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TIBBIYOT OLIY TA'LIM MUASSASALARI TALABALARINING KASBIY KOMPETENSIYALARINI RIVOJLANTIRISHDA VIRTUAL SIMULYATSIYA VA INTERAKTIV TA'LIM TEXNOLOGIYALARIDAN FOYDALANISH METODIKASI

Hamroyev Rustam Rasulovich

Buxoro davlat tibbiyot instituti, assistent.

e-mail: rustamhamtoev@gmail.com **ORCID:** <https://orcid.org/0009-0000-1869-4336>

Annotatsiya.

Maqolada tibbiyot talabalari kasbiy kompetensiyalarini rivojlantirishda virtual simulyatsiya va interaktiv ta'lim texnologiyalaridan foydalanish metodikasi yoritilgan. Mazkur yondashuv talabalarning nazariy bilimlarini amaliy faoliyat bilan uyg'unlashtirish, klinik vaziyatlarni xavfsiz muhitda modellashtirish, mustaqil qaror qabul qilish, jamoada ishlash va kasbiy ko'nikmalarni shakllantirishga yo'naltirilgan.

Kalit so'zlar: tibbiy ta'lim, kasbiy kompetensiya, virtual simulyatsiya, virtual bemor, interaktiv ta'lim, simulyatsion ta'lim, debriefing, pedagogik tajriba-sinov.

МЕТОДИКА ИСПОЛЬЗОВАНИЯ ВИРТУАЛЬНОЙ СИМУЛЯЦИИ И ИНТЕРАКТИВНЫХ ОБРАЗОВАТЕЛЬНЫХ ТЕХНОЛОГИЙ В РАЗВИТИИ ПРОФЕССИОНАЛЬНЫХ КОМПЕТЕНЦИЙ СТУДЕНТОВ МЕДИЦИНСКИХ ВУЗОВ

Хамроев Рустам Расулович

Бухарский государственный медицинский институт, ассистент.

Аннотация.

В статье рассматривается методика использования виртуального моделирования и интерактивных образовательных технологий для развития профессиональных компетенций студентов медицинских вузов. Данный подход направлен на интеграцию теоретических знаний студентов с практической деятельностью, моделирование клинических ситуаций в безопасной среде, развитие способности самостоятельно принимать решения, работать в команде и формировать профессиональные навыки.

Ключевые слова: медицинское образование, профессиональная компетенция, виртуальное моделирование, виртуальный пациент, интерактивное обучение, симуляционное обучение, дебрифинг, педагогический эксперимент.

METHODOLOGY FOR USING VIRTUAL SIMULATION AND INTERACTIVE LEARNING TECHNOLOGIES IN DEVELOPING PROFESSIONAL COMPETENCIES OF MEDICAL UNIVERSITY STUDENTS

Hamroyev Rustam Rasulovich

Bukhara State Medical Institute, Assistant.

Abstract.

The article examines the methodology of using virtual simulation and interactive educational technologies to develop the professional competencies of medical students. This approach aims to integrate students' theoretical knowledge with practical activities, simulate clinical situations in a safe environment, develop independent decision-making abilities, promote teamwork, and foster professional skills.

Keywords: medical education, professional competence, virtual simulation, virtual patient, interactive learning, simulation-based education, debriefing, pedagogical experiment.

Introduction. The quality of healthcare depends directly on the professional competence of physicians. Over the last two decades, medical education worldwide has shifted from a time-based model, in which students accumulate hours and credits, to competency-based medical education (CBME), in which graduation depends on demonstrated ability to perform the tasks of a doctor (Frank et al., 2010). This shift raises a practical question: where and how can students practise clinical skills often enough, and safely enough, to reach a verified level of competence?

Classical bedside teaching cannot fully answer this question. Patient safety concerns, growing student numbers, shorter hospital stays, and the ethical limits of learning on real patients restrict how often students can perform procedures or manage acute cases (Ziv et al., 2003). As a result, many graduates meet critical situations for the first time in real practice.

Simulation-based education offers a solution. Virtual patients, screen-based simulators, high-fidelity manikins, and standardised patients allow students to practise repeatedly, make mistakes without harm, and receive structured feedback. Interactive methods such as case-based learning, the flipped classroom, and team-based learning move

students from passive listening to active problem-solving (Prober & Heath, 2012). In Uzbekistan, this issue is especially relevant. Resolution of the President of the Republic of Uzbekistan No. PQ-4310 of 6 May 2019, "On measures for the further development of the system of medical and pharmaceutical education and science", provides for modernising medical and pharmaceutical education, gradually introducing the credit-module system, integrating education with clinical practice, and improving continuing professional medical education.

However, the availability of equipment does not by itself guarantee results. Simulators are often used episodically, without a clear link to learning outcomes, a staged progression of difficulty, or systematic assessment. What is missing is a coherent methodology: a set of principles, stages, methods, and assessment tools that connects simulation and interactive technologies to specific professional competencies.

THE AIM OF THIS STUDY

The aim of this study is to develop and experimentally test a methodology for using virtual simulation and interactive learning technologies to develop professional competencies of students in higher medical education institutions.

The objectives are:

1. To analyse the theoretical foundations and international evidence on simulation-based and interactive medical education.
2. To define the structure of professional competencies of medical students that can be developed through simulation.
3. To design a staged methodology integrating virtual simulation, interactive methods, and debriefing.
4. To evaluate the effectiveness of the methodology in a pedagogical experiment.

LITERATURE REVIEW

COMPETENCE IN MEDICINE

Miller (1990) described clinical competence as a pyramid of four levels: knows, knows how, shows how, and does. Lectures and textbooks mainly address the first two levels. Simulation is one of the few settings where students can reach the shows how level under observation before working with real patients. The CanMEDS framework and CBME further define competence as a combination of medical expertise, communication, collaboration, professionalism, and leadership (Frank et al., 2010).

EVIDENCE FOR SIMULATION

A systematic review by Issenberg et al. (2005) identified the conditions under which high-fidelity simulation leads to effective learning: feedback, repetitive practice, curriculum integration, a range of difficulty, multiple learning strategies, and clearly defined outcomes. A meta-analysis of 609 studies by Cook et al. (2011) found that technology-enhanced simulation was consistently associated with large effects on knowledge, skills, and behaviour compared with no intervention. McGaghie et al. (2011) showed that simulation combined with deliberate practice produced better skill outcomes than traditional clinical education.

VIRTUAL PATIENTS

Virtual patients are interactive computer simulations of clinical scenarios. A meta-analysis by Kononowicz et al. (2019) concluded that virtual patients are at least as effective as traditional methods for knowledge and more effective for developing skills, particularly clinical reasoning. Their advantages are low cost per use, scalability, and the ability to learn outside the classroom.

INTERACTIVE LEARNING

The flipped classroom moves content delivery before class and uses class time for application and discussion (Prober & Heath, 2012). Case-based and team-based learning develop clinical reasoning and teamwork. These methods fit naturally with simulation: students prepare theory in advance and use contact hours for practice.

DEBRIEFING

Many authors consider debriefing the most important part of simulation learning. Rudolph et al. (2006) proposed "debriefing with good judgment", in which the instructor shares an honest view while exploring the learner's reasoning. Without debriefing, simulation risks becoming a demonstration rather than a learning experience.

GAP

Most studies evaluate a single tool (a simulator or a virtual patient platform) in isolation. Fewer describe an integrated methodology that combines several technologies in a staged sequence linked to a competency model, especially in the context of medical universities in Central Asia. This study addresses that gap.

MATERIALS AND METHODS

THEORETICAL BASIS

The methodology rests on four ideas. Competency-based education defines what students must be able to do. Kolb's (1984) experiential learning cycle (experience, reflection, conceptualisation, experimentation) defines how learning happens. Deliberate practice (Ericsson, 2004) requires repeated, focused practice with immediate feedback. Miller's pyramid sets the target level of each activity.

COMPETENCY MODEL

Five groups of professional competencies were selected as targets (Table 1). Each is linked to the technologies best suited to develop it.

Competency group	Content	Main technologies
Clinical reasoning	History taking, differential	Virtual patients, case-based

	diagnosis, choice of investigations and treatment	learning
Practical skills	Physical examination, procedures, CPR, emergency care	Task trainers, high-fidelity manikins
Communication	Patient interviews, breaking bad news, informed consent	Standardised patients, role play
Teamwork and leadership	Role allocation, closed-loop communication, crisis resource management	Team scenarios on high-fidelity simulators
Professionalism and safety	Ethics, error reporting, reflective practice	Debriefing, reflective journals

STAGES OF THE METHODOLOGY

The methodology organises each training module as a four-stage cycle that repeats with increasing difficulty.

1. Preparation (flipped classroom). Students study theory, algorithms, and video demonstrations on the learning platform before class. A short online test checks readiness and admits them to simulation.

2. Virtual simulation. Students work through virtual patient cases individually or in pairs. The platform records their decisions and gives automatic feedback on diagnostic and treatment choices.

3. Hands-on simulation. In the simulation centre, students practise skills on task trainers, then manage full scenarios on high-fidelity manikins in teams of 3–5, with rotating roles.

4. Debriefing and reflection. After each scenario, an instructor leads a structured debriefing in three phases: reactions, analysis, and summary. Students then write a short reflection and set goals for the next cycle.

Difficulty increases across three levels: basic (single skills, standard cases), intermediate (full clinical scenarios), and advanced (complications, time pressure, team crises).

Each module repeats a four-stage cycle at rising difficulty

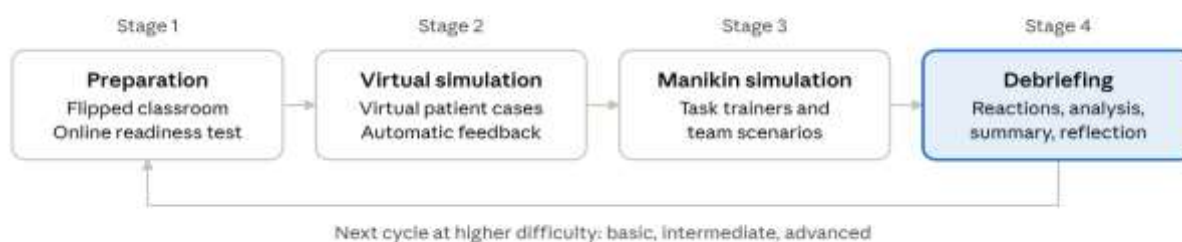


Figure 1. Four-stage cycle of the methodology

Figure 1. The four-stage cycle of the methodology. Debriefing closes each cycle and sets goals for the next, more difficult one.

STUDY DESIGN

A pedagogical experiment was conducted in the 2024–2025 academic year at three medical universities of Uzbekistan: Bukhara State Medical Institute named after Abu Ali ibn Sino (BSMI), Urgench State Medical Institute (UrSMI), and Samarkand State Medical University (SamSMU). Participants were 843 first-year students of the General Medicine and Pediatrics programmes. They were divided into an experimental group (EG, $n = 423$) taught by the proposed methodology and a control group (CG, $n = 420$) taught by the standard curriculum. The methodology was applied in the course "Information Technologies in Medicine" and supported by the author's teaching guide "Innovative Methods of Teaching Information Technologies in Medicine".

The experiment had three phases: ascertaining (baseline assessment), formative (implementation over 4 weeks), and control (final assessment).

ASSESSMENT TOOLS

The same tools were used at the start and at the end of the experiment:

- Tests on the course content.
- Written assignments (written control work).
- Laboratory work with the software and virtual tools studied in the course.

Each student's final result was graded on the national 5-point scale: 2 (unsatisfactory), 3 (satisfactory), 4 (good), and 5 (excellent).

STATISTICAL ANALYSIS

Data were processed in Microsoft Excel. The grade distributions of the EG and CG were compared with Pearson's χ^2 test for a 2×4 contingency table ($df = 3$). The null hypothesis H_0 stated that the distributions did not differ; the alternative hypothesis H_1 stated that they did. At a significance level of $\alpha = 0.05$, the critical value is 7.815, so H_0 was rejected when the empirical χ^2 was 7.815 or higher. We also calculated the mean grade of each group ($\bar{x}$ for the EG, $\bar{y}$ for the CG), the efficiency coefficient $\eta = \bar{x} / \bar{y}$, coefficients of variation, and 95% confidence intervals for the means.

RESULTS

At baseline, the grade distributions of the EG and CG were almost identical (Table 2). About half of the students in

each group (49.9% and 49.3%) had "good" or "excellent" grades, and the mean grade was 3.39 in both groups. The difference was not significant ($\chi^2 = 0.10$, $p = 0.99$), which confirms that the groups were comparable.

After the experiment, the distribution in the EG shifted towards higher grades. The share of "excellent" grades was 16.8% in the EG and 10.2% in the CG, and the share of "good" grades was 60.0% and 49.3%. The share of "satisfactory" grades was 14.7% versus 24.8%, and that of "unsatisfactory" grades was 8.5% versus 15.7%.

Table 2. Grade distribution before and after the experiment, n (%)

Group	Stage	n	2 (unsatisfactory)	3 (satisfactory)	4 (good)	5 (excellent)	Mean grade
EG	Baseline	423	85 (20.1)	127 (30.0)	170 (40.2)	41 (9.7)	3.39
CG	Baseline	420	84 (20.0)	129 (30.7)	165 (39.3)	42 (10.0)	3.39
EG	Final	423	36 (8.5)	62 (14.7)	254 (60.0)	71 (16.8)	3.85
CG	Final	420	66 (15.7)	104 (24.8)	207 (49.3)	43 (10.2)	3.54

The mean final grade was 3.85 in the EG and 3.54 in the CG, giving an efficiency coefficient $\eta = 1.088$: on average, the EG scored 8.8% higher. The 95% confidence intervals for the means did not overlap (EG 3.78–3.93; CG 3.46–3.63). The coefficients of variation in both groups were below 30%, indicating a homogeneous sample.

The effect was consistent across all three universities (Table 3). At each university, the empirical χ^2 exceeded the critical value of 7.815, so H_0 was rejected and H_1 accepted. For the pooled sample, $\chi^2 = 31.11$ ($p < 0.001$).

Table 3. Final results by university

University	EG, n	CG, n	Mean grade, EG	Mean grade, CG	η	χ^2	p
BSMI (Bukhara)	152	147	3.86	3.57	1.081	11.45	0.009
UrSMI (Urgench)	146	140	3.84	3.53	1.087	11.04	0.012
SamSMU (Samarkand)	125	133	3.86	3.52	1.096	9.94	0.019
Total	423	420	3.85	3.54	1.088	31.11	< 0.001

Note. EG, experimental group; CG, control group; η , efficiency coefficient (mean grade of EG / mean grade of CG). The critical value of χ^2 at $df = 3$ and $\alpha = 0.05$ is 7.815.

DISCUSSION

The results support the hypothesis that an integrated, staged use of virtual simulation and interactive technologies improves learning outcomes more than traditional teaching. The share of students with "good" or "excellent" grades rose from 49.9% to 76.8% in the EG, compared with 49.3% to 59.5% in the CG, and the effect was reproduced at three universities. This agrees with the meta-analyses of Cook et al. (2011) and McGaghie et al. (2011), which reported large effects of simulation on knowledge and skills. In terms of Kirkpatrick's (1994) model, these results correspond to level 2, learning.

We believe the effect comes less from any single tool than from the way the tools are combined. The flipped classroom frees contact hours for practice. Virtual patients build clinical reasoning cheaply and at scale, so that expensive manikin time is spent on students who are already prepared. Hands-on scenarios add the physical and team dimensions that screen-based tools lack. Debriefing turns each experience into conscious learning, as Kolb's cycle and the work of Rudolph et al. (2006) suggest. This sequence reflects the conditions for effective simulation described by Issenberg et al. (2005): feedback, repetition, increasing difficulty, and integration into the curriculum.

The methodology also has practical value for medical universities in Uzbekistan. Many institutions already have simulation centres, but equipment is often underused. The staged cycle gives teachers a ready structure for planning modules, and the competency model links each session to measurable outcomes.

LIMITATIONS

Groups were formed from existing academic groups and were not randomised. Outcomes were measured by course grades for tests, written assignments, and laboratory work, not by direct observation of clinical performance, so the effect on clinical skills, communication, and teamwork needs separate confirmation. The follow-up period was short, so long-term retention and transfer to real clinical practice (the does level of Miller's pyramid) were not assessed. Implementation also requires trained instructors, especially for debriefing, and investment in equipment and software.

FUTURE RESEARCH

Future research should include randomised studies, OSCE-based assessment of clinical skills (Harden & Gleeson, 1979), longer follow-up, and assessment of performance in real clinical settings.

CONCLUSION

1. Virtual simulation and interactive learning technologies create conditions for developing professional competencies that traditional teaching cannot provide: safe, repeated practice with immediate feedback.

2. The proposed methodology integrates the flipped classroom, virtual patients, hands-on simulation, and structured debriefing into a four-stage cycle with three levels of difficulty, linked to a five-group competency model.

3. The pedagogical experiment with 843 students at three medical universities showed that students taught by

this methodology achieved significantly higher results than the control group (mean grade 3.85 vs. 3.54; $\chi^2 = 31.11$, $p < 0.001$).

4. The methodology can be recommended for inclusion in clinical discipline curricula of medical universities, provided that teachers are trained in simulation-based teaching and debriefing.

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