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Immersive virtual reality simulation for practice-readiness competencies in pharmacy and health professions education: a scoping review

Farhamzah Farhamzah
Universitas Buana Perjuangan Karawang
Sriwidodo Sriwidodo
sriwidodo@unpad.ac.id

Universitas Padjadjaran
Eri Amalia
Padjadjaran University
Henderi Henderi
Universitas Raharja

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Abstract

Background

Immersive virtual reality (VR) simulation is increasingly used in pharmacy and health professions education, yet the evidence remains fragmented across technologies, pedagogical approaches, competency domains, assessment strategies, and implementation contexts. This review mapped how immersive VR is designed, implemented, and assessed to support practice-readiness competencies, with pharmacy education retained as an explicit analytical subgroup.

Methods

A JBI-informed scoping review was conducted, with reporting guided by PRISMA-ScR. The Population–Concept–Context framework guided eligibility. ERIC, MEDLINE Ultimate via EBSCOhost, Scopus, and PubMed/MEDLINE were searched for English-language empirical studies published from 2014 to 2026; core database searches were completed between 10 and 14 July 2026. Backward and forward citation checking was completed on 15 July 2026. Eligible studies evaluated an explicit immersive VR component in pharmacy or health professions education; virtual patients were included only when embedded within immersive VR. One primary reviewer screened and charted the evidence, with a structured second-pass audit of uncertain or high-impact decisions; no independent duplicate screening was undertaken. Data were synthesized using descriptive numerical summaries and thematic evidence mapping.

Results

Eighty-three records were identified, including three pharmacy-specific studies located through supplementary citation checking. After screening, 29 studies were included: 14 in nursing, seven in medicine, three in pharmacy, two interprofessional studies, and one each in physiotherapy, multidisciplinary nursing/medicine, and general health professions education. Evidence was mapped across five domains: technology and immersion, practice-readiness competencies, pedagogical design, assessment and outcomes, and implementation conditions. Clinical or practical performance, communication or counselling, and clinical reasoning were the most frequently represented competency domains. Outcomes predominantly focused on short-term knowledge, performance, confidence, usability, engagement, and learner experience, whereas assessment validity, transfer to practice, and longitudinal outcomes were less consistently reported. Pharmacy-specific evidence was concentrated on experiential orientation, sterile compounding, and aseptic preparation.

Conclusions

The review proposes an integrated design–competency–assessment–implementation taxonomy for interpreting heterogeneous immersive VR applications and identifying evidence gaps. Differences in study design and short follow-up periods limit what can be concluded about long-term practice readiness. Pharmacy-specific research should prioritize validated performance assessment and transfer to authentic practice.

Background

Health professions education must prepare learners to integrate knowledge, technical skill, communication, professional judgement, and safe decision-making before they assume responsibility in authentic practice. Simulation-based education can provide structured opportunities for deliberate practice when access to clinical sites, patients, procedures, or laboratory facilities is limited [1]. Immersive virtual reality (VR) extends this approach by placing learners inside interactive or panoramic environments that can reproduce clinical, laboratory, and patient-care situations while allowing repetition and standardization [2–11].

The educational contribution of immersive VR is not determined by novelty or fidelity alone. Learning depends on alignment among objectives, scenario design, level of immersion, learner preparation, agency, cognitive load, feedback, debriefing, assessment, and curricular placement [4, 5, 12–15]. Higher presence may increase engagement, but poorly structured immersive experiences may also increase extraneous cognitive load or distract learners from essential content [4, 5]. An effectiveness-only question may overlook the instructional conditions under which immersive VR is used.

Previous reviews have documented rapid growth and substantial heterogeneity. Across previous health professions reviews, VR has encompassed both desktop simulation and fully immersive head-mounted displays [2, 6–11]. Reviews focused on immersive nursing and medical education suggest potential benefits for selected knowledge and performance outcomes, but they also identify inconsistent definitions, small samples, variable comparators, short follow-up, limited validity evidence, and under-reporting of adverse effects and implementation requirements [6–11, 16–18]. Aiello and colleagues examined the affordances of immersive technology in clinical simulation [11], while Mangan and colleagues focused on immersive VR simulation design in healthcare education [19].

These issues are especially relevant to practice readiness. Practice-readiness competencies extend beyond knowledge acquisition to communication, counselling, dispensing, medication safety, clinical reasoning, decision-making, procedural or laboratory skills, interprofessional collaboration, empathy, and patient-centred care. Interpreting this evidence requires distinguishing knowledge, confidence, satisfaction, and usability from demonstrated performance and transfer to practice. Immersive VR may support these competencies through embodied patient encounters, interactive scenarios, multi-user collaboration, and repeatable task rehearsal, but the supporting pedagogy and assessment strategy must be visible in the evidence synthesis.

Pharmacy education requires an explicit analytical lens because much of the secondary literature on virtual patients and computer-based simulation is non-immersive [20–23]. Pharmacy-focused studies nevertheless show emerging immersive VR applications in experiential orientation and sterile preparation [24–26], while simulated-patient methods have been used for communication training and assessment [27]. A cross-professional review can therefore preserve sufficient breadth while using a pharmacy-specific subgroup to identify transferable lessons and gaps relevant to pharmacy curricula.

This scoping review focused on the links among immersive VR design, competency targets, assessment, and implementation, with pharmacy education retained as an explicit analytical subgroup. It mapped immersive VR design, level of immersion, device type, pedagogical sequence, feedback and debriefing, assessment approach, outcome domain, implementation barriers, cost and scalability, cybersickness and safety, equity and accessibility, faculty readiness, and pharmacy-specific implications. Artificial intelligence (AI)-enhanced VR and virtual patients were considered only when an explicit immersive component was present.

Objectives

The primary objective was to map the design, implementation, assessment, and educational outcomes of immersive VR simulation for practice-readiness competencies in pharmacy and health professions education.

The secondary objectives were to:

- develop a taxonomy linking immersive VR devices, delivery formats, interaction modes, and levels of immersion with pedagogical design, competency targets, assessment, and implementation conditions;
- map practice-readiness competency domains and the pedagogical designs used to support them;
- describe assessment methods, outcome domains, and the extent to which validity or transfer evidence was reported, distinguishing demonstrated performance from knowledge, confidence, and learner-experience outcomes;
- identify implementation barriers and facilitators, including cost, scalability, cybersickness, safety, accessibility, equity, and faculty readiness;
- synthesize pharmacy-specific evidence and implications within the wider health professions evidence base; and
- identify emerging uses of AI-enhanced immersive VR and embodied virtual patients.

Methods

Review design and reporting

This review was conducted as a JBI-informed scoping review using the Population–Concept–Context framework [28]. Reporting was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR), and search reporting was informed by its literature-search extension (PRISMA-S) [29, 30]. A prospective protocol (version 0.2, 14 July 2026) was developed before completion of the review and is available from the authors. The protocol was not registered in PROSPERO.

Eligibility criteria

Eligibility was based on the Population–Concept–Context framework and the criteria in Table 1.

Table 1. Eligibility criteria based on the Population–Concept–Context framework.

Domain	Inclusion criteria	Exclusion criteria
Population	Pharmacy students, pharmacy interns, student pharmacists, pharmacists in training, and health professions students or trainees. Educators or faculty were eligible when the study evaluated implementation, feasibility, curricular integration, or educational delivery.	Patients receiving VR therapy, public users, general school students, veterinary learners, or non-health professions learners without a health-professions education component.
Concept	Immersive VR simulation delivered through a head-mounted display, VR headset, Cave Automatic Virtual Environment (CAVE), immersive 360-degree format, immersive virtual environment, or an embodied virtual patient within VR. AI-enhanced VR was eligible when AI was part of the immersive simulation.	Desktop-only or web-based virtual patients, screen-based simulations, virtual classrooms, learning management systems (LMS), serious games without immersive VR, augmented reality (AR)-only or mixed reality (MR)-only studies without separable VR data, and digital simulations without an explicit immersive component.
Context	Undergraduate, professional, postgraduate, or continuing health professions education, including clinical skills, counselling, dispensing, medication safety, laboratory skills, clinical reasoning, patient-care skills, teamwork, and simulation-based learning.	Clinical treatment, rehabilitation, diagnosis, or patient care without an education or training purpose.
Evidence type	Peer-reviewed empirical quantitative, qualitative, mixed-methods, randomized, quasi-experimental, comparative, usability, design-based, validation, and implementation studies. Empirical conference proceedings were eligible.	Reviews, editorials, commentaries, letters, protocols without results, purely conceptual papers, bibliometric studies, and technical descriptions without learner, educator, implementation, or educational evaluation data.
Language and date	English-language publications from January 2014 through 2026 that were available by the final database searches in July 2026.	Non-English publications and publications outside the date window, except seminal sources used for background.

Within these criteria, immersive 360-degree video refers to delivery through an immersive device rather than a conventional desktop display. Passive viewing does not imply active task manipulation. Anatomy visualization and design or framework studies must also meet the educational-context and empirical-evidence requirements in Table 1.

Information sources

Electronic searches were conducted in ERIC, MEDLINE Ultimate via EBSCOhost, Scopus, and PubMed/MEDLINE between 10 and 14 July 2026. The institutional EBSCOhost database list did not include CINAHL; therefore, MEDLINE Ultimate was reported transparently and was not described as CINAHL. Web of Science Core Collection was planned but could not be searched because institutional

access was unavailable. Reference lists of included studies and key reviews were examined, and forward citation checking was undertaken through Scopus and supplementary Google Scholar searching on 15 July 2026. Google Scholar was used only for citation checking and snowballing, not as a core bibliographic database. Search logs and export records were consolidated on 16 July 2026 and retained in the project audit files.

Search strategy

The search strategy combined four concepts: (1) immersive VR technology; (2) simulation, immersive environment, virtual laboratory, or virtual patient; (3) pharmacy and health professions education; and (4) practice-readiness competencies. In the reported search strings, simulation and competency terms were combined within the same Boolean block. Controlled vocabulary was combined with title, abstract, and keyword terms where supported. The reported search strings did not use VR or XR as stand-alone search terms. Virtual-patient terms were never used as a stand-alone core concept. Broad exclusions using NOT operators, such as NOT surgery, NOT rehabilitation, or NOT therapy, were not used because they could remove relevant educational studies. Full database-specific strategies are provided in Supplementary Table S3 (Additional file 1).

Study selection

Retrieved records were managed in Mendeley, which was also used to organize full texts. Potential duplicates were assessed using title normalization and manual comparison; no duplicate was confirmed in the final 83-record set. Title and abstract screening was managed in Rayyan, and full-text assessment was managed with Mendeley. Farhamzah served as the primary reviewer for title/abstract and full-text screening. Records with unclear immersion, population, empirical status, or educational context were advanced to full-text review, and full-text exclusions were assigned one primary reason. Uncertain or high-impact decisions underwent a structured second-pass audit in Microsoft Excel by the same primary reviewer against the prespecified operational definitions and source records. This second pass was a self-audit rather than independent duplicate screening; any inconsistencies were resolved by rechecking the eligibility criteria and the source record. For source-level reporting in Table 2, records are shown under the information source recorded in the project screening log; these counts describe the review workflow and should not be interpreted as unique database coverage. The final decision trail was retained for the PRISMA flow diagram. Full-text exclusion reasons are summarized in Supplementary Table S2 (Additional file 1).

Data charting

Farhamzah charted all included studies in Microsoft Excel using a standardized form that captured citation, country, discipline, learner population, sample size, study design, VR type, device or platform,

level of immersion, scenario, competency targeted, pedagogical design, prebriefing, feedback or debriefing, assessment method, outcome domain, main findings, usability or acceptability, implementation barriers, cost or scalability, cybersickness or safety, equity or accessibility, faculty readiness, pharmacy-specific relevance, AI or virtual-patient features, author-reported limitations, and reviewer notes. The form was refined iteratively as recommended for scoping reviews [28]. The five organizing domains were prespecified from the protocol and review objectives, while competency subcategories were refined during charting. During manuscript preparation, critical fields and study-to-domain assignments were rechecked against the available source records; no independent duplicate data extraction was undertaken. A separate formal codebook was not maintained. The non-exclusive study-to-domain mapping used for the reported competency counts is provided in Supplementary Table S4 (Additional file 1). For interpretation, the absence of reported information does not establish that a feature or outcome was absent.

Methodological mapping

No formal risk-of-bias or critical-appraisal tool was applied. The purpose of the review was to map a heterogeneous evidence base rather than estimate a pooled treatment effect. Instead, study design, sample, comparator, assessment method, validity evidence, follow-up, and implementation reporting were charted to support descriptive methodological interpretation. This descriptive mapping is not equivalent to a formal risk-of-bias assessment.

Synthesis

The synthesis combined descriptive numerical summaries with thematic evidence mapping. Technologies and levels of immersion were mapped alongside competency domains, pedagogical features, assessment methods, and implementation conditions. The organizing domains reflect the protocol and review objectives rather than a wholly data-derived taxonomy. Competency coding was non-exclusive because a single simulation could target multiple domains. Knowledge, confidence, and learner experience are distinguished conceptually from demonstrated performance and transfer to practice. A distinct pharmacy subgroup synthesis examined pharmacy learners, pharmacy practice tasks, and implications for curriculum design. No meta-analysis was planned because of heterogeneity in interventions, learners, outcomes, and study designs.

Use of artificial intelligence

Generative AI tools, including ChatGPT (OpenAI), were used to assist manuscript drafting and revision, language refinement, document organization, screening triage and consistency auditing, reference checking, and preparation of code for figures. AI-generated suggestions were not treated as independent reviewer decisions. Farhamzah retained responsibility for final eligibility decisions, numerical summaries,

coding, interpretation, and manuscript content. The submission figures were rendered programmatically from the reported counts and conceptual labels; they are not generative-image outputs. No AI system is listed as an author.

Results

Study selection

The database searches yielded 80 records. Three additional pharmacy-specific empirical studies were identified through supplementary citation checking, resulting in 83 records. No duplicate was confirmed after title normalization and manual review. Of the 83 records screened, 36 were excluded at title and abstract screening. Forty-seven full-text reports were assessed; 18 were excluded: 15 were secondary or narrative reviews rather than primary evidence, two did not meet the explicit immersive-VR criterion on source verification, and one provided insufficient empirical educational evaluation. Twenty-nine studies were included in the final synthesis (Fig. 1). Full-text excluded reports and their primary reasons are listed in Supplementary Table S2 (Additional file 1).

Table 2 summarizes the records screened, exclusions at the title/abstract and full-text stages, and studies included by information source. The overall selection process is shown in Fig. 1.

Table 2
Study selection outcomes by information source.

Source	Records screened	Records excluded at title/abstract	Reports excluded at full text	Studies included
ERIC	20	5	5	10
MEDLINE Ultimate via EBSCOhost	23	14	5	4
Scopus	16	3	2	11
PubMed/MEDLINE	21	12	8	1
Supplementary citation checking	3	0	0	3
Total	83	36	18	29

Note: Counts are reported by information source and should not be interpreted as the unique contribution of each database.

Characteristics of included studies

The 29 included studies were published between 2020 and 2026. Nursing was the dominant discipline (14/29, 48.3%), followed by medicine (7/29, 24.1%), pharmacy (3/29, 10.3%), interprofessional education (2/29, 6.9%), physiotherapy (1/29, 3.4%), multidisciplinary nursing/medicine (1/29, 3.4%), and general health professions education (1/29, 3.4%) (Fig. 2) [31–34]. Study designs were heterogeneous and

included qualitative studies, randomized and quasi-experimental evaluations, controlled and comparative studies, cross-sectional evaluations, usability and validation studies, design-based research, and mixed-methods implementation evaluations. Sample sizes ranged from small usability studies to a quasi-experimental evaluation with more than 1700 participants. Characteristics of individual studies are provided in Supplementary Table S1 (Additional file 1).

Technology and level of immersion

Head-mounted displays (HMDs), including standalone VR headsets, were used in the included studies. Applications included procedural and practical simulations, anatomy environments, patient embodiment, simulated operating rooms, multi-user collaborative spaces, disaster scenarios, and immersive clinical encounters. Three distinct design patterns were evident: interactive six-degrees-of-freedom simulations; immersive 360-degree video used for orientation, perspective taking, or situated exposure; and embodied or conversational virtual patients. Multi-user environments were used for interprofessional or case-based learning [35, 36], while AI-enhanced systems were used for scenario generation or conversational interaction [37, 38]. No included study used a CAVE as the primary delivery system.

Practice-readiness competency domains

Competency domains were non-exclusive. Clinical or practical performance was mapped in 15/29 studies, communication or counselling in 14/29, clinical reasoning or decision-making in 10/29, knowledge or anatomy in 8/29, and empathy, professional identity, or patient perspective in 7/29. Teamwork or leadership was a central target in 3/29 studies (Fig. 3). The included studies covered both technical and patient-facing competency domains. These counts describe the domains addressed, not the number of studies demonstrating improved competence. The contributing studies for each domain are shown in Supplementary Table S4 (Additional file 1).

Pedagogical design

Interventions with more detailed pedagogical reporting embedded VR within a broader learning sequence rather than presenting the headset experience as a self-contained event. Reported elements included orientation or prebriefing, guided case structure, facilitator prompts, repetition, reflective learning, feedback, and debriefing. Reflective learning was described in mental-health nursing simulation [39], while facilitator support was described in pedagogical-model and interprofessional studies [35, 40]. However, pedagogical reporting was inconsistent: many studies described the application and outcome measures more clearly than the learning theory, prebriefing, facilitation, or debriefing process.

Assessment and outcomes

Outcome measurement concentrated on short-term knowledge, skill performance, self-confidence, satisfaction, usability, engagement, and learner experience. Performance assessment was reported in sterile-preparation and VR objective structured clinical examination (OSCE) studies [24, 26, 41], whereas anatomy-focused studies addressed knowledge and learner-reported outcomes [42, 43]. Communication

and history-taking studies used interviewer ratings, confidence measures, or validity-oriented development processes. Mohd Salim et al. reported acceptable face and content validity but limited reliability, construct validity, and concurrent validity [44]. Neher et al. examined performance, workload, and fairness in a comparison with in-person assessment [41]. Longitudinal transfer to authentic practice, patient-level outcomes, and durable behaviour change were infrequently reported.

Implementation, safety, and equity

Implementation themes included hardware availability, software stability, speech recognition, tactile limitations, setup time, facilitator expertise, curricular scheduling, and institutional support. Cost and resource requirements were noted as implementation concerns [45]. Five of the 29 studies explicitly reported cybersickness, discomfort, or adverse-effect monitoring [26, 33, 36, 41, 46]. Reported findings included minimal adverse effects [41], no significant cybersickness symptoms reported [46], and mild discomfort in some users [36]. Esumi et al. queried participants about dizziness, nausea, and eye strain after the task and documented reported discomfort [26]. Saab et al. also recorded symptoms such as headache, eye strain, cybersickness, and dizziness during evaluation of a Meta Quest-based communication intervention [33]. Systematic evaluation of accessibility and equity was infrequently reported. Device sharing, physical space, bandwidth, disability accommodation, and the readiness of faculty and technical staff were noted as practical concerns.

Pharmacy-specific subgroup

Three pharmacy-specific empirical studies (3/29) were identified through supplementary citation checking. They targeted experiential orientation to hospital pharmacy, sterile compounding, and aseptic preparation (Table 3). Outcomes included knowledge, satisfaction, compounding performance, workload, and procedural performance [24–26]. The subgroup remained small and provided limited evidence for patient counselling, medication history taking, dispensing accuracy, clinical reasoning, or interprofessional medication management in fully immersive VR.

Table 3
Pharmacy-specific included studies.

Study	Population and design	Immersive VR format	Practice-readiness focus	Reported findings and limitations
Alkhudair et al., 2024 [25]	PharmD students; n = 336; quasi-experimental	VR headset with three 360° hospital-pharmacy environments	Experiential orientation; pharmacist roles; knowledge; satisfaction	Standardized exposure and high learner satisfaction; emphasizes curricular integration.
Contaifer et al., 2024 [24]	Second-year student pharmacists; n = 19; randomized cross-sectional	Immersive 360° sterile-compounding video	Knowledge; compounding performance; workload	Reported feasibility and workload measurement; limited by small enrolment.
Esumi et al., 2026 [26]	Pharmacy students; n = 17; comparative trial (VR, n = 9; text-based training, n = 8)	Interactive aseptic-preparation VR application (Meta Quest 2)	Procedural workflow; operational fluency; practical performance; safety	Faster task completion and better performance at selected checkpoints were reported with VR; the difference in holistic ratings was not statistically significant. Small sample and immediate assessment.

AI-enhanced VR and immersive virtual patients

AI-enhanced immersive VR was represented by scenario-generation and conversational patient-encounter applications [37, 38]. AI supported scenario creation in the skills simulation evaluated by Hesse et al. [37], while the study by He et al. examined learner experiences with an immersive patient encounter enhanced with generative AI (GenAI) [38]. Reported limitations in immersive patient-encounter studies included technical difficulties, speech recognition, believability, and empathy [38, 47].

Integrated evidence map and taxonomy

The synthesis organized the evidence across five domains identified in the protocol and review objectives: technology and immersion; pedagogical design; practice-readiness competencies; assessment and outcomes; and implementation conditions. Pharmacy-specific relevance functions as an interpretive lens across all five domains rather than as a separate technology category (Fig. 4).

Table 4 presents the mapped evidence within each domain, with illustrative examples from the included studies.

Table 4
Integrated evidence map with illustrative study examples.

Domain	Mapped evidence	Illustrative study examples
Technology and immersion	HMD/headset, immersive 360° video, multi-user VR, embodied virtual patient, AI-supported scenario generation or interaction	360° pharmacy experiences [24, 25]; HMD/360° healthcare learning [31, 32]; Meta Quest communication training [33]; multi-user or avatar-based VR [34–36]; AI applications [37, 38]; virtual-patient studies [44, 47, 48].
Pedagogical design	Orientation, prebriefing, scenario sequencing, facilitator support, repetition, reflection, feedback, debriefing	Pedagogical model [40]; interprofessional simulation [34, 35]; reflective mental-health nursing simulation [39].
Competency domain	Practical skills, communication/counselling, clinical reasoning, knowledge, empathy, teamwork/leadership	Practical skill/performance [24, 26, 31, 32]; communication training [33, 34]; interprofessional teamwork [34, 35]; leadership [49]; history taking and communication [44, 48].
Assessment and outcomes	Knowledge tests, performance ratings, confidence, usability, engagement, qualitative experience, validity evidence	Compounding performance and workload [24]; VR OSCE [41]; controlled 360° learning [32]; engagement and confidence across modalities [50]; face/content validity [44].
Implementation	Cost, scalability, technical support, cybersickness, safety, accessibility, equity, faculty readiness	Tactile limitations [51]; usability/cybersickness [33, 46]; mild discomfort [36]; speech recognition [47]; costs/resources and human feedback [45].
Pharmacy-specific subgroup	Experiential orientation, pharmacist roles, knowledge, satisfaction, sterile compounding, aseptic preparation, performance, and workload	Hospital-pharmacy orientation [25]; sterile compounding [24]; aseptic preparation [26].

Examples are illustrative, not an exhaustive study-to-domain matrix. The competency counts are reported in the text and Fig. 3. Mention of an implementation issue does not establish that it was formally evaluated.

Discussion

Principal findings and integrated taxonomy

This review maps immersive VR simulation in anatomy teaching, procedural rehearsal, communication, reflection, interprofessional learning, and assessment. The 29 included studies formed a heterogeneous but interpretable evidence base. Their common feature was not a single headset or outcome, but the attempt to place learners in a situated environment where action, judgement, communication, or perspective could be practised before entering practice. The present review adds an integrated design–

competency–assessment–implementation map. The five domains reflect the review objectives and organize the included evidence; they do not constitute a validated causal model. The taxonomy helps explain why a 360-degree orientation video, a multi-user collaborative environment, a procedural simulation, and an embodied virtual patient should not be interpreted as interchangeable interventions.

Aiello and colleagues examined immersive clinical simulation, authentic learning design, and stress-related responses [11]. Mangan and colleagues developed a framework addressing the rationale, content design and modification, and development of immersive VR simulations [19]. These reviews already address educational design. The present review links design, competency targets, assessment, and implementation, with an explicit pharmacy subgroup. Table 5 summarizes this positioning.

Table 5
Positioning of the present review in relation to selected previous reviews.

Review	Main focus	Emphasis of the present review
Aiello et al., 2023 [11]	Immersive clinical simulation, authentic learning design, and stress responses.	Competency–assessment–implementation links and a pharmacy subgroup.
Mangan et al., 2026 [19]	Rationale, content design and modification, and simulation development.	Practice-readiness-related outcomes, assessment validity, transfer, and pharmacy relevance.
Pharmacy virtual-patient reviews [20–22]	Virtual patients and computer-based simulation for pharmacy learning and communication.	An explicit immersive VR boundary rather than virtual patients generally.
VR effectiveness reviews [2, 10]	Effects on educational outcomes, including knowledge and skills.	Descriptive mapping of heterogeneous evidence, without pooled effectiveness estimates.

The comparison highlights differences in emphasis; it does not imply that previous reviews omitted all of these topics.

Fit-for-purpose immersion: modality–competency alignment

Interactive VR environments were used for procedural and practical performance tasks [26, 32, 41]. In contrast, immersive 360-degree video was used for experiential orientation, practical positioning, environmental familiarization, and perspective-taking [24, 25, 32, 52]. Embodied virtual patients introduced opportunities for repeated patient-facing encounters, yet studies identified limitations in speech recognition, believability, and empathy [38, 47].

The present synthesis suggests a principle of fit-for-purpose immersion, whereby technological complexity should be justified by the competency being developed or assessed. For communication-intensive scenarios, increased visual fidelity alone may provide limited educational benefit unless

accompanied by responsive dialogue, meaningful feedback, and authentic interpersonal interaction. Reports should distinguish device, field of view, tracking, locomotion, interaction, and embodiment from the educational task.

Studies with clearer prebriefing, scenario structure, facilitation, reflective learning, feedback, or debriefing provided a more coherent explanation of how the immersive experience was expected to support learning. This is consistent with simulation standards and with the Cognitive Affective Model of Immersive Learning (CAMIL) proposition that immersive media interact with instructional method rather than guaranteeing learning through presence alone [4, 5, 13–15]. This review does not establish that pedagogy mediated the observed outcomes. Describing the instructional sequence and its objectives would help replication and comparison across settings.

From learner engagement to demonstrated competence and transfer

The findings also reinforce caution against equating presence, engagement, or satisfaction with learning. Confidence may encourage participation and willingness to engage with clinical situations, but it does not necessarily indicate accurate clinical judgement or consistent procedural performance. Similarly, highly immersive experiences may generate strong feelings of presence while simultaneously increasing cognitive load or introducing usability constraints that influence learning efficiency [4, 5].

Knowledge and confidence should therefore be interpreted as supporting educational outcomes, while usability and satisfaction describe learner experience. Empathy and professional-identity findings also require interpretation according to the instruments and methods used. A clinical reasoning test also provides different evidence from decision-making observed under task conditions. Performance in a simulated task is more direct evidence of competence, but does not itself establish transfer to authentic practice. For example, lower performance in the VR OSCE than in the in-person comparison [41] and more favourable ratings of standardized patients for believability and empathy [47] caution against assuming that immersion is sufficient for communication assessment.

Future research should align the level of outcome with the educational claim. Knowledge acquisition can be assessed with well-designed tests, but claims about practice readiness require performance assessment, defensible rating processes, and evidence of transfer. Communication, clinical reasoning, and patient-care simulations should report rater training, scoring frameworks, reliability, and validity evidence. Greater attention to longitudinal retention and transfer into authentic clinical environments would strengthen the evidentiary basis for claims regarding practice readiness.

Pharmacy-specific evidence and implications for education

The pharmacy-specific evidence comprised three of the 29 studies and was concentrated in experiential orientation, sterile compounding, and aseptic preparation [24–26]. Pharmacy-focused literature has

included virtual patients and computer-based simulation for experiential education and communication, but much of this evidence does not involve fully immersive VR [20–23]. Evidence from these adjacent approaches should not be treated as direct evidence for immersive VR.

Medication counselling, prescription verification, medication-history collection, dispensing decisions, and interprofessional medication management require learners to integrate clinical reasoning, communication, and professional judgement [20–23, 27]. Future studies should develop and evaluate immersive environments for medication histories, counselling, dispensing decisions, medication safety, interprofessional handovers, and complex patient-care scenarios, with outcomes that extend beyond satisfaction. These are proposed research directions, not benefits established by the three pharmacy-specific studies.

The pharmacy subgroup identified in this review therefore represents an emerging foundation rather than a mature evidence base. Pharmacy participants and tasks should be reported separately to distinguish direct pharmacy evidence from potentially transferable findings in other professions. Such an approach would allow pharmacy education to adapt lessons from broader health professions education while avoiding the assumption that evidence generated in nursing or medicine can be directly adopted without contextual modification. Immersive VR is most defensible as a complement to, rather than a universal replacement for, authentic practice and human feedback.

Implementation, safety, equity, and AI governance

Pharmacy-specific implementation should also address the realities of laboratories and experiential education. Tactile fidelity, medication products, prescription data, privacy, faculty workload, equipment turnover, infection control, technical support, and access across student cohorts may influence feasibility. The implementation account by Li and colleagues emphasizes centralized institutional support and integration with guided discussion [23]. Cost and scalability require explicit resource reporting, not assumptions based on reusable software.

Cybersickness and discomfort should be monitored using recognized tools and reported alongside exposure duration, device, locomotion, and withdrawal [16–18]. Equity-focused research should examine disability accommodation, digital access, cultural representation, language, avatar bias, and infrastructure constraints. Faculty development should be treated as part of the intervention rather than an invisible background resource. These priorities concern implementation and reporting; they are not evidence that all included interventions lacked these features.

AI may increase scenario variability, responsiveness, and scalability, particularly for embodied virtual patients. However, AI also adds risks related to factual accuracy, unpredictable dialogue, bias, privacy, data governance, and over-reliance on automated feedback [53]. AI used to create a scenario is not necessarily an AI system interacting with the learner [37, 38]. The pedagogical role of AI should be explicit: scenario generation, conversational interaction, feedback, assessment, or adaptation are distinct functions. Clear reporting of embodiment, interaction channel, model architecture, feedback

logic, privacy safeguards, and human oversight is therefore needed. These are reporting recommendations, not claims that governance outcomes were evaluated across the included studies.

Strengths and limitations

Strengths of this review include a prospective PCC framework, an explicit definition of immersive VR, separation of immersive virtual patients from non-immersive systems, charting of pedagogy and implementation, and a pharmacy-specific analytical subgroup. Supplementary citation checking identified the three pharmacy-specific studies.

Several limitations should be considered. Web of Science and CINAHL were not available through the institutional subscriptions used, and PubMed and MEDLINE Ultimate have overlapping coverage. The review was limited to English-language studies available through the July 2026 searches. Terminology was inconsistent, and some reports did not describe device or immersion clearly. The evidence base was heterogeneous and dominated by nursing and medicine. Study selection, data charting, and competency coding were primarily conducted by one reviewer, with a structured self-audit rather than independent duplicate review; this may increase the risk of selection or coding error. No formal risk-of-bias appraisal was undertaken, and descriptive methodological mapping does not establish certainty about comparative effectiveness. Many studies used small samples, short follow-up, and self-reported outcomes. Finally, gaps in reporting should not be interpreted as proof that a feature or outcome was absent.

Conclusions

This scoping review maps immersive VR applications in pharmacy and health professions education, including technical and procedural training, communication, clinical reasoning, patient perspective, teamwork, reflection, and assessment-oriented activities. However, heterogeneous study designs, short follow-up, and infrequent reporting of assessment validity and transfer to authentic practice limit conclusions about long-term practice readiness. The integrated design–competency–assessment–implementation taxonomy developed in this review provides a framework for interpreting this evidence. For pharmacy education, the evidence base remains limited and is currently concentrated on experiential orientation, sterile compounding, and aseptic preparation. Future pharmacy-specific research should evaluate immersive VR for medication counselling, dispensing, medication safety, clinical reasoning, and interprofessional medication management, using validated performance measures and examining transfer to practice.

Abbreviations

Abbreviation	Meaning
AI	Artificial intelligence
AR	Augmented reality
CAMIL	Cognitive Affective Model of Immersive Learning
CAVE	Cave automatic virtual environment
GenAI	Generative artificial intelligence
HMD	Head-mounted display
HPE	Health professions education
IVR	Immersive virtual reality
LMS	Learning management system
MR	Mixed reality
OSCE	Objective structured clinical examination
PCC	Population–Concept–Context
PRISMA-S	Preferred Reporting Items for Systematic Reviews and Meta-Analyses literature search extension
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews
VR	Virtual reality
XR	Extended reality

Declarations

Ethics approval and consent to participate

Not applicable. This scoping review synthesized evidence from published literature and did not involve the recruitment of human participants, the collection of primary participant data, or access to identifiable personal data or human biological material. Ethics committee approval and informed consent were therefore not required for this review. The Declaration of Helsinki requirements for research involving human participants were not applicable to this literature-based evidence synthesis. The review used a JBI-informed approach, and reporting was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR), as described in the Methods section.

Consent for publication

Not applicable.

Availability of data and materials

The screening summary, evidence-charting framework, search strategies, included-study characteristics, and study-to-domain matrix are presented in the manuscript and supplementary material. Additional audit files, including search logs, screening records, and the extraction workbook, are retained by the review team and may be provided by the corresponding author on reasonable request. No public repository was used.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

F: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing, Project administration.

S: Supervision, Methodology, Writing – review & editing.

E.A: Supervision, Writing – review & editing.

H: Supervision, Writing – review & editing.

All authors read and approved the final manuscript and agree to be accountable for the work.

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AI-use statement

Use of generative AI is described in the Methods section. All authors retain responsibility for the integrity and final content of the manuscript. No AI system is listed as an author.

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Figures

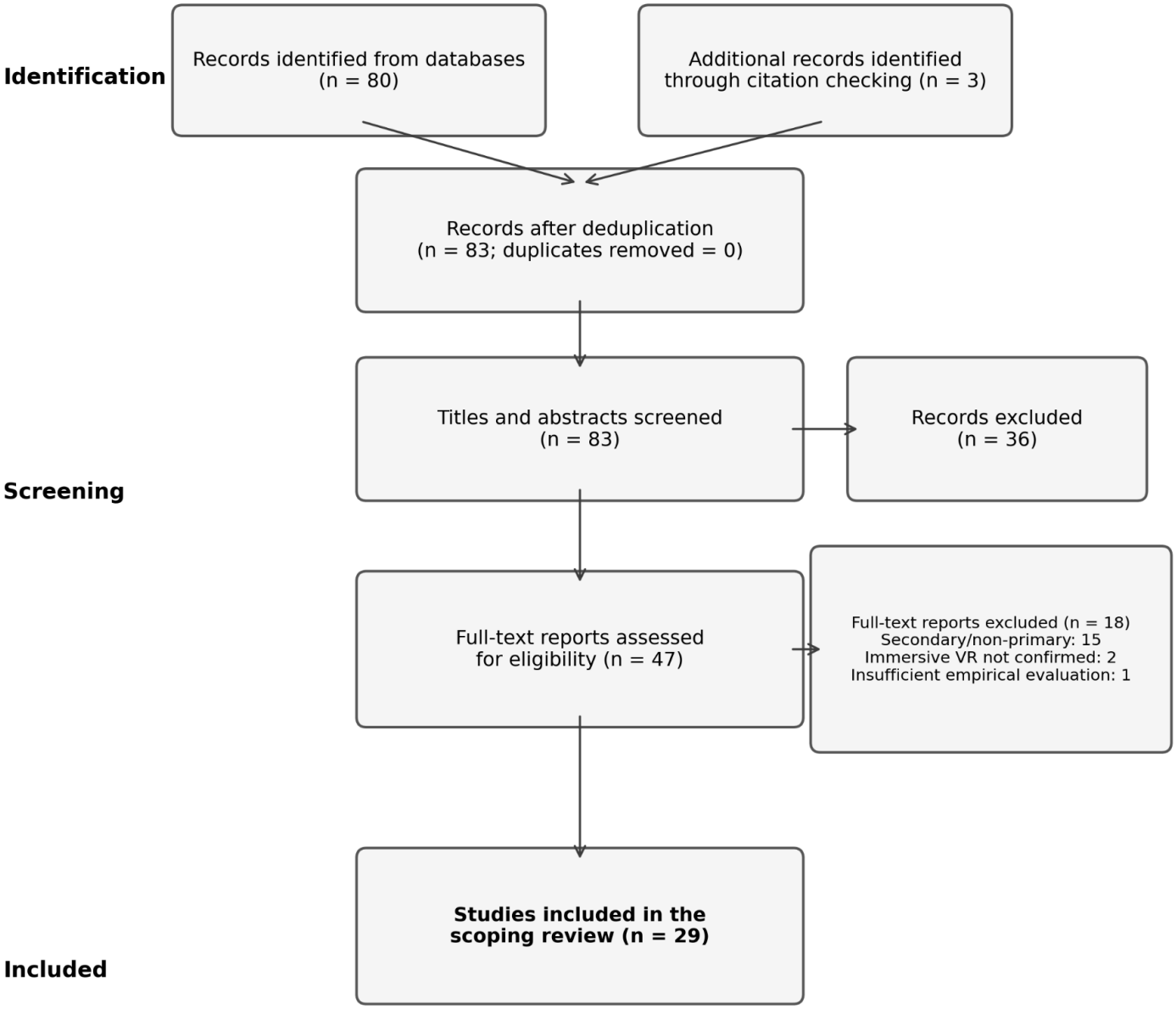


Figure 1

PRISMA-ScR flow diagram for study selection.

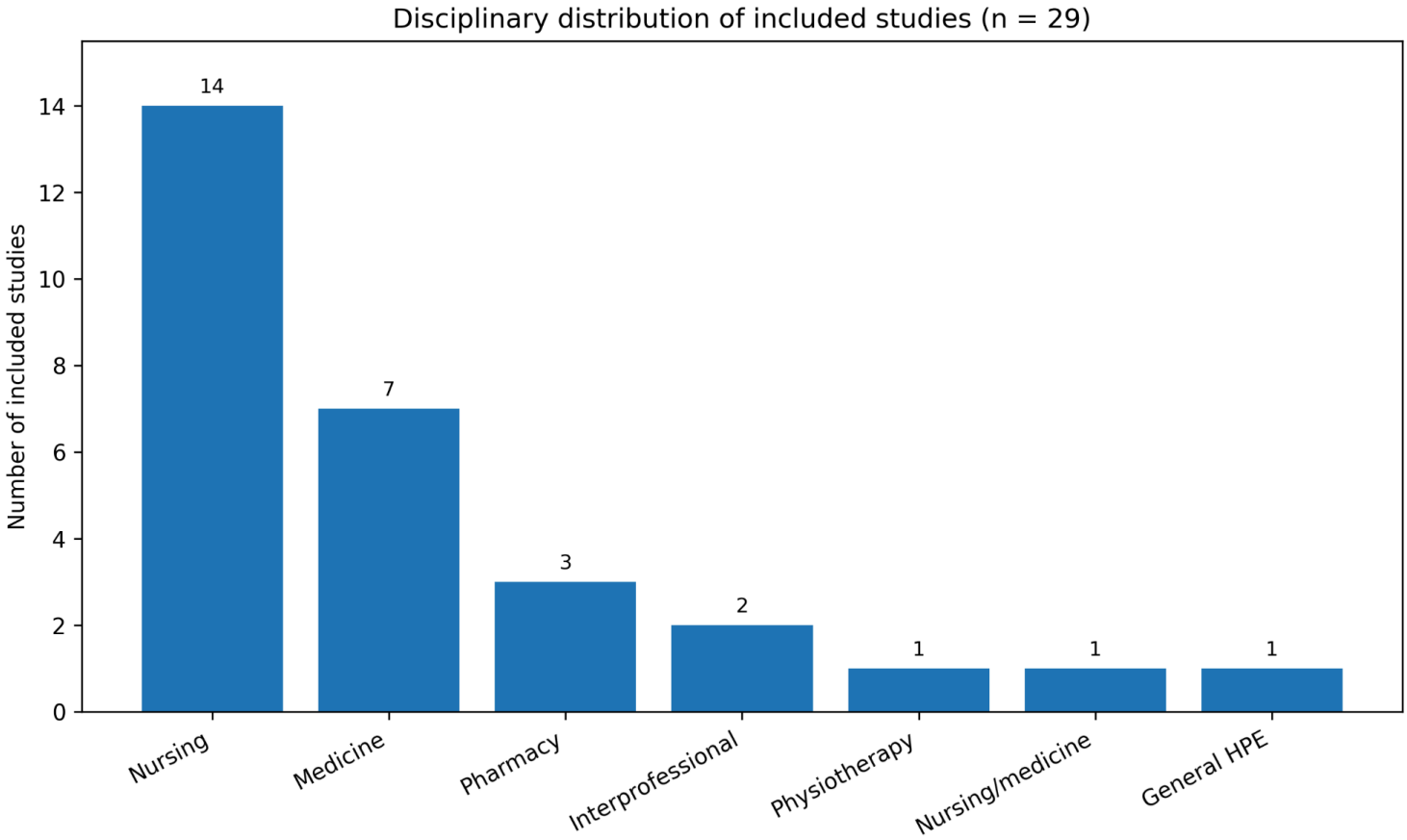


Figure 2

Disciplinary distribution of included studies.

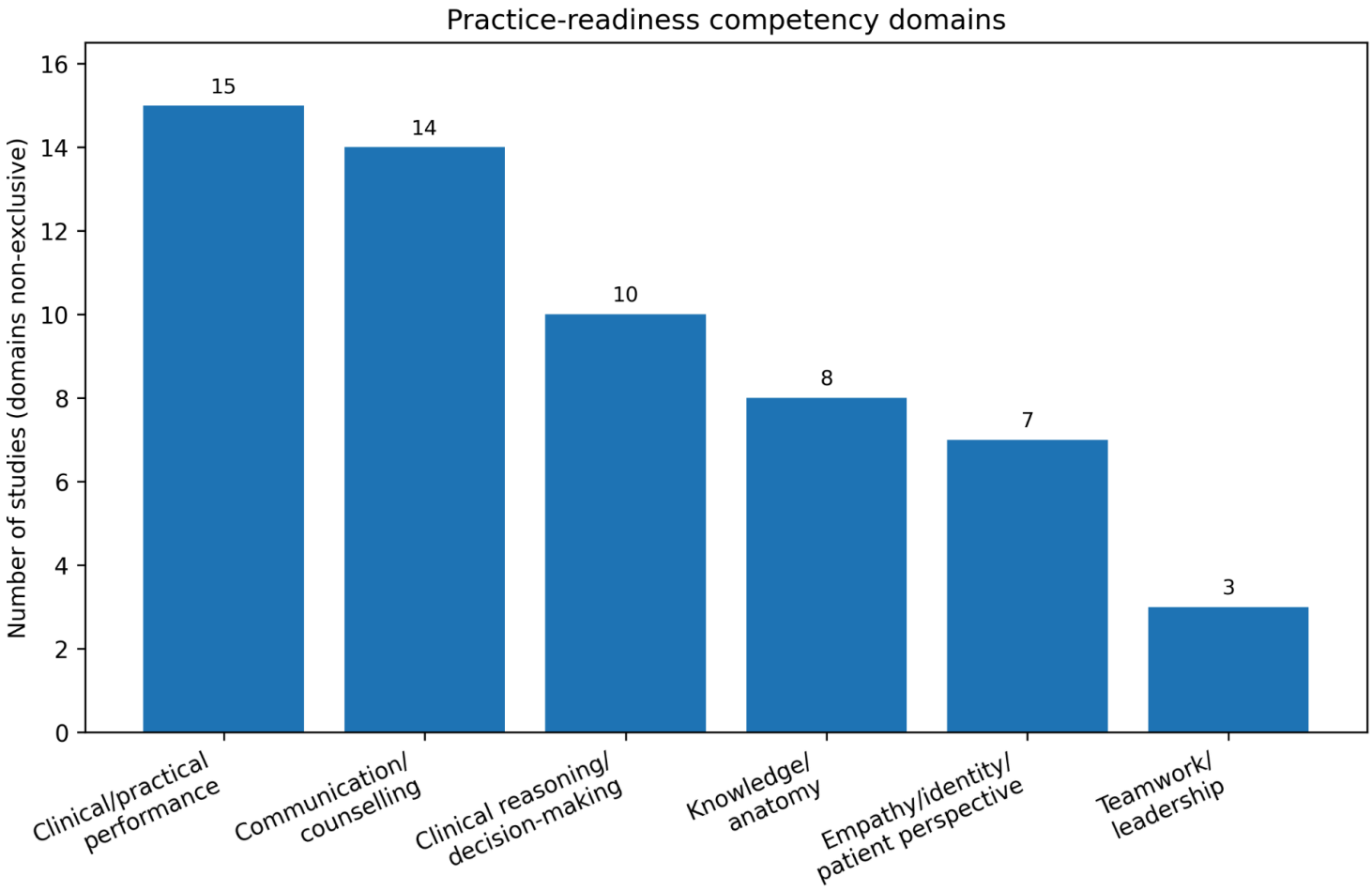


Figure 3

Practice-readiness competency domains represented in the included studies (n = 29). Domains were non-exclusive; one study could contribute to more than one domain.

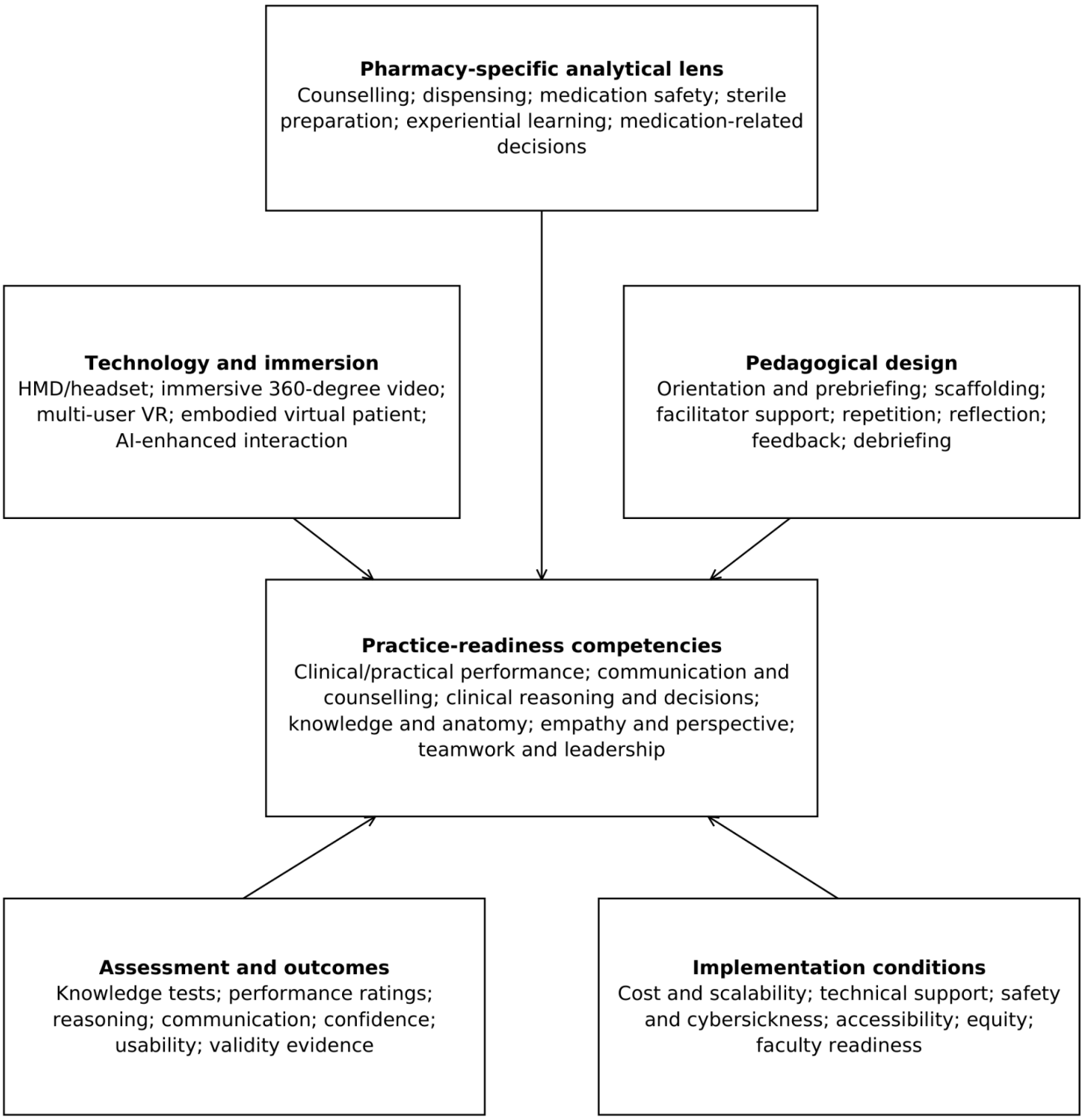


Figure 4

Integrated design–competency–assessment–implementation taxonomy for immersive VR simulation. The five domains reflect the review objectives. Arrows indicate conceptual links, not estimated effects. The pharmacy lens includes curriculum-relevant topics beyond the tasks evaluated in the three pharmacy-specific studies.

Supplementary Files

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