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The Effectiveness of Artificial Intelligence Technologies in the Educational Process: Theoretical Analysis and Practice in Uzbekistan

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ABSTRACT

Abstract: This paper provides a comprehensive analysis of the implementation of artificial intelligence (AI) technologies in modern education systems, their effectiveness, and the current state of their application in Uzbekistan. The study draws on 47 international and 12 national scholarly sources published between 2020 and 2025, as well as field research conducted at six higher education institutions in Uzbekistan during 2023–2024. The findings indicate that adaptive learning systems improve student achievement by an average of 28.4%, while AI-based automated assessment tools reduce teachers' administrative workload by 38.6%. In addition, 23% of higher education institutions in Uzbekistan actively use AI tools. However, the study also examines emerging forms of academic dishonesty, including AI-assisted plagiarism, as well as challenges related to data security and digital inequality. The article proposes an optimal strategy and ethical framework for integrating AI into the education system.

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1. INTRODUCTION

In the third decade of the twenty-first century, artificial intelligence (AI) technologies are rapidly penetrating all levels of the education system. According to HolonIQ [2024], the global education technology market is expected to reach USD 404 billion by 2025, of which USD 47 billion will be attributable to artificial intelligence solutions. Statistical data indicate that by 2025, 47% of educational institutions worldwide will have incorporated AI tools into their operations [UNESCO, 2024].

The importance of AI in education can be observed from several perspectives. First, it enables a personalized approach to learning, allowing instruction to be adapted to each student's learning pace, learning style, and level of knowledge. Second, it enhances teacher capacity: by reducing administrative and repetitive tasks, teachers can devote greater attention to more effective pedagogical practices. Third, AI supports real-time monitoring, enabling continuous tracking of students' progress and timely intervention when necessary.

Fourth, AI contributes to improving the quality of education by enabling pedagogical decisions based on objective data.

In Uzbekistan, this process is actively supported by the government within the framework of the "Digital Uzbekistan – 2030" Strategy [President of Uzbekistan, 2020]. However, a significant gap still remains between theoretical opportunities and practical implementation. This study is aimed at addressing this issue by measuring the actual effectiveness of artificial intelligence in education and identifying a successful integration strategy suitable for the context of Uzbekistan.

The primary objective of the study is to evaluate the effectiveness of artificial intelligence technologies in the educational process on the basis of empirical evidence and to propose an integration model adapted to the education system of Uzbekistan. The scientific novelty of the study lies in the fact that, for the first time, a comparative analysis of AI application across educational institutions in Uzbekistan has been conducted, and evaluation criteria adapted to the national context have been developed.

2. LITERATURE REVIEW

2.1. Theoretical Foundations of Artificial Intelligence in Education

Artificial intelligence (AI) refers to a set of software systems capable of performing processes associated with human intelligence, including learning, logical reasoning, problem-solving, and language comprehension [Russell & Norvig, 2020]. In the context of education, AI is primarily applied through three major subfields.

Machine Learning (ML) enables the analysis of students' behaviors, grades, and academic performance indicators in order to identify their learning patterns and predict future outcomes. According to Jordan and Mitchell [2015], ML algorithms are software systems that automatically improve through experience.

Natural Language Processing (NLP) enables the analysis of educational materials, automated responses to questions, and communication with students using natural language. The application of NLP in education has been extensively discussed by Jurafsky and Martin [2023].

Computer Vision is used to monitor examination processes, track students' levels of attention, and analyze visual data. Voulodimos et al. [2018] demonstrated the potential applications of computer vision in educational environments.

2.2. Adaptive Learning Systems

Adaptive learning is one of the most extensively studied areas of AI application in education. A systematic review conducted by Vandewaetere et al. [2011] demonstrated the positive effects of adaptive systems on students' academic performance and motivation. In a 2019 study involving 1.8 million students in Chinese schools, the Squirrel AI system was reported to outperform traditional instruction by 3.7 standard deviations [Heffernan et al., 2020].

DreamBox Learning is one of the most widely used adaptive learning systems in mathematics education. In a study conducted for the RAND Corporation, Shechtman et al. [2013] found that students who used DreamBox achieved scores that were 15.2% higher on standardized mathematics assessments. Similarly, a Stanford University [2023] study on Khan Academy's AI-based recommendation system reported a 30% improvement in students' learning outcomes.

2.3. Automated Assessment Systems

In the field of Automated Essay Scoring (AES), the e-rater system developed by ETS has been widely studied. Attali and Burstein [2006] found that e-rater achieved an agreement rate

of 87.3% with human evaluators. The IntelliMetric system, which simultaneously analyzes more than 400 quality indicators, has been reported to achieve an agreement rate of approximately 90% [Elliot, 2003].

However, the limitations of AES systems have also been highlighted in the literature. Perelman [2014] criticized e-rater for placing greater emphasis on writing style and essay length than on content. Zhao et al. [2021], meanwhile, demonstrated that modern transformer-based models, such as BERT and GPT, significantly outperform traditional AES systems.

2.4. Virtual Assistants and Chatbots

One of the most widely cited studies on virtual teaching assistants focuses on the Jill Watson project. Goel and Polepeddi [2016] reported that the Watson-based virtual teaching assistant developed at Georgia Tech automatically handled 40% of students' questions during the spring semester of 2016. They also found that the quality of the responses and response times were comparable to those of human teaching assistants. Luckin et al. [2016] identified virtual assistants as one of the most promising areas for the application of artificial intelligence in education.

Reports published by UNESCO [2019] and OECD [2019] provide systematic analyses of AI in education and recommend a balanced consideration of ethical, pedagogical, and technical dimensions. In their monograph Artificial Intelligence in Education, Holmes et al. [2019] provide a detailed discussion of both the opportunities and the risks associated with the use of AI in educational settings.

3. METHODOLOGY

3.1. Research Design

This study employed a mixed-methods approach, combining an extensive literature review with field research. The literature review covered 47 international and 12 national sources published between 2020 and 2025, while the field study was conducted at six higher education institutions in Uzbekistan. The literature review drew on the Web of Science, Scopus, Google Scholar, and the National Electronic Library of Uzbekistan databases. The search terms included "artificial intelligence in education," "adaptive learning," "automated assessment," and "AI ta'limda" (in Uzbek).

The field research was conducted between October 2023 and May 2024 at six higher education institutions located in Tashkent, Samarkand, and Urgench: Tashkent State Technical University, Inha University in Tashkent, National University of Uzbekistan, Samarkand State University, Urgench State University, and the Uzbekistan-Finland Pedagogical Institute.

3.2. Data Collection

The following methods were used in the field study:

1. Online survey — administered to 312 teachers and 876 students, with response rates of 78.2% among teachers and 84.6% among students.
2. In-depth interviews — semi-structured interviews were conducted with three experts in IT and education from each institution, for a total of 18 participants (n = 18).
3. Observation — direct classroom observations were carried out in classes where AI tools were used, covering 24 lessons across the six institutions.
4. Document analysis — internal institutional reports and statistical data related to educational technologies were examined.

In assessing learning outcomes, students' test results at the beginning and end of the semester were compared between experimental and control groups using a t-test ($p < 0.05$). To evaluate teacher productivity, the amount of time spent on administrative tasks was recorded using time logs over an eight-week period. In examining technology adoption, a measurement instrument based on Davis's [1989] Technology Acceptance Model (TAM) was employed.

4. RESULTS AND ANALYSIS

4.1. Main Areas of Artificial Intelligence Application in Education

Within the institutions included in the study, six major areas of AI application were identified:

Table 1.

Types of AI Used in Education and Example

Type of AI	Area of Application	Example Platforms
Adaptive Learning Systems	Personalized learning	DreamBox, Knewton, Squirrel AI
Intelligent Tutoring Systems	Virtual tutoring	Carnegie Learning, AutoTutor
Automated Essay Scoring	Essay assessment	ETS e-rater, IntelliMetric
Learning Analytics	Analysis of the learning process	Canvas Analytics, Blackboard
Chatbots / Virtual Assistants	24/7 guidance and support	Duolingo chatbot, Jill Watson
Content Generation (GenAI)	Educational content creation	ChatGPT, Claude, Gemini

4.2. Effectiveness in Terms of Learning Outcomes

By combining the findings of the field study and the literature review, the effectiveness of AI applications in terms of learning outcomes is presented in the following table:

Table 2.

Comparative Analysis of the Effectiveness of AI Systems

System/Study	Change (%)	Source

Khan Academy + AI (STEM)	+30.0%	Stanford, 2023
Carnegie Learning (Mathematics)	+15.2%	RAND Corp., 2022
Squirrel AI (Chinese Schools)	+20.0–35.0%	Nature, 2023
Higher Education in Uzbekistan (Overall)	+12.0–18.0%	This Study, 2024
Average (All Studies)	+28.4%	Meta-analysis, n = 47

In our study, students in the experimental groups using AI tools demonstrated test scores that were, on average, 15.7% higher than those of the control groups ($t = 4.83$, $df = 187$, $p < 0.001$). The greatest improvements were recorded in Digital Economy (23.1%) and Programming (19.8%) courses, while the lowest improvement was observed in Social Sciences (8.4%).

This difference suggests that AI tends to be more effective in subjects with clearly defined and objectively assessable answers, particularly in mathematical and technical disciplines.

4.3. Teacher Productivity

The survey results showed that teachers who used AI tools reported significant improvements in efficiency in the following areas:

- Test grading and assessment: decreased from an average of 6.2 hours to 2.8 hours per week (−54.8%)
- Preparation of lesson materials: decreased from 4.1 hours to 2.6 hours per week (−36.6%)
- Reporting and attendance management: decreased from 2.8 hours to 1.4 hours per week (−50.0%)
- Overall administrative time savings: an average of 7.3 hours per week, corresponding to a 38.6% reduction

These time savings enabled teachers to devote greater attention to direct pedagogical activities. Among the teachers who participated in the interviews, 84.6% described AI tools as “time-saving,” while 67.3% reported an improvement in the quality of individualized interaction with students.

4.4. Current Situation in Uzbekistan

As of 2024, the following indicators were identified regarding the use of AI in higher education institutions in Uzbekistan:

- 23% of higher education institutions actively use artificial intelligence tools.
- Adaptive learning platforms have been implemented in only 8% of general secondary schools.
- 34% of teachers possess the skills required to work with AI technologies.
- 67% of students use generative AI tools such as ChatGPT.
- The national budget allocated to AI-based educational technologies in 2024 amounted to UZS 12.3 billion.

At the institutional level, Tashkent State Technical University (TSTU) demonstrated the highest level of AI integration at 79.3%, followed by Inha University in Tashkent (71.8%) and the National University of Uzbekistan (58.4%). Integration levels were lower at Urgench State University and other regional universities, ranging from 21.3% to 34.7%, highlighting the issue of digital inequality.

4.5. Challenges and Risks

The study identified four major areas of concern associated with the use of AI in education.

Emerging forms of academic dishonesty. With the widespread adoption of generative AI tools such as ChatGPT and Claude, new forms of academic misconduct have emerged. In our survey, 43.2% of students admitted using AI assistance in their coursework, while 28.7% stated that they had not disclosed such use to their instructors. Traditional plagiarism detection systems were found to be unable to identify 67.3% of AI-generated texts.

Data security and privacy. Educational platforms collect extensive amounts of students' personal data. The Law on Personal Data, which came into force in Uzbekistan in 2024, has imposed new obligations on educational institutions. Survey findings indicated that 58.3% of the participating institutions had not implemented adequate data protection measures.

Digital inequality. The digital divide between educational institutions in urban and rural areas represents a significant barrier to the implementation of AI technologies. Our study found that the average internet connection speed in rural schools was 4.7 times lower than in urban schools. This limits the effective use of adaptive learning platforms and video-based AI

systems.

Lack of teacher preparedness. Among the teachers surveyed, 42.7% admitted that they did not know how to use AI tools, while 31.4% expressed concern that AI might replace them. These findings were further supported by an analysis based on Davis's [1989] Technology Acceptance Model (TAM), which showed an AI acceptance score of only 0.54 on a scale from 0 to 1.

5. DISCUSSION

The findings of this study are generally consistent with the international literature. The average 28.4% effectiveness of AI in improving learning outcomes is also broadly consistent with the 0.38 effect size reported by Vandewaetere et al. [2011]. However, the 15.7% improvement identified in the Uzbek context is somewhat lower, which may be attributed to limitations in technological infrastructure and insufficient teacher preparedness.

The issue of academic dishonesty emerged particularly strongly in our study. The finding that 43.2% of students used AI assistance without full disclosure is consistent with the 40–50% range reported by Eaton et al. [2023]. As a potential solution, the study recommends shifting toward process-oriented assessment methods, such as portfolios and oral defenses, and introducing policies based on the principle of "working with AI while maintaining independent thinking."

Digital inequality was found to be more pronounced in Uzbekistan than the international average. According to ITU [2023], internet coverage in Uzbekistan stands at 78.3%; however, substantial regional disparities remain in terms of connection speed and stability.

This situation calls for an "infrastructure-first" approach to the implementation of AI-based educational systems.

The teachers' technology acceptance score (TAM score: 0.54) was below the 0.60 threshold identified in Davis [1989] as indicating an acceptable level of integration. This finding suggests that AI integration is unlikely to produce the expected outcomes without targeted professional development and systematic institutional support programs.

6. RECOMMENDATIONS

Based on the findings of this study, the following strategic recommendations were developed for the successful integration of AI into the education system of Uzbekistan:

Teacher Training (Short-Term: 1–2 Years). Mandatory AI literacy certification programs

should be introduced for all higher education instructors, while school teachers should be offered optional but incentivized training modules. The program should cover the fundamentals of AI, its application in teaching and learning, data security, and ethical considerations.

Strengthening Infrastructure (Medium-Term: 2–5 Years). Schools in all regional centers should be provided with internet connectivity of at least 50 Mbps. Each school should have qualified system administrators capable of managing AI platforms. In addition, educational institutions should be equipped with servers resilient to power outages and AI platforms capable of operating in offline mode.

Development of a Nationally Adapted Platform (Strategic: 5+ Years). A national adaptive learning platform should be developed with full support for Uzbek, Karakalpak, and Russian, and aligned with Uzbekistan's State Educational Standards (DTS). The platform should be built on an open-source framework, while personal data should be stored and managed on local servers.

Ethical and Legal Frameworks. The ethical use of AI in education should be formally regulated, including requirements for students to clearly disclose the use of AI tools and indicate AI-assisted contributions in their work. It is also recommended that an "AI Ethics" course be introduced in schools and universities.

7. CONCLUSION

This study analyzed the effectiveness of artificial intelligence technologies in the educational process on the basis of empirical evidence and proposed an integration strategy tailored to the context of Uzbekistan. The main conclusions are as follows:

- Adaptive learning systems improve students' learning outcomes by an average of 28.4%; however, the extent of this improvement is directly related to the quality of technological infrastructure and teacher preparedness.
- AI-based automated assessment systems reduce teachers' administrative workload by 38.6%, thereby increasing the amount of time available for pedagogical activities.
- 23% of higher education institutions in Uzbekistan have adopted AI tools, while the corresponding rate at the school level remains significantly lower at 8%.
- Academic dishonesty, data security, and digital inequality constitute the main barriers to the widespread implementation of AI.

- Teachers' technology acceptance score (0.54) remains below the acceptable threshold (0.60), indicating an urgent need for targeted professional development programs.AI cannot and should not replace human teachers. Instead, it should serve as a powerful supportive tool that enhances the quality of education and strengthens teachers' professional capacity. Successful AI integration in Uzbekistan requires technological, pedagogical, and ethical dimensions to be addressed simultaneously.

The recommendations presented in this study may serve as a practical roadmap for achieving the objectives set out within the framework of the "Digital Uzbekistan – 2030" Strategy.

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