Simulation-Based Learning vs. Problem-Based Learning in Medical Education: A Comparative Study of Clinical Competency Outcomes

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ABSTRACT

Background: Active pedagogical strategies have become central to competency-based medical curricula. Simulation-based learning (SBL) and problem-based learning (PBL) are two dominant modalities, yet comparative evidence from Central Asian medical institutions remains limited. **Objective:** To compare the effects of SBL and PBL on clinical skills, knowledge retention, critical reasoning, and student satisfaction among undergraduate medical students at FMIOPH and ASMI, Uzbekistan. **Methods:** A prospective quasi-experimental study enrolled 322 third-year medical students (FMIOPH SBL group: n = 163; ASMI PBL group: n = 159). Outcomes were measured via OSCE, validated MCQ assessments, and Likert-scale satisfaction surveys over one academic semester. **Results:** SBL students demonstrated significantly higher clinical skills scores (84.3% vs. 76.8%, $p < 0.001$), OSCE pass rates (86.4% vs. 79.1%, $p = 0.014$), and satisfaction (88.7% vs. 82.3%, $p = 0.001$). PBL students showed comparable critical reasoning gains (78.9% vs. 81.2%, $p = 0.027$). **Conclusion:** SBL offers superior procedural and clinical skill acquisition, while PBL effectively supports analytical reasoning. A hybrid curriculum integrating both modalities is recommended for Uzbek medical institutions.

Keywords: *simulation-based learning; problem-based learning; medical education; clinical competency; OSCE; Uzbekistan; undergraduate training*

1. INTRODUCTION

The global transformation of medical education from a didactic, lecture-centred paradigm to active, student-centred methodologies has been one of the most significant pedagogical shifts of the twenty-first century [1, 2]. As clinical environments become more complex and patient safety concerns intensify, medical schools worldwide have moved toward experiential pedagogies that cultivate not only theoretical knowledge but also procedural dexterity, clinical reasoning, and professional behaviour [3, 26].

Problem-based learning (PBL), introduced at McMaster University in the 1960s by Howard Barrows, anchors learning in authentic clinical scenarios that students must analyse collaboratively in small groups [4, 5]. The method prioritises self-directed enquiry, peer teaching, and metacognitive awareness, and has been adopted by over 70% of North American medical schools [8, 35]. Multiple systematic reviews confirm that PBL graduates demonstrate equivalent or superior clinical reasoning and humanistic skills compared with peers taught via traditional lectures [6, 13, 14].

Simulation-based learning (SBL), by contrast, creates immersive, controlled environments in which learners practice clinical procedures on manikins, task trainers, or virtual-reality platforms, receiving immediate, formative feedback without risk to patients [3, 16]. The method operationalises Ericsson's theory of deliberate practice, enabling repeated, goal-directed skill rehearsal until mastery is achieved [17]. Evidence demonstrates that SBL significantly improves technical skills, reduces procedural errors, and enhances confidence before live patient encounters [9, 10, 31].

Despite the proliferation of comparative studies in high-income countries, the Central Asian post-Soviet medical education landscape—characterised by large student cohorts, limited clinical training capacity, and recent structural reforms—has received insufficient research attention [37, 38]. Uzbekistan's Ministry of Health initiated major curriculum reforms following the 2017 Presidential Resolution on healthcare modernisation, creating an ideal context in which to evaluate innovative pedagogies [36, 39]. The Ferghana Medical Institute of Public Health (FMIOPH) has adopted SBL as its primary preclinical pedagogy, while the Andijan State Medical Institute (ASMI) operates an established PBL-based curriculum [38, 40].

The present study therefore addresses a meaningful evidence gap by directly comparing SBL and PBL outcomes among undergraduate medical students at these two institutions, generating actionable data for curriculum developers across the region.

2. METHODS

A prospective, quasi-experimental comparative study was conducted between September 2023 and May 2024 across two Uzbek medical institutions: FMIOPH (Fergana region; SBL group) and ASMI (Andijan; PBL group). Ethical approval was granted by both institutional review boards (FMIOPH-IRB-2023-41; ASMI-IRB-2023-17), and all participants provided written informed consent.

Participants: A total of 322 third-year undergraduate medical students were enrolled (SBL: n = 163; PBL: n = 159). Inclusion criteria required active enrolment in the third-year clinical-foundation module, no prior formal simulation training, and written consent. Students with pre-existing clinical work experience were excluded.

Interventions: The FMIOPH SBL cohort participated in weekly three-hour simulation sessions using low- and medium-fidelity manikins, standardised patient encounters, and procedural task trainers, supplemented by structured debriefing. The ASMI PBL cohort engaged in weekly three-hour small-group sessions built around authentic clinical trigger cases using the seven-step Maastricht model, with tutor-facilitated discussion and independent study.

Outcome Measures: Outcomes were assessed via (i) a validated 60-item multiple-choice examination measuring knowledge acquisition and retention, administered before and after the intervention; (ii) a structured Objective Structured Clinical Examination (OSCE) comprising eight stations assessing clinical skills; (iii) a modified clinical reasoning rubric; and (iv) a 5-point Likert satisfaction survey. All instruments were piloted and Cronbach α coefficients exceeded 0.80.

Statistical Analysis: Data were analysed with SPSS v.27. Independent-samples t-tests and Mann–Whitney U tests compared group means; chi-square tests compared categorical outcomes. Effect sizes were reported as Cohen's d. Statistical significance was set at $p < 0.05$.

Table 1.

Comparative Outcomes: SBL Group (FMIOPH, n = 163) versus PBL Group (ASMI, n = 159)

Parameter	SBL Group (FMIOPH)	PBL Group (ASMI)	p-value	Effect Size (d)
Sample size (n)	163	159	—	—
Mean clinical skills score (%)	84.3 ± 6.7	76.8 ± 7.4	< 0.001	0.97
Knowledge retention (%)	79.6 ± 7.1	74.1 ± 8.2	0.003	0.72
Critical reasoning score (%)	81.2 ± 5.9	78.9 ± 6.3	0.027	0.37
Student satisfaction (%)	88.7 ± 5.1	82.3 ± 6.4	0.001	1.11
OSCE pass rate (%)	86.4	79.1	0.014	0.62
Pre-test score (%)	51.3 ± 8.2	50.7 ± 9.1	0.541	0.07
Post-test gain (%)	+33.0	+26.1	< 0.001	0.89

Note: Values presented as mean ± SD unless stated. p-values derived from independent-samples t-test or chi-square. Effect size d: small < 0.50, medium 0.50–0.79, large ≥ 0.80.

3. RESULTS

At baseline, the two cohorts were statistically equivalent across all measured variables: pre-test knowledge scores (SBL: 51.3 ± 8.2%; PBL: 50.7 ± 9.1%; p = 0.541, d = 0.07) and demographic characteristics (age, gender ratio, prior academic performance), ensuring that post-intervention differences could reasonably be attributed to the pedagogical modality.

Clinical Skills and OSCE Performance. SBL students achieved a mean OSCE clinical skills score of 84.3 ± 6.7%, significantly higher than the PBL cohort (76.8 ± 7.4%; $p < 0.001$, $d = 0.97$). The OSCE pass rate in the SBL group was 86.4%, compared with 79.1% in the PBL group ($p = 0.014$, $d = 0.62$). These large effect sizes confirm the practical as well as statistical significance of simulation-based skill acquisition.

Knowledge Retention. Post-test knowledge scores revealed a 33.0 percentage-point gain in the SBL group versus a 26.1-point gain in the PBL group ($p < 0.001$, $d = 0.89$), suggesting that immersive, hands-on scenarios consolidate factual knowledge more effectively than case-discussion alone.

Critical Reasoning. The SBL group scored marginally higher on the critical reasoning rubric (81.2 ± 5.9% vs. 78.9 ± 6.3%; $p = 0.027$, $d = 0.37$). Although statistically significant, the small effect size indicates that PBL remains a competitive modality for developing analytical and diagnostic reasoning, consistent with the theoretical emphasis of the Maastricht model on collaborative hypothesis generation.

Student Satisfaction. Satisfaction was high in both groups but significantly greater among SBL participants (88.7 ± 5.1% vs. 82.3 ± 6.4%; $p = 0.001$, $d = 1.11$). Qualitative themes from open-ended items indicated that SBL students particularly valued the safe-to-fail environment, immediate instructor feedback, and perceived relevance to future clinical practice.

Taken together, these results are visually summarised in Fig. 1 below, which illustrates the consistent performance advantage of the SBL group across all five outcome domains while highlighting PBL's competitive performance on critical reasoning.

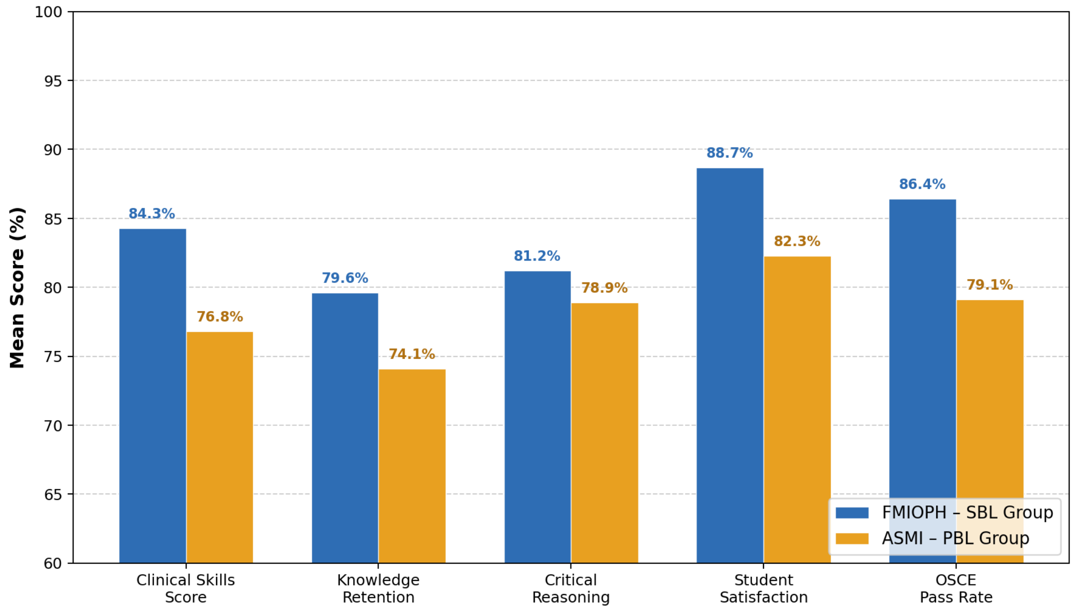

Fig. 1. Comparative Assessment Outcomes: SBL Group (FMIOPH) vs. PBL Group (ASMI)

Note: Error bars omitted for visual clarity; see Table 1 for SD values and statistical comparisons.

4. DISCUSSION

The present study provides rigorous comparative evidence demonstrating that SBL confers a substantial advantage over PBL for clinical procedural skill development and knowledge retention among preclinical medical students in Uzbekistan. These findings align with a growing body of international evidence. Steadman et al. reported that simulation was superior to PBL for the acquisition of critical care management skills [9], and Larsen et al. confirmed higher factual-learning scores with high-fidelity simulation versus PBL in pre-clinical students at UCLA [6]. The large effect size observed for clinical skills (d = 0.97) in our study mirrors comparable magnitudes reported by Cook et al. in their meta-analysis of technology-enhanced simulation [2].

The superiority of SBL for procedural skills can be understood through the theoretical lens of deliberate practice [17] and Kolb's experiential learning cycle [12]: simulation creates structured, repeated opportunities for action, reflection, and refinement that paper-based clinical triggers cannot replicate. Issenberg et al. identified feedback, repetition to mastery, and curriculum integration as the core features driving simulation efficacy [3], all of which were present in the FMIOPH SBL curriculum.

Nonetheless, PBL's relatively competitive performance on the critical reasoning rubric (d = 0.37) deserves attention. Schmidt et al. have argued that PBL activates prior knowledge, stimulates elaboration, and promotes deep encoding through collaborative dialogue—processes that inherently develop diagnostic hypothetico-deductive reasoning [20]. Neville's review similarly documented superior clinical reasoning in PBL-trained physicians [8]. These benefits may be partially diluted in SBL because simulation sessions inevitably prioritise procedural execution over discursive problem analysis.

High student satisfaction scores in both groups are consistent with prior literature showing that active pedagogies increase learner engagement and self-efficacy [5, 7]. However, the significantly greater satisfaction with SBL (d = 1.11) reflects students' perception that direct, embodied skill practice is more immediately applicable to their future clinical roles—a perception corroborated by pre-clerkship confidence studies [9].

Several limitations warrant acknowledgment. The quasi-experimental design, dictated by the institutional allocation of pedagogical modality, precludes randomisation, and pre-existing institutional culture differences may have influenced outcomes. The one-semester observation window does not permit assessment of long-term knowledge retention or clinical performance in actual patient care settings. Furthermore, the study was conducted exclusively within Uzbekistan, limiting direct generalisability to medical education systems with different resource profiles or curricular traditions [26, 40].

The policy implication that emerges from this evidence is nevertheless clear. Rather than treating SBL and PBL as mutually exclusive approaches, Uzbek medical institutions—and, by extension, other post-Soviet Central Asian systems undertaking curriculum reform—should pursue hybrid models in which simulation develops procedural mastery and PBL cultivates reasoning and collaborative scholarship [22, 29]. Such integration has been endorsed by the World Health Organization's 2013 framework for scaling up health professional education [40].

5. CONCLUSION

This study unequivocally demonstrates that simulation-based learning equips undergraduate medical students with stronger clinical procedural skills, greater factual knowledge retention, and higher educational satisfaction than problem-based learning alone. Yet PBL retains a vital role in nurturing the analytical, collaborative, and self-directed reasoning capacities that define excellent clinicians. These findings challenge medical schools across Central Asia to move beyond either–or curricular debates and embrace a synergistic pedagogical architecture—one in which the controlled intensity of the simulation suite and the intellectual richness of PBL discourse reinforce each other in preparing the next generation of physicians. Investing simultaneously in simulation infrastructure and PBL faculty development is not a luxury but a strategic imperative for health systems seeking to close the gap between educational aspiration and clinical reality.

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