluated the literature on the impact of utilising VPS on pharmacy education at higher education facilities. In addition, many educators are skeptical about the potential additional benefit of using VPS as compared to traditional didactic teaching. This systematic review summarised evidence on VPS use in pharmacy education and the effect of adapting VPS on pharmacy students' engagement, confidence, knowledge, skills, and satisfaction.

Methods

This review is designed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist (Page et al., 2021).

Study selection and search strategy

The following keywords were used: "simulation" OR "virtual simulation" OR "virtual patient simulation" OR "virtual patient learning" AND "pharmacy" OR "pharmacy education" OR "pharmacy students" AND "knowledge" OR "satisfaction" OR "clinical competent." Relevant literature was extracted from PubMed, Cochrane Library, and Web of Science databases. Additional studies were identified by searching through the references of highly cited reviews and meta-analyses covering similar topics.

Eligibility criteria

Original studies evaluating VPS's impact on pharmacy education were screened for eligibility.

Randomised controlled trials or observational studies that evaluated web-based interactive VPS as a learning or assessment tool in pharmacy education at higher education facilities were included. Full-text articles in English published in the last decade were reviewed. This review summarised evidence on the impact of VPS alone or in comparison with other instructional methods on pharmacy students' competency.

Studies that evaluated the impact of VPS in disciplines other than pharmacy and those that used high-fidelity VPS, such as virtual reality or robotic human scale mannequins, or those with crossover trial design and unpublished studies, were excluded. In addition, studies that did not state the objective of VPS or studies that only reported VPS design and implementation were also excluded.

Data extraction

Data related to the authors, year of publication, the study objective, country, number of participants, type of intervention, type of comparators, skills assessed, and outcome, purpose, and satisfaction of students were extracted systematically. The data extracted by three of the co-authors (A.P.M., A.A.M. and S.A.B) was reviewed by (S.G.L, E.M.E, N.H, and A.S.S). When there was disagreement about the extracted data, a discussion was held to reach an agreement.

Quality assessment and result synthesis

The Medical Education Research Study Quality Instrument (MERSQI) (Reed *et al.,* 2007) checklist was used to assess the quality of the selected studies. This tool includes ten items covering six domains. Each domain is rated on 3. A maximum score of 18 indicates the highest quality. The MERSQI checklist was chosen because the domains used to assess quality are relevant to medical education studies, and it has been used in similar reviews. The results of the quality assessment of the studies are summarised in Table I.

Table I: Quality assessment of included studies

References	Study design (3)	Sampling (3)	Type of data (3)	Validity of evaluation instrument (3)	Data analysis (3)	Outcomes (3)	Total score (18)
(Benedict & Schonder, 2011)	1.5	2	3	3	3	1.5	14
(Cavaco & Madeira, 2012)	1	2.5	1	3	3	1	11.5
(Hussainy, Styles & Duncan, 2012)	2	1.5	1	3	2	1.5	11
(Douglass et al., 2013)	1.5	2	3	3	3	2	14.5
(Al-Dahir et al., 2014)	3	2	3	3	3	1.5	15.5
(Bindoff et al., 2014)	3	1	3	2	3	1.5	13.5
(Mesquita et al., 2015)	1.5	2	3	2	3	1.5	13
(Barnett et al., 2016)	2	2	3	2	3	2	14
(Lichvar et al., 2016)	2	2	3	3	3	1.5	14.5
(Smith, Siemianowski & Benedict, 2016)	1.5	2.5	3	3	3	1.5	14.5
(Gustafsson, Englund & Gallego, 2017)	1	1.5	3	3	2	1.5	12
(Smith & Waite, 2017)	2	1	3	2	3	1.5	12.5
(Bernaitis et al., 2018)	2	1	3	3	3	1.5	13.5
(da Silva et al., 2020)	1.5	2.5	3	3	3	1.5	14.5
(Fidler, 2020)	1.5	2	3	2	3	2	13.5
(Huang et al., 2020)	3	1	3	2	3	1.5	13.5
(Tai et al., 2020)	2	2	3	2	3	2	14
(Johnson et al., 2021)	3	2	3	2	3	1.5	14.5
(Thomas et al., 2021)	1	2	3	3	2	1.5	12.5

Medical Education Research Study Quality Instrument

Domain 1- Study design: if single group cross-sectional or single group post-test only (1); Single group pre-test & post-test (1.5); Nonrandomised or two groups (2); Randomised controlled trial (3)

Domain 2- Sampling: if Institutions studied is one (0.5), two (1), or three (1.5); and if the response rate is <50% or not reported (1), 50%- 74% (1), ≥ 75% (1.5)

Domain 3- Type of data: if assessment done by participants (1) or if objective measurement (3)

Domain 4- Validity of evaluation instrument: if Internal structure not reported (0), or reported (1); and if content not reported (0), or reported (1); and if relationships to other variables not reported (0), or reported (1)

Domain 5- Data analysis: if the type of analysis is Inappropriate for study design (0), or if it's appropriate for study design (1); and if complexity analysis is descriptive analysis only (1), and if its beyond descriptive analysis (2)

Domain 6- Outcomes: if the outcomes include satisfaction, attitudes, perceptions, opinions, or general facts (1), or if its knowledge and skills (1.5), if it's about behaviours (2), if it includes patient or healthcare outcomes (3)

Results

Study selection

Nineteen studies were selected for this review. Figure 1 depicts the flow diagram of study identification and selection.

General characteristics of included studies

Table II shows the characteristics of included studies. All included studies evaluated VPS use among pharmacy students. The average number of pharmacy students included in the virtual simulations across the studies was 80.

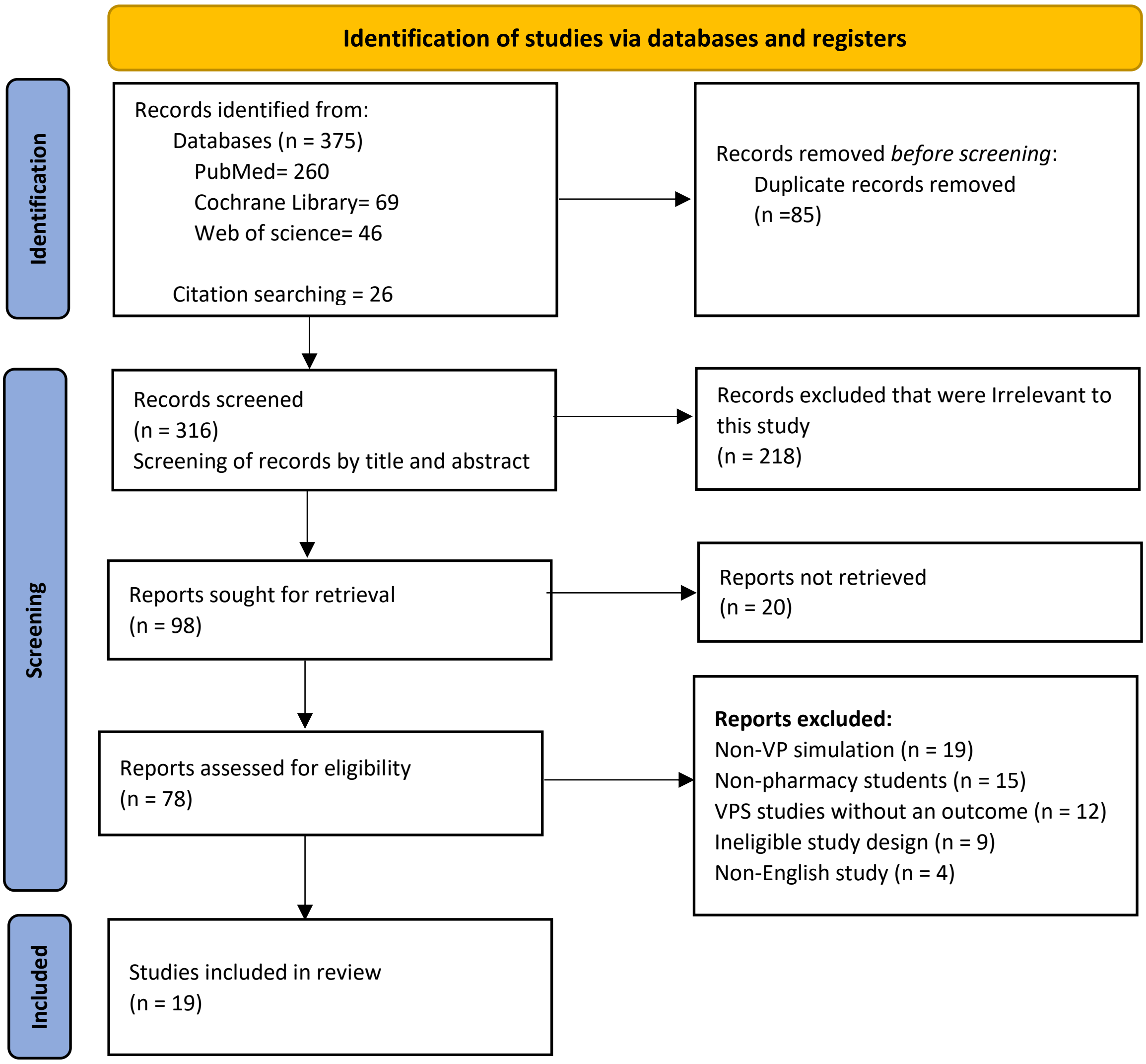

Figure 1: Identification and selection of studies

Most studies (84%) were single-site studies. About one-half (53%) of the reviewed studies were conducted in the United States, while the remaining others were from Australia (n = 3), Brazil (n = 2), Sweden, China, the United Arab Emirates (U.A.E.), and 23 European countries (Table II).

The design of VPS varied according to the purpose and intent of VPS use. Some were designed as a one-off learning tool, whereas others assessed the effects of VPS exposure later when students were exposed to actual patients during training. In three reviewed studies, students were allowed to complete their VPS activity at their own pace (Douglass *et al.,* 2013; Lichvar *et al.,* 2016; Bernaitis *et al.,* 2018). Among the included studies, nine were comparative studies, comparing VPS to other teaching and learning modalities, such as classroom lectures (Huang *et al.,* 2020), problem-based learning (PBL) (Al-Dahir *et al.,* 2014), paper-based cases (PBC) (Bindoff *et al.,* 2014; Barnett *et al.,* 2016; Smith & Waite, 2017; Bernaitis *et al.,* 2018;), flipped classroom using PBC (Lichvar *et al.,* 2016), and introductory pharmacy practice experience (IPPE) (Tai *et al.,* 2020; Johnson *et al.,* 2021). The remaining ten studies evaluated VPS without any control group (Table II).

Simulation software

Several simulation tools were used. Six studies employed the Decision Simulation software, and two used MyDispense (Table II). Of the remaining 11 studies, seven used various simulation software (Warrior, OpenSimulator, Therasim, Virtual Patient for Geriatric Education Software, Unity3D, a pharmacal program, or Case Scenario/Critical Reader), and four did not include the description of the simulation software used (Cavaco & Madeira, 2012; Hussainy, Styles & Duncan, 2012; Mesquita *et al.,* 2015; Thomas *et al.,* 2021).

Table II: General characteristics of the included studies

Reference	Objective of the study	Setting/Study design and participants	Intervention/ control	Number of students	Simulation design and duration of studies	Type of cases
(Benedict & Schonder, 2011)	To implement and evaluate the effectiveness of adding pharmaceutical care into advanced therapeutics course	Single site, United States/ longitudinal study 3rd year PharmD Students and faculty	**VPS:** A Pharmaceutical Care Simulation No control group	190 N/A	A pharmacal program Duration-not specified	Critically ill and chronic kidney disease and anaemia
(Cavaco & Madeira, 2012)	To describe how virtual patients are being used to simulate real-life clinical scenarios in undergraduate pharmacy education in Europe	Multiple sites, 23 countries in Europe from 46 universities/ Cross- sectional Undergarduate Pharmacy students from 46 universities	**VPS:** Virtual Patient Technology No control group	194 N/A	Simulation design and duration-not specified	-
(Hussainy, Styles & Duncan, 2012)	To develop communication skills in second-year pharmacy students using a virtual practice environment and to assess students' and tutors' (instructors') experiences	Single site, Australia/ longitudinal study 2nd and 3rd year BPharm students Faculty member present	**VPS:** Virtual Practice Environment No control group	110 N/A	Simulation design not specified Two years	Antibiotics, asthma and antihypertensive medications
(Douglass et al., 2013)	To implement and evaluate the impact of virtual patient pilot programme on pharmacy students' clinical competence skills	Single site, United States/ Longitudinal study 3rd year PharmD students Faculty member present	**VPS:** Virtual Patient Software No control group	135 N/A	Therasim seven weeks	Multiple patient comorbidities with drug therapy problems
(Al-Dahir et al., 2014)	To evaluate the efficacy of PBL vs online virtual simulation-based learning within pharmacy students	Single site, United States/ RCT 4th year PharmD students Faculty member present	**VPS:** Online Virtual Simulation **Traditional method:** PBL	59 60	Decision simulation six weeks	Atrial fibrillation
(Bindoff et al., 2014)	To provide a virtual learning method for pharmacy students that is as effective as paper-based learning but more engaging and less labor-intensive	Single site, Australia/ RCT 3rd and 4th year BPharm students Faculty member present	**VPS:** Computer Based Simulation group **Traditional method:** PBC	16 17	Unity3D simulation technology Duration not specified	Back pain and heart failure

Reference	Objective of the study	Setting/Study design and participants	Intervention/ control	Number of students	Simulation design and duration of studies	Type of cases
(Mesquita et al., 2015)	To evaluate the perception and performance of student competency in a pharmaceutical care course using active learning methodologies	Single site, Brazil/ quasi-experimental study 1st year BPharm students Faculty member present	**VPS and other active learning methods:** VPS (written exam, seminar, OSCE) No control group	33 N/A	Simulation design and duration-not specified	Drug related problems
(Barnett et al., 2016)	To evaluate online case simulation vs a paper case on student confidence and engagement	Single site, United States/ quasi-experimental study 3rd year PharmD students Faculty member present	**VPS:** Virtual Case Simulation **Traditional method:** PBC	81 53	Case scenario/ critical reader (CSCR) one week	Osteoporosis
(Lichvar et al., 2016)	To design and evaluate the integration of a virtual patient activity in a required therapeutics course already using a flipped-classroom teaching format	Single site, United States/ longitudinal study 2nd year PharmD students Faculty member present	**VPS:** Virtual Patient Case **Traditional method:** Flipped classroom method of learning using PBC from prior year students	109 109	Decision simulation five weeks	Complications of liver disease
(Smith, Siemianowski & Benedict, 2016)	To expand the use of VPS at 2 pharmacy schools through virtual patient case sharing	Two sites, United States/ longitudinal study 3rd year PharmD students Faculty member present	**VPS:** Virtual Patient No control group	102 N/A	Decision simulation Duration-not specified	Pain, Agitation and Delirium, Sepsis, ICU Prophylaxis, Hemodynamic, ICU Hyperglycemia
(Gustafsson, Englund & Gallego, 2017)	To describe and evaluate the use of a 3-dimensional virtual world (3DVW) in a clinical pharmacy course	Single site, Sweden/ longitudinal study Master of Pharmacy students Faculty member present	**VPS:** 3-Dimensional virtual world (3DVW) No control group	42 N/A	OpenSimulator (OS) or SecondLife® (SL) three years	Complex drug-related problems (DRPS)
(Smith & Waite, 2017)	To assess student's performance and achievement of course objectives following the integration of a virtual patient case designed to promote active, patient-centered learning in a required pharmacy course	Single site, United States/ longitudinal study 3rd year PharmD students Faculty member present	**VPS:** Virtual Patient Technology **Traditional method:** Students from prior year with PBC	156 188	Decision simulation	Pain management

Reference	Objective of the study	Setting/Study design and participants	Intervention/ control	Number of students	Simulation design and duration of studies	Type of cases
(Bernaitis et al., 2018)	To assess student's satisfaction and performance in oncology therapeutics course after implementing VPS	Single site, Australia/ longitudinal study 4th year PharmD students Faculty member present	**VPS:** Computer Based Simulation group **Traditional method:** PBC	28 34	Decision simulation	Management of oncological emergencies
(da Silva et al., 2020)	To implement and evaluate the impact of VPS on pharmacy students' knowledge and attitude towards geriatrics patients	Two sites, Brazil/ longitudinal study 2nd to 5th year year BPharm students Faculty member present	**VPS:** Virtual Simulation No control group	109 N/A	Virtual patient for geriatric education (VIPAGE) software	Resolving drug therapy problems of the virtual elderly patient
(Fidler, 2020)	To evaluate if utilising a VPS programme in a required pharmacy course improves the history taking and physical assessment skills of 1st year pharmacy students	Single site, United States/ longitudinal study 1st year PharmD students Faculty member present	**VPS:** VPS prior IPPE training No control group	171 N/A	VPSP - a web-based virtual patient simulation	Cough
(C. Huang et al., 2020)	To evaluate the impact of VPS application in the emergency medical education of clinical pharmacy students	Single site, China/ RCT Clinical pharmacy students	**VPS:** Emergency medical training using simulation **Traditional method:** Classroom teaching	10 10	"Warrior" simulation system	Simulated hemorrhage, arrhythmia and acute airway obstruction emergency cases
(Tai et al., 2020)	To evaluate the impact of incorporating VPS into 1st year pharmacy course on student's confidence, frequency of interactions, and preceptor-reported student performance during their 2nd year community pharmacy IPPE	Single site, United States/ longitudinal study 1st year PharmD students Faculty member present	**VPS:** Virtual Simulation activities prior IPPE **Traditional method:** Knowledge-based laboratory activities prior IPPE	22 26	MyDispense	Based on self-care therapeutics course objectives
(Johnson et al., 2021)	To evaluate student learning and preparedness for community IPPEs after implementation of "MyDispense" into experiential education	Single site, United States/ RCT 1st year PharmD students Faculty member present	**VPS:** VPS exercises prior to IPPE training **Traditional method:** No VPS exercises prior IPPE training	32 24	MyDispense	Prescription related queries

Reference	Objective of the study	Setting/Study design and participants	Intervention/ control	Number of students	Simulation design and duration of studies	Type of cases
(Thomas et al., 2021)	To describe the feasibility and acceptability of distance assessment of students' counselling skills using a high quality 'virtual patient' simulator	Single site, U.A.E./ longitudinal study Masters of clinical pharmacy students and graduating PharmD students during their exit exam Faculty member present	**VPS:** Virtual Patient Learning No control group	30 N/A	-	Thyrotoxicosis, BPH, MI, colon cancer, infectious disease

Abbreviations:
BPH- Benign Prostatic Hyperplasia; BPharm- Bachelor of Pharmacy; ICU- Intensive Care Unit; IPPE- Introductory Pharmacy Practice Experience; MI- Myocardial Infarction; N/A – Not Applicable; OSCE- Objective Structured Clinical Examination; PBC- Paper-Based Cases; PBL- Problem- Based Learning; PharmD - Doctor of Pharmacy; RCT- Randomised Control Trial; U.A.E.- United Arab Emirates; United States- United States of America; VPS- Virtual Patient Simulation

Types of cases

Pharmacy students' competencies were assessed using diverse clinical cases (Table II). The scenarios used in the VPSs included cardiovascular diseases (atrial fibrillation, heart failure, and myocardial infarction), endocrine disorders (thyroid, diabetes), respiratory disease (asthma), oncological diseases, infectious diseases, and other cases (pain management, osteoporosis, geriatric conditions, and liver disease). These cases were used to develop students' competencies for the provision of pharmacy practice services. Competencies included identifying and resolving drug-related problems, history-taking, counselling, clinical decision-making, physical assessment, dispensing, and subjective, objective, assessment, and plan (SOAP) note documentation. However, one of the studies did not use a case; instead, it used surveys to assess students' perceptions of prior experience with VPS (Cavaco & Madeira, 2012).

Faculty role

Most of the reviewed studies (90%) described the function of faculty members, except two (Cavaco & Madeira, 2012; Huang *et al.,* 2020) (Table II). In six studies, faculty members were involved in developing and reviewing the cases (Douglass *et al.,* 2013; Al-Dahir *et al.,* 2014; Mesquita *et al.,* 2015; Barnett *et al.,* 2016; Smith, Siemianowski & Benedict, 2016; Tai *et al.,* 2020). In several studies, faculty members gave students information on how to use VPS or supervised them through the exercise (Hussainy, Styles & Duncan, 2012; Douglass *et al.,* 2013; Al-Dahir *et al.,* 2014; Mesquita *et al.,* 2015; Bernaitis *et al.,* 2018; da Silva *et al.,* 2020). Instructors also served as evaluators in other instances (Hussainy, Styles & Duncan, 2012; Barnett *et al.,* 2016; Smith & Waite, 2017; da Silva *et al.,* 2020; Fidler, 2020; Tai *et al.,* 2020; Johnson et al., 2021; Thomas *et al.,* 2021). In five studies, instructors gave feedback to students based on their performance in the VPS scenarios (Barnett *et al.,* 2016; Gustafsson, Englund & Gallego, 2017; Hussainy, Styles & Duncan, 2012; Smith & Waite, 2017; Thomas et al., 2021). Lecturers were also involved in helping students resolve technical difficulties in two studies (Douglass *et al.,* 2013; Thomas *et al.,* 2021). According to one study, a faculty member answered students' worries and uncertainties during the activity (Lichvar *et al.,* 2016).

Quality assessment

All the reviewed studies had an experimental (RCT and quasi-experimental) or an observational design (cross-sectional and longitudinal) (Table II). The mean MERSQI score was 13.5 (range: 11 to 15.5), indicating high-quality research designs (Table I). Four studies did not mention the response rate of students (Bindoff *et al.,* 2014; Smith & Waite, 2017; Bernaitis *et al.,* 2018; Huang *et al.,* 2020;). Three studies had overall response rates ranging from 50% to 74% and 62% (Cavaco & Madeira, 2012; Hussainy, Styles & Duncan, 2012; Gustafsson, Englund & Gallego, 2017), while the remaining 12 had response rates of 75% or higher. In two studies, self-assessment surveys were the only method used to assess the impact of VPS (Cavaco & Madeira, 2012; Hussainy, Styles & Duncan, 2012). The remaining studies evaluated the impact of VPS on knowledge and skills using exams or surveys. The results were summarised using descriptive statistics (Hussainy, Styles & Duncan, 2012; Gustafsson, Englund & Gallego, 2017; Thomas *et al.,* 2021).

Reasons for a career change

The purpose of using VPS in pharmacy education:

VPS was used as a learning or assessment tool to gauge the improvement in history-taking (Hussainy, Styles & Duncan, 2012; Gustafsson, Englund & Gallego, 2017), counselling skills (Barnett *et al.,* 2016), clinical reasoning (Barnett *et al.,* 2016; Tai *et al.,* 2020), physical assessment skills, decision-making, or SOAP note documentation skills. A total of 17 studies used VPS as a learning tool, while the remaining two used it as a formative assessment tool (Table III) (Gustafsson, Englund & Gallego, 2017; Thomas *et al.,* 2021). Students perceived VPS as a feasible and acceptable assessment method (Thomas *et al.,* 2021). However, in one study, students preferred the use of VPS as a learning tool rather than an assessment tool (Cavaco & Madeira, 2012).

Assessment and evaluation of the impact of VPS

Knowledge:

Twelve studies assessed the impact of VPS on students' knowledge based on their performance in the examinations or tests (Table III), eight of which performed pre-VPS and post-VPS quizzes. Two studies compared the examination or test scores between VPS groups and intervention groups (Smith & Waite, 2017; Huang *et al.,* 2020;). One study assessed knowledge improvement by comparing pre-VPS and post-VPS knowledge scores and through a final examination (Benedict & Schonder, 2011). In general, post-VPS exposure test scores were better than pre-VPS exposure test scores in all studies (Bindoff *et al.,* 2014; Barnett *et al.,* 2016; Lichvar *et al.,* 2016; Smith & Waite, 2017; Bernaitis *et al.,* 2018; Huang *et al.,* 2020; Johnson *et al.,* 2021). In studies that compared PBC/lectures with VPS, the VPS group demonstrated a significantly better improvement in post-test scores (Lichvar *et al.,* 2016; Bernaitis *et al.,* 2018; Huang *et al.,* 2020) and in learning new concepts (Barnett *et al.,* 2016). Similar results were found when comparing test scores after VPS exposure with previous-year PBC exposure (Lichvar *et al.,* 2016). The results showed that post-VPS test scores were higher than pre-test scores (33% vs 50%) in VPS groups. Also, overall median examination scores and higher-level learning were significantly higher in the VPS group than in the control group (Smith & Waite, 2017). However, one study failed to show a difference in exam performance between VPS and PBC groups (Smith & Waite, 2017). Nevertheless, students who had been exposed to VPS performed much better on Bloom's Taxonomy problems requiring them to develop pharmacological regimens (p=0.0005) (Smith & Waite, 2017). In a study comparing VPS and PBL, post-exposure scores were better than pre-test scores for both groups. When the two groups were compared, the post-experience test results of the PBL group (74.8±11.7) were significantly higher than those of the VPS (66.5±13.6) group (Al-Dahir *et al.,* 2014).

Skills:

Several studies evaluated the impact of VPS-based training on counselling abilities (Bindoff *et al.,* 2014; Tai *et al.,* 2020; Johnson *et al.,* 2021; Thomas *et al.,* 2021), history-taking skills (Bindoff *et al.,* 2014; Fidler, 2020), decision-making capacity (Bernaitis *et al.,* 2018), the ability to document SOAP notes (Barnett *et al.,* 2016), and communication skills (Hussainy, Styles & Duncan, 2012; Gustafsson, Englund & Gallego, 2017). VPS exposure had a favourable impact on these skills. One study assessing clinical decision-making abilities during oncological emergencies found that VPS significantly enhanced decision-making skills compared to PBC (Bernaitis *et al.,* 2018), as evaluated by the end-of-term examination. Another study performed a distance assessment of counselling skills using video-recorded VPS during the COVID-19 pandemic (Thomas *et al.,* 2021). Students were assessed through a virtual objective-structured clinical examination (OSCE). VPS was considered a feasible tool for remote assessment (Thomas *et al.,* 2021). VPS exposure was also linked with improved counselling (Mesquita *et al.,* 2015; Thomas *et al.,* 2021), physical assessment (Gustafsson, Englund & Gallego, 2017), and history-taking skills (Gustafsson, Englund & Gallego, 2017). The ability of students to document SOAP notes was assessed in another study (Barnett *et al.,* 2016). Although there were no differences in total SOAP note scores between the two groups, the simulation group fared better in the subjective SOAP note domain.

Self-confidence:

Few studies assessed the impact of VPS-based learning on self-confidence (Douglass *et al.,* 2013; Barnett *et al.,* 2016; Fidler, 2020; Tai *et al.,* 2020). In these studies, students reported improved self-confidence after using VPS (Table III). Two of the studies exposed students to VPS before IPPE training and found that VPS group students had an improved confidence level during their IPPE training when interacting with actual patients (Fidler, 2020; Tai *et al.,* 2020), but their perceived confidence to express empathy did not improve significantly between Week 1 and Week 24 (Fidler, 2020). Similarly, VPS-exposed students had an improved confidence level when delivering educational information throughout their IPPE training (Fidler, 2020). Another study also reported that VPS-exposed students exhibited improved performance and confidence when using electronic medical records and managing chronic diseases (Douglass *et al.,* 2013).

Table III: Impact of VPS use on pharmacy students knowledge, skills, and perception

Reference	Tools used to assess the impact of VPS			Knowledge	Skills				Students' perception			
	Exam/ tests	Pre- & Post-VPS quiz	Survey	Improved Post-test or Exam scores after using VPS	Improved Clinical Competency skills	Improved Counselling skills	Improved History taking skills	Improved Communication skills	Improved Self-Confidence	Improved Satisfaction	Positive Perception towards VPS	VPS increased engagement
(Al-Dahir et al., 2014)	-	✓	-	✓	-	-	-	-	-	-	-	-
(Barnett et al., 2016)	✓	-	✓	✓	-	-	-	-	✓	-	-	✓
(Benedict & Schonder, 2011)	✓	✓	✓	✓	-	-	-	-	-	✓	-	-
(Bernaitis et al., 2018)	-	✓	✓	✓	-	-	-	-	-	✓	-	✓
(Bindoff et al., 2014)	-	✓	✓	✓	-	✓	✓	-	-	-	-	✓
(Cavaco & Madeira, 2012)	-	-	✓	-	-	-	-	-	-	✓	✓	-
(da Silva et al., 2020)	-	✓	-	✓	-	-	-	-	-	-	-	✓
(Douglass et al., 2013)	-	✓	✓	✓	✓	-	-	-	✓	-	✓	-
(Fidler, 2020)	-	✓	✓	✓	-	-	✓	-	✓	-	✓	-
(Gustafsson, Englund & Gallego, 2017)	✓	-	✓	-	-	-	-	✓	-	✓	-	✓
(C. Huang et al., 2020)	✓	-	✓	✓	-	-	-	-	-	-	✓	-
(Hussainy, Styles & Duncan, 2012)	-	-	✓	-	-	-	-	✓	-	-	✓	✓
(Johnson et al., 2021)	-	-	✓	-	-	✓	-	-	-	-	✓	-
(Lichvar et al., 2016)	-	✓	-	✓	-	-	-	-	-	-	-	✓
(Mesquita et al., 2015)	-	-	✓	-	-	-	-	-	-	-	✓	-
(Smith, Siemianowski & Benedict, 2016)	-	✓	✓	✓	-	-	-	-	-	✓	-	-
(Smith & Waite, 2017)	✓	-	-	✓	-	-	-	-	-	-	-	✓
(Tai et al., 2020)	-	-	✓	-	-	✓	-	-	✓	-	✓	✓
(Thomas et al., 2021)	✓	-	✓	-	-	✓	-	-	-	✓	-	✓

Abbreviation: VPS – Virtual Patient Simulation

Satisfaction and perception:

Six studies reported students' satisfaction with VPS use, and eight studies described students' perceptions of VPS. The impact of VPS on students' satisfaction and perception was measured using self-reported surveys. The results of these studies indicate that students had a positive perception and a high level of satisfaction with VPS-based learning (Table III). Students from various studies reported that VPS helped them bring their knowledge into practice (Benedict & Schonder, 2011; Mesquita *et al.,* 2015; Lichvar *et al.,* 2016; Smith, Siemianowski & Benedict, 2016; Bernaitis *et al.,* 2018; Huang *et al.,* 2020). A cross-sectional study that evaluated pharmacy students from 46 universities also showed a positive perception regarding VPS (Cavaco & Madeira, 2012). One study reported that students preferred VPS more than traditional methods because of active learning, virtual representation of real-world conditions, and the availability of immediate feedback (Huang *et al.,* 2020). In another study, students felt that VPS gave a visual experience of the role of clinical pharmacists in hospitals (Gustafsson, Englund & Gallego, 2017).

Student engagement:

Ten studies explored students' engagement levels with VPS (Table III). Students felt that learning using VPS was more enjoyable, intriguing, engaging, relevant, and realistic than traditional techniques (Hussainy, Styles & Duncan, 2012; Bindoff *et al.,* 2014; Barnett *et al.,* 2016; da Silva *et al.,* 2020;). Two studies showed that the use of VPS encouraged active learning (Gustafsson, Englund & Gallego, 2017; Smith & Waite, 2017). Students in two other studies declared that VPS increased their engagement and interest in learning (Bernaitis *et al.,* 2018; Thomas *et al.,* 2021). A similar study reported that VPS helped students learn complex pharmacological courses interactively (Bernaitis *et al.,* 2018).

Discussion

This review assessed the impact of using VPS alone or with other teaching and learning methods on pharmacy education and showed the following results: Firstly, VPS is an effective teaching or assessment tool in pharmacy education. Secondly, VPS is well-perceived by students, as shown in the reviewed studies. Thirdly, VPS-exposed groups showed improved knowledge (Bindoff *et al.,* 2014; Kolb, 2014; Lichvar *et al.,* 2016; Bernaitis *et al.,* 2018; Huang *et al.,* 2020), history-taking skills (Bindoff *et al.,* 2014), and decision-making skills (Barnett *et al.,* 2016; Bernaitis *et al.,* 2018). However, some studies found that VPS was as effective as the traditional methods in improving overall SOAP documentation and exam performance (Barnett *et al*., 2016; Smith & Waite, 2017).

Summary of evidence on the benefits of using VPS in pharmacy education

The result regarding the benefits of VPS in pharmacy education is mixed due to differences in methods employed, topics covered, and skills assessed. In general, VPS has been shown to be an effective tool to help equip students with competencies that are vital to providing individualised patient-centred pharmaceutical care, such as history-taking and clinical decision making (Smith & Benedict, 2015; Fidler, 2020). VPS can be used to prepare students for clinical training or practice. Given the benefits of VPS, pharmacy educators and other stakeholders ought to consider incorporating it into pharmacy education.

Enhancing access to pharmacy education through VPS

About half of the studies in this review were conducted in the USA. The reamining studies were carried out in Australia or European countries, and very few studies were done in Asian countries (China, the United Arab Emirates). VPS-based learning has been used in developed countries, with only a few studies from developing countries (Mesquita *et al.,* 2010).

Spreading the use of VPS globally can enable pharmacy students in developing countries to acquire pharmacy-related competencies similar to those in developed countries. It also helps produce a global pharmacy workforce. However, internet access limitations, a lack of demand for patient-centred services, the high cost of implementing VPS, and the lack of a worldwide consensus on pharmacy practice norms (Hassali, Ahmadi & Yong, 2013) could be limiting factors. The involvement of global and local stakeholders is crucial to curb these differences and standardise pharmacy practice and education (Hassali, Ahmadi & Yong, 2013).

The MyDispense Project is a good example of a global collaborative effort to improve pharmacy education. This web-based tool was developed by Monash University, Australia, to teach dispensing skills to pharmacy students. It is now being customised by educators in different parts of the world to create a more realistic learning experience (Mak *et al.,* 2021).

Impact of VPS on pharmacy-related knowledge and skills

These findings show that VPS is a versatile tool that allows the simulation of diverse topics in pharmacotherapy (Richardson, White & Chapman, 2020). Its adaptability ensures exposure to cases that are required to fulfil curriculum needs. Unlike real-life clinical training, VPS not only provides exposure to common cases but also introduces rare or uncomfortable to deal with situations. The diversity of cases in VPS enhanced communication skills (Bindoff *et al.,* 2014; Gustafsson, Englund & Gallego, 2017; Tai *et al.,* 2020; Johnson *et al.,* 2021) dispensing skills, drug-related problem-solving skills, SOAP note documentation skills (Barnett *et al.,* 2016), physical assessment abilities (Fidler, 2020), counselling skills, and decision-making skills. Exposing students to various scenarios enhanced their ability to make decisions in different conditions.

According to Ericsson's theoretical framework, learning and mastering any skill requires repetitive, deliberate practice (Ericsson, Krampe & Tesch-Römer, 1993). The theory states that expertise can be acquired when a structured, repetitive practice alongside focused and targeted efforts is adapted to improve performance. This calls for breaking down a skill into intricate components and striving to improve each skill through feedback and review (Wang & Zorek, 2016). Based on the theory of deliberate practice, a framework for advanced interprofessional experiential education has been suggested to meet accreditation standards in healthcare and pharmacy education (Wang & Zorek, 2016). Deliberate practice of communication and other procedural skills using simulation before pharmacy students participate in real-life practice has the potential to improve performance and safety while reducing faculty workload (Felix *et al.,* 2021).

Impact of VPS in removing the time and space limitations

VPS enables educators to create a reproducible, time-flexible, fun, realistic, engaging, interactive, and face-to-face or distance learning environment for learners (Barnett *et al.,* 2016; Gustafsson, Englund & Gallego, 2017). Adults learn best when they are provided with the opportunity to learn at their pace, which is not always possible during clinical training. Furthermore, VPS could partly reduce the cost associated with student clinical placement. It also helped navigate through the disruptions that occurred in clinical placements of pharmacy students during the COVID-19 pandemic (Bokolo, 2020; De Ponti *et al.,* 2020). Using VPS-based learning in pharmacy education may also prepare pharmacy students with the skills required to provide telepharmacy services to patients (Poudel & Nissen, 2016; Win, 2017). Telepharmacy services have enabled pharmacists to provide distance medication review and patient counselling services in a timely manner. The American Medical Association has recommended the use of computer-based simulation as one of the instructional methods to enable students to acquire telemedicine-based competencies (American Medical Association, 2016).

VPS improves safety of patients and students

VPS allows learners to practice skills in a repetitive, risk-free environment (Smith & Waite, 2017; Fidler, 2020). This implies that students can learn from their mistakes (Bernaitis *et al.,* 2018) without causing harm to themselves or others, which is challenging to replicate during clinical training with actual patients. While protecting patient privacy, VPS helps students learn more effectively by offering a secure and comfortable atmosphere.

VPS improves students' confidence, engagement, and the transfer of knowledge to practice

VPS helps students develop competence and confidence before exposure to actual patients by securing a realistic, safe environment to acquire and test the skills. One study showed that VPS enabled students to experience the whole process of counselling, starting from greeting a patient to patient education during dispensing (Bindoff *et al.,* 2014). Thus, students played the role of the pharmacist, which is expected to enhance confidence and performance through repetitive and deliberate practice.

One of the many acknowledged benefits of VPS is the opportunity to integrate theoretical knowledge and skills into actual clinical practice (Fernandez *et al.,* 2007). Three studies demonstrated that prior VPS exposure could enhance the competence of students while interacting with patients during their IPPE training (Fidler, 2020; Tai *et al.,* 2020; Johnson *et al.,* 2021). Additionally, VPS-exposed students engaged more with patients in their IPPE than the control group (Tai *et al.,* 2020). These findings show that students could translate the skills gained from VPS into actual practice in their community IPPE. Moreover, most students felt more prepared to enter advanced pharmacy practice experience (APPE) training after completing VPS-based learning (Douglass *et al.,* 2013). Thus, pre-training VPS exposure helped students develop the necessary skills needed for training. Therefore, VPS can strengthen the pharmaceutical care competencies of pharmacy students (Cavaco & Madeira, 2012; Hussainy, Styles & Duncan, 2012; Smith, Siemianowski & Benedict, 2016; Gustafsson, Englund & Gallego, 2017).

VPS facilitates feedback

In some studies, students were presented with a VPS challenge, with multiple choices, and were provided with a positive or negative patient consequence along with standardised feedback unique to their intervention (Benedict & Schonder, 2011; Lichvar *et al.,* 2016). In some cases, immediate feedback was provided throughout the activity based on the intervention selected by the students (Douglass *et al.,* 2013; Lichvar *et al.,* 2016; Smith & Waite, 2017). In other studies, for every correct and incorrect choice, feedback was provided with detailed supporting literature (Benedict & Schonder, 2011; Al-Dahir *et al.,* 2014). Feedback enabled the students to understand the connection between the intervention selected and the virtual patient's treatment outcome (Benedict & Schonder, 2011).

Impact of VPS use on students' satisfaction and perception

In most studies, VPS enhanced students' satisfaction and perception (Benedict & Schonder, 2011; Mesquita *et al.,* 2015; Lichvar *et al.,* 2016; Smith, Siemianowski & Benedict, 2016; Bernaitis *et al.,* 2018; Huang *et al.,* 2020). In some studies, students were satisfied with VPS because it was an engaging tool (Hussainy, Styles & Duncan, 2012; Barnett *et al.,* 2016; Bindoff *et al.,* 2014; da Silva *et al.,* 2020). In other studies, students reported that VPS enabled self-paced learning (Douglass *et al.,* 2013; Lichvar *et al.,* 2016; Bernaitis *et al.,* 2018) and repetitive practice (Bernaitis *et al.,* 2018) in a controlled and stress-free environment that mimicked real-world practice. Improved satisfaction with the use of VPS is anticipated because VPS enables self-directed learning, reflection on learning, and the development of new understanding based on a scenario, which are pivotal elements in experiential learning theory (Kolb, 1984). Accordingly, adult learners have different learning styles. These include diverging (enjoy learning by watching and feeling), assimilating (enjoy learning by watching and thinking), converging (enjoy learning by doing and thinking), and accommodating (enjoy learning by doing and feeling) learning styles (Kolb, 1984). Studies reported that students positively perceived VPS-based training during the COVID-19 pandemic (De Ponti et al., 2020; Barakat et al., 2021). Understanding the different learning models can help design better individualised learning VPS. Individual learning styles may also influence student perceptions of VPS-based learning and performance. Students with a reflective learning style preferred traditional methods, while those with an active learning style preferred virtual computer-based learning (Al-Dahir *et al.,* 2014; Baumann-Birkbeck *et al.,* 2017). To be more effective, VPS should be developed based on an understanding of learning stages, different learning styles, learning objectives, and specific assessment methods. Hence, the designs of VPS varied accordingly based on their purpose (Richardson, White & Chapman, 2020). During focus group discussions, study participants involved in VPS-based communication skills development sessions reported improved communication skills, while their tutors expressed feeling comfortable using the VPS technology (Hussainy, Styles & Duncan, 2012; Mesquita et al., 2015). Similar improvements and satisfaction were reported by Brazilian pharmacy students who used VPS (Mesquita *et al.,* 2015), suggesting that VPS can help pharmacists advance their communication skills, which is essential for improving patient safety by minimising miscommunication errors.

Challenges of using VPS

In some studies, learners reported difficulty using VPS (Bindoff *et al.,* 2014), while others declared being uncertain whether they could translate their learning into clinical practice (Cavaco & Madeira, 2012). Others also stated that VPS limited their opportunity to handle actual medications (Hussainy, Styles & Duncan, 2012). In some studies, technological glitches distracted students from learning (Hussainy, Styles & Duncan, 2012; Douglass *et al.,* 2013; Gustafsson, Englund & Gallego, 2017; Thomas et al., 2021). Other studies also highlighted the need for more time and resources to develop, test, and maintain VPS software (Benedict & Schonder, 2011; Hussainy, Styles & Duncan, 2012; Douglass et al., 2013; Al-Dahir *et al.,* 2014; Lichvar et al., 2016; Smith & Waite, 2017; Tai *et al.,* 2020). The cost and time for standardising and developing VPS is a one-time expense that can be minimised by sharing VPS case scenarios between institutions (Smith, Siemianowski & Benedict, 2016). Sharing VPS can improve the return on investment, reduce the time needed to create a new VPS, and maximise the efficiency of the teaching method (Smith, Siemianowski & Benedict, 2016).

Strength and limitations

The strength of this study lies in the extensive search that was conducted using three databases. Moreover, this study addresses the void in the literature regarding the impact of VPS on pharmacy education. The results can inform pharmacy educators wishing to use VPS to improve pharmacy-related competencies. Although most studies emphasised the advantages of VPS, some reported drawbacks or limitations to using it in pharmacy education.

This study also has some limitations. Firstly, many of the reviewed studies were not longitudinal, thus limiting the assessment of the long-term impact of VPS on knowledge retention or skills. Secondly, the study search was limited to the years 2010–2021; therefore, only the studies available within this period were included. However, since the ACPE recognised the use of VPS to replace the portion of IPPE in 2010, the cutoff time was reasonable. Thirdly, the variability in the definition of VPS, the design, and the intent of VPS use in the different studies limits the ability to draw general conclusions regarding the impact of VPS on pharmacy education. Fourthly, the generalisability of these findings is limited in other allied healthcare professions since the review included studies on pharmacy students. Moreover, a meta-analysis was not possible because of the inclusion of various study designs and the heterogeneous nature of the results.

Conclusion

In the reviewed studies, students found VPS to be an interactive learning and dynamic tool that enabled them to transfer the knowledge learned in lectures to practice. In these studies, VPS was adopted as a tool to develop or evaluate pharmacy-related knowledge and skills, such as history-taking, counselling, clinical reasoning, physical assessment, decision-making, or SOAP note documentation. Studies found improvement in students' knowledge, skills, and confidence after VPS exposure. Additionally, the studies showed that pharmacy students, in general, positively perceive VPS-based learning. In some studies, VPS was more effective than traditional paper-based cases or lectures in improving learning, history-taking, and clinical decision-making skills. Therefore, the use of VPS, in addition to conventional methods, has the potential to improve pharmacy education. The collaboration of educators, policy-makers, and educational institutions is required to increase the utilisation of VPS. Recent technological advancements have significantly boosted the potential use of virtual reality (VR) in pharmacy education. VR provides immersive learning that closely resembles real-world situations. VR-based training in pharmacy education is still in its infancy, although more instructional VR applications are starting to become available.

Further controlled studies are necessary to determine the long-term impact and cost-effectiveness of VPS in comparison with traditional teaching methods. There is also a need to explore whether VPS design variabilities have an impact on knowledge and skills acquisition by pharmacy students. Finally, the potential impact of using virtual reality in pharmacy education should be explored.

Conflict of interest

None.

Disclosure statement

None.

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