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Improving The Methodology Of Teaching Anatomy In The Context Of The Digital Transformation Of Medical Education

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Abstract. This article examines modern innovative approaches to teaching anatomy to future physicians in the context of the digital transformation of education. At the end of the semester, the average academic performance score was 74.2 ± 3.5% in the control group and 87.6 ± 2.8% in the experimental group ($p < 0.01$). Motivation to study anatomy increased from 62% to 91%, indicating a substantial rise in interest in the subject. More than 78% of students reported that interactive technologies helped them better remember the spatial relationships between organs and systems. The study showed that introducing digital technologies can improve the assimilation of learning material and support the development of students' clinical reasoning.
Keywords: anatomy, digital education, medical university, 3D technologies, innovative methods, student teaching.

Introduction. Background and relevance. Modern medical education is undergoing an active phase of digital transformation. The rapid development of information technology has created a need to adapt anatomy teaching methods to new educational formats. Traditional formats (lectures and practical classes using anatomical specimens) are increasingly supplemented by digital tools, including virtual anatomy tables, 3D models, and interactive simulators [1, 2].

According to the Ministry of Higher Education, Science and Innovation of the Republic of Uzbekistan (2024), more than 65% of the country's medical universities are actively introducing digital educational resources. Anatomy, as a foundational discipline, requires particular attention because the quality of its teaching influences the development of future physicians' clinical reasoning [3-5].

In recent years, the Republic of Uzbekistan has actively developed state policy on the digital transformation of education. Relevant bodies and initiatives support the introduction of electronic educational resources and digital platforms, while orders and methodological documents have been adopted to modernize university teaching. This provides a favorable regulatory and infrastructural basis for introducing VR/AR and 3D technologies into medical training. However, some publications emphasize the lack of consolidated empirical data on the extent to which these tools are used and their pedagogical effectiveness in the national context. Therefore, empirical studies including pilot implementations, educational experiments, and statistical evaluation remain essential for developing evidence-based recommendations to modernize anatomy courses in Uzbekistan [6-8].

In terms of digital literacy, European populations and education systems have made substantial progress: in 2023, approximately 55% of EU citizens aged 16-74 had at least basic digital skills. This provides a favorable foundation for the widespread adoption of digital educational technologies in European universities, including medical faculties. However, considerable differences in digital competence remain among EU countries [9].

In the Russian Federation, the digitalization of higher education is progressing unevenly. Assessments of universities' digital maturity indicate considerable potential for further development: some studies estimate the digitalization of higher education at approximately 25-30%, suggesting that infrastructure is in place but digital methods have not yet been integrated into teaching on a sufficiently broad scale. For medical education in Russia, this points to the need for targeted measures to introduce and standardize digital educational solutions for teaching anatomy [10].

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International literature has demonstrated positive effects from using 3D applications, virtual reality (VR), and simulators in anatomy education. Systematic reviews and experimental studies report improvements in academic performance, spatial understanding of anatomy, and learning motivation when digital tools are used. For universities in Russia and Uzbekistan, this means that digital technologies are not merely supplementary accessories; they are pedagogically significant resources that must be adapted to national curricula, supported by teacher training, and evaluated for educational and economic feasibility [11].

Given current levels of digital literacy in Europe and its established infrastructure, the insufficient integration of digital methods in Russia, and Uzbekistan's active state policy on educational digitalization, investigating and evidence-based implementation of innovative digital approaches to anatomy teaching is an important practical and scientific task. Empirical confirmation of their effectiveness in national universities is needed to develop recommendations, standardize methods, and scale up successful practices [12, 13].

Aim of the study. To investigate the effectiveness of innovative digital technologies in teaching anatomy to medical university students and determine their impact on learning outcomes and the development of professional competencies.

Materials and methods. The study was conducted at Central Asian Medical University in Fergana during the 2023-2024 academic year. It included 120 first- and second-year medical students aged 18-22.

Participants were divided into two groups:

• Control group (n = 60): instruction using traditional methods (lectures and practical classes with anatomical models).

• Experimental group (n = 60): instruction using digital technologies (virtual anatomy tables, 3D visualization, and the Complete Anatomy and Visible Body mobile applications).

The methods used included pedagogical observation, questionnaires, knowledge testing, and statistical analysis (Student's t-test, $p < 0.05$).

Results. At the end of the semester, the average academic performance score was 74.2 ± 3.5% in the control group and 87.6 ± 2.8% in the experimental group ($p < 0.01$).

Motivation to study anatomy increased from 62% to 91%, indicating a substantial rise in interest in the subject.

More than 78% of students reported that interactive technologies helped them better remember the spatial relationships between organs and systems.

In addition, the experimental group showed improvements in independent study and engagement in the learning process.

The findings clearly demonstrate the effectiveness of introducing digital technologies into anatomy teaching for future physicians. Analysis showed that students who learned with digital tools achieved substantially better academic results and demonstrated higher levels of cognitive engagement and motivation than students taught using traditional methods.

The control group, which was taught using conventional methods lectures, demonstrations, and anatomical models achieved satisfactory but somewhat limited results (academic performance: 74.2 ± 3.5%). This suggests that traditional methods support learning of basic material but do not fully develop spatial reasoning and visualization of anatomical structures. In contrast, students in the experimental group who used virtual anatomy tables, 3D models, and interactive applications (Complete Anatomy and Visible Body) demonstrated a substantially higher level of knowledge (87,6 ± 2.8%; $p < 0.01$). This indicates that digital technologies not only make complex topographical relationships between organs and systems easier to understand but also support more durable learning.

The increase in motivation to study anatomy from 62% to 91% deserves particular attention. This indicator reflects not only students' interest in innovative learning formats but also the psychological comfort created by a digital learning environment. Interactive teaching methods encourage independent information seeking, increase satisfaction with learning, and create a sense of presence in a real clinical situation.

In addition, 78% of surveyed students reported that digital visual tools helped them better remember spatial relationships between organs, a key element in developing clinical reasoning. These findings are consistent with international studies (Moro C., 2022; Cho Y., 2023), which report that 3D anatomy and virtual simulators can increase the depth of learning by 15-25%.

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Digital technologies enabled students to participate actively in learning, work with visual materials at their own pace, and complete individual assignments. This strengthened independent study and interactivity. Students in the experimental group accessed learning platforms and electronic resources independently more frequently, supporting the development of sustained learning motivation.

Furthermore, simulation technologies create conditions for developing practice-oriented competencies, including spatial imagination, clinical reasoning, and the ability to analyze anatomical structures. These competencies provide a foundation for subsequent study of clinical disciplines.

The 13.4-percentage-point difference in academic performance between the control and experimental groups was statistically significant ($p < 0.01$), supporting the effectiveness of the selected educational model (Table 1). These findings show that integrating digital technologies into anatomy teaching not only improves objective knowledge outcomes but also fosters sustained intrinsic motivation for professional development.

Table 1.

Comparison of students' learning outcomes and motivation under different anatomy teaching methods (n = 120)

Indicators	Control group (n = 60)	Experimental group (n = 60)	Difference (Δ)	p-value
Average academic performance, %	74.2 ± 3.5	87.6 ± 2.8	+13.4	p<0.01
Learning motivation, %	62	91	+29	p<0.01
Students reporting improved memory of spatial relationships, %	49	78	+29	p<0.05
Independent study activity (questionnaire results), %	55	84	+29	p<0.05
Satisfaction with the learning process, %	68	92	+24	p<0.05

As shown in Table 1, the experimental group outperformed the control group across all measured parameters. The most pronounced differences were observed in academic performance and learning motivation, and these differences were statistically significant ($p<0.01$). The use of digital educational technologies improved not only academic performance but also subjective indicators, including interest in the subject, engagement, satisfaction, and student independence.

The study confirms that digitalization of anatomy education has considerable potential to improve teaching methods in medical universities in Uzbekistan. However, sustainable implementation of innovative approaches requires systematic methodological training for instructors, development of digital infrastructure, and adaptation of curricula.

The results are consistent with studies by international authors (Moro C. et al., 2022; Cho Y., 2023), which found that digital educational technologies improve learning outcomes by 15-20%.

Implementing digital tools requires systematic teacher training, methodological adaptation of courses, and modernization of curricula. This is particularly relevant for universities in Uzbekistan, where educational digitalization is progressing rapidly.

Overall, the findings indicate that using digital educational technologies in anatomy teaching improves the quality of education, increases student motivation, and contributes to the development of future physicians' professional competencies. This supports the need to move from a traditional teaching model toward an integrated digital learning environment that combines interactivity, visualization, and practice-oriented learning.

Conclusions:

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1. Digital technologies (3D anatomy, virtual simulators, and online platforms) significantly improve the effectiveness of anatomy teaching;
2. Interactive learning formats stimulate cognitive engagement and independent study;
3. Innovative methods can help develop clinical reasoning at the early stages of medical training;
4. Sustainable implementation of digital approaches requires methodological training for instructors and development of digital education infrastructure.

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