

# Transformation of the Quality of Technical Education in Kazakhstan in the Age of Artificial Intelligence: Strategies and Pedagogical Risks

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**Abstract.** The article studies the transformation of higher technical education quality in Kazakhstan under the state strategy «AI-Sana» for 2025-2026. The study is relevant due to the gap between digitalization speed and fundamental engineering competencies. The author compares global trends (MIT, NTU, TUM) and their adaptation in domestic universities (Astana, Almaty). Systemic risks, including «cognitive outsourcing» and erosion of engineering intuition, are classified. A mathematical model for calculating an integral quality indicator of the educational environment is proposed.

**Keywords:** higher education, artificial intelligence, pedagogical risks.

## Introduction

Global engineering education is undergoing transformation under Industry 5.0, requiring rapid digitalization while preserving core competencies such as analytical calculation, material understanding, and critical evaluation. By early 2026, Kazakhstan completed institutional preparation for AI integration within the Concept for the Development of Higher Education and Science (2023-2029) [1-2], including pilot programmes at leading universities in Astana and Almaty.

International experience shows diverse AI integration strategies: MIT (USA) emphasizes computational thinking and ethical AI use in generative design; TUM (Germany) focuses on digital twins and Hands-on Engineering; NTU (Singapore) implements adaptive learning systems monitoring students' cognitive load [4-5].

For Kazakhstan, adaptation must consider a multilingual environment (Kazakh, Russian, English) and collaboration with major industri-

al enterprises such as Kazatomprom, ERG, and KAZ Minerals.

**Aim:** Determine theoretical and methodological foundations for ensuring the quality of technical education amid digital transformation and develop practical recommendations to mitigate pedagogical AI risks.

Analyze the development and digital maturity of engineering education in Kazakhstan.

Review international AI practices and assess their suitability for national standards.

Identify cognitive and institutional risks in hybrid education.

Develop a quality assessment model incorporating human-AI interaction.

Test the Engineering Audit methodology and evaluate its effectiveness.

**Object of research:** Higher technical education in Kazakhstan during digital transformation.

**Subject of research:** Pedagogical conditions, quality assurance, and risk management

in AI-integrated engineering training.

Scientific novelty: For the first time in Kazakhstan, cognitive outsourcing risks in technical education are classified. The study shifts focus from evaluating design results to assessing the logic of AI interaction, enabling AI as a tool rather than a substitute and supporting process-oriented engineering education.

Technical education in Kazakhstan began with the Kazakh Mining and Metallurgical Institute (1934, now Satbayev University). The Bologna Process (2010) introduced the bachelor-master-PhD system, professional standards, and a National Qualifications Framework. Current efforts address the technological gap via accelerated digital transformation and AI integration [6-8].

### Research methods

The national AI-Sana programme has expanded opportunities for accelerating engineering developments, but also revealed hidden pedagogical risks that may affect long-term specialist training.

Systemic pedagogical risks were identified based on: Surveys of instructors and students (n=45 instructors, n=1,250 students); Observations of the educational process and LMS statistics; Expert evaluation by methodologists and leading industry engineers.

Threat level (TL) criteria:

Threat levels are assigned on a 5-point scale:

1 – Minimal risk (rare cases, negligible impact on competencies);

2 – Low risk (localized process issues, limited impact);

3 – Moderate risk (regular errors, potential impact on projects);

4 – High risk (systematic skill reduction, significant number of students affected);

5 – Critical risk (major impact on competencies, safety, or professional readiness of graduates).

Identified risks:

Cognitive outsourcing and intellectual dependency: Students widely use generative AI for coding and strength-of-materials calculations, reducing manual verification skills. TL=5

Digital divide and linguistic isolation: Universities in Almaty and Astana have advanced computing resources; regional institutions face limitations. Most AI tools are optimized for English and Russian, increasing inaccuracies for Kazakh-language students. TL=4

Institutional risks and academic integrity: Traditional course projects lose relevance as AI performs calculations instantly. Without process-based evaluation, graduates may acquire only formal competencies. Teaching staff risk burnout. TL=5

Technogenic risks: Errors generated by AI

and unverified by students may propagate to industrial practice (e.g., miscalculations in structural nodes). TL=3

Integrated quality indicator ( $Q_{univ}$ ):

Traditional university rankings do not account for student interaction with intelligent agents. The integral indicator of technical training quality is calculated as:

$$Q_{univ} = \sqrt[n]{\prod_{i=1}^n k_i^{w_i}} = \exp\left(\sum_{i=1}^n w_i \ln k_i\right),$$

where:

K1 – Digital convergence index: ratio of disciplines using digital twins and generative design to the total number of specialized subjects, calculated from curriculum analysis.

K2 – Cognitive independence index: inverse indicator of a student's dependence on AI prompts, determined by analyzing digital footprints in the LMS (number of manual checks per AI-generated solution).

K3 – Industrial validity index: percentage of final projects completed based on real cases from Kazakhstani companies (Kazatomprom, ERG, KAZ Minerals) using AI optimization.

$w_i$  – weighting coefficients: established by expert assessment, reflecting the relative importance of each indicator ( $w_1+w_2+w_3 = 1$ ).

The logarithmic function smooths extreme indicator values and provides a more accurate assessment of systemic quality dynamics.

Experimental study

Conducted at universities in Astana and Almaty (2023-2025) with 1,250 participants. Three stages:

Ascertaining (2023): Initial assessment of engineering knowledge and AI literacy; CG (n=600), EG (n=650).

Formative (2024): EG curriculum incorporated the Engineering Audit methodology; CG used traditional CAD methods. Generative models (nTop, Autodesk Generative Design) were used with mandatory manual verification.

Control (2025): Final competency assessment using a complex problem with deliberately flawed data undetectable by AI alone.

Methods:

Student's t-test: Evaluated significance of differences between CG and EG; significance level  $p < 0.05$ , confidence interval 95%.

Learning analytics: Automated tracking of time spent on each design stage and number of post-AI edits.

Expert audit: Blind evaluation of student projects by industry representatives. The results are shown in Table 1.

The sample covers the largest regions (Almaty and Astana), allowing differences in laboratory and industrial access to be considered. Results are representative for the Kazakh technical education system.

**Scientific results**

The research is based on a longitudinal pedagogical experiment conducted from September 2023 to January 2025 at leading technical universities, with 1,250 senior students in technical disciplines. The study aimed to test the hypothesis that uncontrolled AI use diminishes «engineering intuition», whereas the «critical audit» methodology converts technological capabilities into qualitative growth in professional competencies.

At the initial stage (ascertaining experiment), the baseline level of student interaction with AI systems was measured. The survey results showed the critical importance of technology in the everyday learning process (Table 2).

The survey results in Table 2 highlight the motivational factors for AI use among technical students. These trends are further illustrated in Figure 1, which visually compares the percentage of students engaging with each factor and its assessed impact on learning quality.

The data indicate that students prioritize speed (9.2 points) over critical analysis of explanatory text (5.4 points), reflecting a risk of superficial understanding. In experimental groups (EG), the author’s Protocol-based Design method was applied in the courses Machine Parts and Information Systems Design, following this algorithm:

Formulation of technical specifications and obtaining an initial solution from generative AI.

Decomposition of the AI solution into con-

stituent elements.

Manual or classic software (ANSYS, Solid-Works) verification of critical nodes.

In January 2025, a control test involved solving a problem with a paradoxical error in initial data, undetectable by standard AI. Results: CG (84% accepted the erroneous AI solution); EG (62% successfully identified the error, demonstrating critical thinking).

Using the integral quality indicator Quniv: Traditional model: 0.64; Uncontrolled digital model: 0.52 (due to decline in cognitive independence, K2); Hybrid Intelligence model (EG): 0.87.

This demonstrates that technical education quality peaks when AI is integrated as a tool rather than a substitute. The experimental study highlights three dimensions: pedagogical effectiveness, technological safety, and institutional sustainability. EG results showed a 30% improvement in quality indicators after introducing the Engineering Audit methodology.

Compared with MIT and TUM, Kazakhstan followed a path of rapid AI adaptation under the AI-Sana programme, completing the transition in two years. The risk of rapid implementation is a pedagogical lag: 45% of staff perceive AI as a threat to academic integrity.

Two development scenarios emerge:

Inertia: prohibitive measures against AI, detaching universities from Industry 5.0 realities.

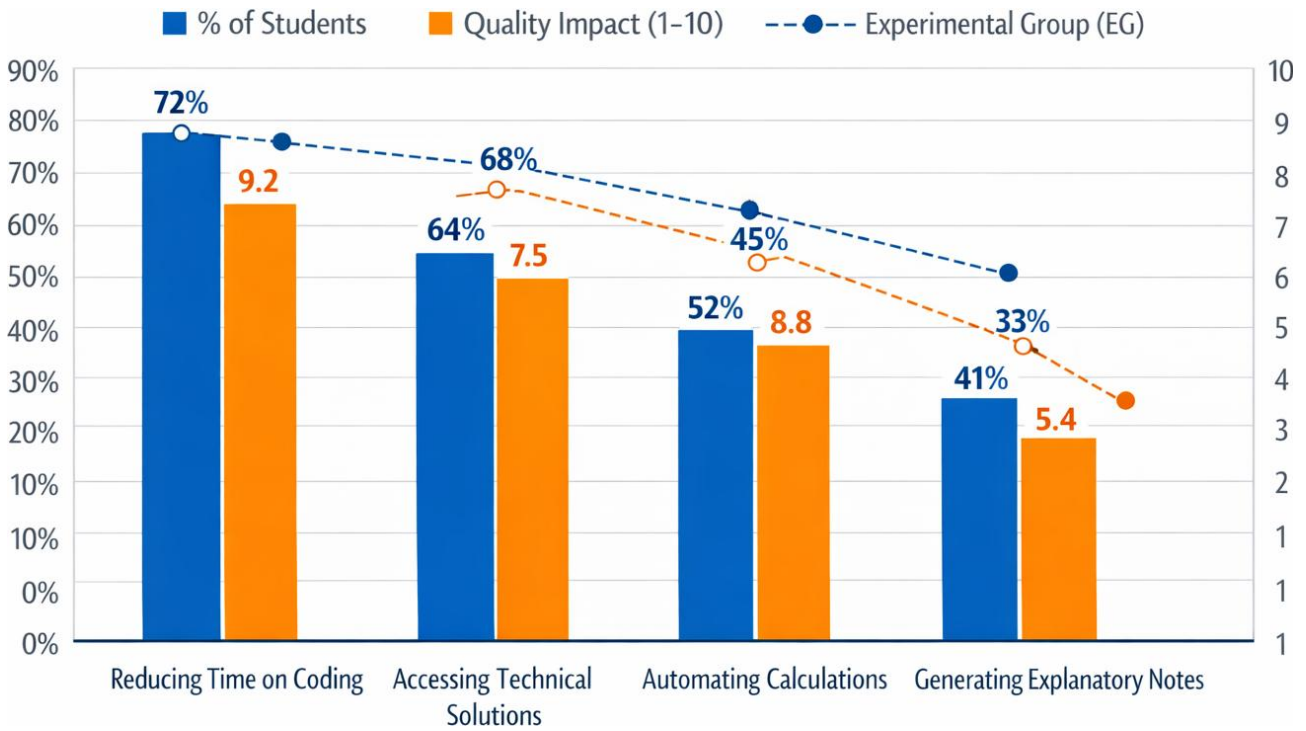
Integrative: «Human-in-the-loop Engineer-

**Table 1 – Results of experimental work**

Group	Use of AI (hours/week)	Level of critical analysis (points 1-10)	Process physics score
Control (CG)	2,5	8,2	7,9
Experimental (EG)	14,8	6,1 (without audit)	6,4
EG (after audit)	12,0	9,1	8,5

**Table 2 – Motivational factors for the use of AI by students of technical universities in Kazakhstan (n=1250)**

Utilization factor	Percentage of respondents (%)	Quality impact assessment (1-10)
Reducing time spent on coding	72	9,2
Accessing technical solutions in open databases	64	7,5
Automating engineering calculations and modelling	52	8,8
Generating explanatory notes	41	5,4



**Motivational factors for AI use by technical students in Kazakhstan (n=1250), showing both the percentage of students and the quality impact assessment (1-10)**

ing» with AI performing 90% of routine calculations, while students focus on system synthesis, safety ethics, and innovation.

In conclusion, technical education in Kazakhstan is undergoing structural transformation. The Hybrid Intelligence model and Engineering Audit methodology allow AI risks to be converted into a competitive advantage in the global Industry 5.0 market.

### Conclusion

The study of technical education transformation under digitalization and the AI-Sana programme (2025-2026) leads to the following conclusions:

1. In 2025, technical university quality shifted from resource metrics to technological adaptability, with Quniv reflecting the use of generative AI as an interactive design environment that enhances student engagement.

2. AI accelerates engineering design by 45%, but uncontrolled use without verification diminishes critical thinking in 84% of control-group students, highlighting the risk of superficial learning when AI acts as a substitute rather than a collaborator.

3. Implementation of the Engineering Audit methodology increased error detection to

62%, confirming the need to evaluate decision-making processes rather than only final results and showing that guided AI use enhances both professional competencies and cognitive independence.

4. Developing national language models (KazLLM) for technical content is essential to ensure equal access to high-quality AI resources, preventing language from becoming a learning barrier.

Recommendations:

University administrations: combine AI-generated plagiarism detectors with analysis of digital footprints; create interdisciplinary platforms for testing AI projects on real equipment.

Teaching staff: increase oral defenses and viva voce exams to ensure understanding of AI-generated parameters. Enhance AI literacy among teaching staff: Conduct regular seminars and certification programs on AI usage in education.

Overall, AI can serve as a strategic pedagogical tool, improving efficiency and quality while preserving critical engineering skills when combined with structured verification and process-oriented methods.

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### **Қазақстанда жасанды интеллект дәуіріндегі техникалық білім сапасын трансформациялау: стратегиялар және педагогикалық тәуекелдер**

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**Аңдатпа.** Мақала Қазақстандағы жоғары техникалық білім сапасының 2025-2026 жылдарға арналған «AI-Sana» мемлекеттік стратегиясы аясында трансформациясын зерттейді. Зерттеудің өзектілігі цифрландыру қарқыны мен негізгі инженерлік құзыреттер арасындағы алшақтықпен анықталады. Автор әлемдік трендтерді (MIT, NTU, TUM) салыстырып, оларды отандық университеттерде (Астана, Алматы) бейімдеуді қарастырады. «Когнитивті аутсорсинг» және инженерлік интуицияның жойылуы сияқты жүйелік тәуекелдер жіктелген. Білім беру ортасының сапасының интегралдық көрсеткішін есептеу үшін математикалық модель ұсынылған.

**Кілт сөздер:** жоғары білім, жасанды интеллект, педагогикалық тәуекелдер.

### **Трансформация качества технического образования в Казахстане в эпоху искусственного интеллекта: стратегии и педагогические риски**

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**Аннотация.** Статья посвящена трансформации качества высшего технического образования в Казахстане в рамках государственной стратегии «AI-Sana» на 2025-2026 гг. Актуальность исследования обусловлена разрывом между темпами цифровизации и фундаментальными инженерными компетенциями. Автор проводит сравнительный анализ мировых тенденций (MIT, NTU, TUM) и их адаптацию в отечественных университетах (Астана, Алматы). Классифицированы системные риски, включая «когнитивный аутсорсинг» и эрозию инженерной интуиции. Предложена математическая модель расчета интегрального показателя качества образовательной среды.

**Ключевые слова:** высшее образование, искусственный интеллект, педагогические риски.

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