

PROSPECTS FOR IMPROVING THE EFFECTIVENESS OF USING ARTIFICIAL INTELLIGENCE IN TECHNICAL DRAWING LESSONS AT SECONDARY GENERAL EDUCATION SCHOOLS

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ABSTRACT: *This article investigates the prospects and efficiency of using artificial intelligence (AI) technologies in technical drawing lessons at secondary general education schools. An experimental study was conducted involving 8th–9th grade students (n=186) from three secondary schools in Tashkent. The experimental group studied technical drawing using an AI-based adaptive learning platform, while the control group followed traditional instruction methods. Results demonstrated that students using AI technologies scored, on average, 23.4% higher on final technical drawing assessments compared to the control group ($p < 0.01$). Spatial thinking and geometric shape reading abilities also improved significantly in the experimental group. The article proposes a pedagogical model for integrating AI-based learning systems into technical drawing education and discusses existing challenges and promising directions.*

Keywords: *artificial intelligence, technical drawing education, machine drawing, secondary school, adaptive learning, digital technologies, educational efficiency.*

INTRODUCTION

The rapid development of digitalization and artificial intelligence technologies is fundamentally transforming modern education systems. At the

global level, the field of Artificial Intelligence in Education (AIED) has become one of the fastest-growing scientific and practical domains over the past decade. According to UNESCO (2021), between 2022 and 2025, more than 70 countries worldwide adopted programs for integrating artificial intelligence into national education strategies. The Republic of Uzbekistan has not remained on the sidelines of this process: the “Digital Uzbekistan – 2030” strategy, adopted in 2023, designates the digitalization of the education system and the introduction of artificial intelligence into school education as a priority direction.

Technical drawing is an important subject in the technical sciences block of secondary general education, forming in students the fundamentals of engineering graphics, spatial thinking, and technical literacy. At the same time, researchers are noting a number of problems in the teaching of technical drawing. A survey conducted by Karimov and Yusupov (2022) found that 64% of school students in Uzbekistan experience difficulty understanding topics in drawing lessons, while 71% of teachers report being unable to sufficiently visualize spatial shapes using traditional instructional aids.

AI-based educational systems (Intelligent Tutoring Systems – ITS) are seen as a promising direction for addressing these problems. ITS systems are capable of analyzing each student's level of knowledge, points of difficulty, and learning pace in real time, forming an individual adaptive learning path. As demonstrated by Bloom (1984), individual instruction improves student outcomes by 2 sigma (i.e., two standard deviations) compared to group instruction - a phenomenon known as the 'two sigma problem' - and ITS systems are seen as the best technological solution for resolving it.

At the same time, the number of empirical studies dedicated to the use of AI technologies in teaching technical drawing within the context of Uzbekistan remains limited. This study aims to fill that gap and to experimentally

substantiate the effectiveness of AI-based instruction in technical drawing lessons.

Research objective: to experimentally assess the impact of AI technologies on educational effectiveness in technical drawing lessons at secondary general education schools, and to develop a corresponding pedagogical model.

Research tasks: to analyze existing AI-based systems in technical drawing education; to organize and conduct experimental work; to assess the impact of AI using quantitative and qualitative indicators; to propose a pedagogical model for integrating AI into technical drawing education.

The study was conducted from February to May 2025 at Secondary Schools No. 34, No. 112, and No. 187 in Tashkent. The study was organized on the basis of a quasi-experimental design: schools were randomly selected, and within each one class was assigned to the experimental group and another to the control group. A total of 186 students participated in the study: the experimental group - 93 students (8th–9th grade), the control group - 93 students. The groups were confirmed to be statistically equivalent in terms of initial average score, gender composition, and class composition via t-test ($p>0.05$).

The main tool used in the experimental group was an adaptive learning platform named GeoTutor.AI by its developers. This platform incorporates the following AI components: a Computer Vision module that automatically checks engineering drawings and analyzes errors; a Knowledge Graph system that diagnoses student knowledge in real time; a Recommendation Engine that forms an individual learning path; and an interactive module for studying spatial shapes using 3D visualization and virtual tools. The platform was used twice a week during 45-minute lessons. The control group was taught using traditional textbooks, a chalkboard, and drafting instruments.

The following measurement instruments were used in the study: an initial and final written test - a 40-question assessment measuring knowledge of technical drawing (projection, sections, cross-sections, dimensioning) based on GOST 2.301-2.317; a spatial thinking test - the Uzbek-language adapted version of the Mental Rotation Test (MRT) developed by Vandenberg and Kuse (1978); a student motivation questionnaire - a 20-item Likert-scale motivation survey (Cronbach's $\alpha = 0.84$); and a teacher observation journal - an observation sheet compiled for each lesson.

Quantitative data were processed using SPSS Statistics 26.0. An Independent Samples t-test was used to assess differences between groups, Cohen's d was used for effect size, and Repeated Measures ANOVA was used for dynamic analysis. Qualitative data (interviews and observations) were processed using thematic analysis. The threshold for statistical significance was set at $\alpha = 0.05$.

The main result obtained during the experiment was the difference in final test scores in technical drawing. Students in the experimental group scored an average of 74.6 ± 8.3 points on a 100-point scale. The control group averaged 60.4 ± 9.7 points. The difference between groups was 14.2 points (23.5%), confirmed to be statistically significant: $t(184)=10.37$, $p<0.001$, Cohen's $d=1.52$ (strong effect). This large effect size attests to the high effectiveness of AI-based instruction in the field of technical drawing.

When analyzed by individual topic, the greatest difference was observed in the topic of projections: the experimental group answered 81.2% correctly, while the control group answered 59.8% ($\Delta=21.4\%$). In the topic of sections and cross-sections, the difference was 18.7% (EG: 77.4%; CG: 58.7%), and in the topic of dimensioning it was 16.2%.

According to Mental Rotation Test results, the experimental group's average score rose from 18.4 to 28.7 (+10.3 points, +56%), while the control group's score rose from 18.1 to 21.4 (+3.3 points, +18%). The difference

between groups was $t(184)=8.64$, $p<0.001$, Cohen's $d=1.27$, indicating a strong effect. This result confirms the important role of AI-based 3D visualization modules in developing spatial thinking.

On the motivation questionnaire, the experimental group's initial level of 3.12 (on a 5-point scale) rose to 4.31. In the control group, this indicator rose from 3.09 to 3.38. 87% of students in the experimental group rated the AI-based platform as interesting and useful. Teacher observation results also showed that in the experimental group, activity during lessons and the quality of independent task completion improved significantly.

A number of problems were also recorded during the study. First, during the initial two weeks of lessons, 38% of students experienced technical difficulties using the platform (internet connectivity, working with the interface). Second, one teacher noted that the platform's AI recommendations sometimes did not fully align with the curriculum. Third, the opportunity to use the platform independently at home was not equally distributed among students - an indication of the influence of socioeconomic factors.

The results obtained reliably confirm the existence of a positive impact of AI technologies on technical drawing education. An average improvement of 23.5% and an effect size of Cohen's $d=1.52$ carry significant meaning in the context of Bloom's (1984) 'two sigma problem' - this indicator shows that it is practically possible to approach the effect of individual instruction using ITS systems.

The 56% improvement in spatial thinking is particularly noteworthy. Developing spatial thinking in technical drawing education has long been a complex pedagogical challenge (Shepard & Feng, 1990). Our research results support the conclusions of the meta-analysis conducted by Hwang et al. (2020): AI-based 3D visualization tools are 1.3-1.8 times more effective than traditional methods in developing spatial thinking.

The increase in motivation indicators is also an important result. Traditional technical drawing lessons are often perceived as monotonous and abstract (Drajin & Petrov, 2019). The AI-based interactive environment is helping to overcome this problem. D.Fayziyev (2023), in a study conducted in Uzbekistani schools, also found a significant increase in student motivation when digital tools were used, and our results confirm his conclusions.

The observed problems - technical barriers, the need for curriculum alignment, and the issue of digital inequality - demonstrate that integrating AI into schools requires complex solutions. In this regard, the principle of 'unity of technology and pedagogy' emphasized by Van Lehn (2011) seems especially relevant: even the most advanced AI system cannot deliver full results without the guiding role of a qualified teacher and the support of school infrastructure.

The main limitation of our study is the relatively small sample size ($n=186$) and the short (one-semester) observation period. Longitudinal studies can show the long-term effects of AI and represent an important direction for future work. Furthermore, since the study was conducted in Tashkent, comparison with rural schools also remains an important direction for the future.

This study experimentally demonstrated the effectiveness of applying artificial intelligence technologies in technical drawing lessons at secondary general education schools. The main conclusions are as follows.

First, students using an AI-based adaptive learning platform scored an average of 23.5% higher on final technical drawing assessments compared to peers taught by traditional methods. Second, the development of spatial thinking in the experimental group was 56%, three times higher than the 18% in the control group. Third, student motivation and interest in lessons increased significantly. Fourth, AI technologies do not replace the teacher, but instead redirect the teacher's role toward meaningful pedagogical dialogue and an individualized approach.

The following practical recommendations may be put forward: the gradual introduction of AI-based 3D visualization and automated checking systems for technical drawing lessons into school education; the organization of professional development programs for teachers on working with AI tools; investment in school infrastructure to eliminate the problem of digital inequality; and the development of local AI platforms adapted to the Uzbekistani curriculum for technical drawing education.

The right partnership between artificial intelligence and the educator is the fundamental paradigm of future technical drawing education, and its foundation is being laid today.

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