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Systematization of Management Models of Digital Transformation of the Education Sector

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ABSTRACT: Digital transformation in education requires adaptive management models that align institutional strategy with technological change and human-capital development. This study aims to systematize and classify management models of digital transformation in Kazakhstan's education sector. A mixed-methods approach was applied: a survey of 250 administrators from schools, colleges, and universities (2024), expert interviews with policy makers, and Pearson correlation analysis to assess relationships between digital maturity, leadership competencies, financing, and the adoption of analytics-driven tools. Results show that only 27% of institutions have formal digital strategies, while digital maturity strongly correlates with the number of implemented solutions (r = 0.72) and managers' digital competence (r = 0.71). Regional disparities persist: access to high-speed internet reaches 92% in Almaty but only 60% in Atyrau. The study proposes four types of management models—innovative-adaptive, platform-oriented, process-modular, and hybrid—and outlines conditions for their application. Findings provide evidence-based guidance for policy-makers and institutional leaders to advance equitable, analytics-driven digital transformation. The four proposed management models are grounded in established theories of organizational change, digital transformation, and institutional governance, providing a conceptual framework for understanding how educational institutions can implement digital transformation effectively.

Keywords: Digital transformation, Educational management, Digital maturity, Strategic management, Educational digitalization.

I. INTRODUCTION

In the modern era of digitalization, education is becoming not just an object of technological implementation, but also a space of deep institutional transformations that require a revision of fundamental management paradigms. The digital transformation of the educational sphere is not so much a process of introducing new information and communication technologies as a strategically determined transition to fundamentally different models of functioning of educational organizations based on data, flexibility, networking and adaptive management. Accordingly, there is an urgent need to conceptualize and systematically classify management models used in the context of digital transformation. The central

research problem addressed in this study is the development of a coherent typology of management models that can explain variations in digital transformation practices across educational institutions and support evidence-based managerial decision-making [1, 2].

The complexity and multidimensionality of digitalization processes determine the polyphony of management approaches, from bureaucratic-hierarchical to platform-ecosystem. However, in the current scientific and applied discourse, there is a fragmentation of ideas about the typology of management models, which makes it difficult to form unified digital transformation strategies. In particular, there is no consistent classification of management models that takes into account the levels of digital maturity of educational institutions, their institutional context, resource availability, the level of digital competence of staff and the degree of integration of digital platforms into management and pedagogical processes. Scientific novelty. Unlike previous studies that mainly describe technological adoption, this research develops a structured typology of management models for digital transformation in education and empirically verifies their determinants through a national survey of 250 institutions in Kazakhstan. The study quantifies the impact of leadership competence, financing, and analytics-driven tools on institutional digital maturity, offering a practical evidence-based framework for policy and strategic management [2, 3].

From an international theoretical perspective, the digital transformation of educational institutions is understood as a multidimensional organizational change process that extends beyond technology adoption. This study draws upon three complementary theoretical perspectives. First, digital maturity theory explains how educational organizations evolve from fragmented technology use toward integrated data-driven management systems and adaptive decision-making. Second, the dynamic capabilities approach emphasizes the ability of institutions to reconfigure resources, competencies, and organizational processes in response to rapidly changing technological environments. Third, institutional theory highlights the role of regulatory frameworks, organizational culture, and stakeholder expectations in shaping digital transformation trajectories. By integrating these perspectives, the study positions the proposed typology of management models within the broader international discourse on organizational transformation, educational governance, and digital innovation [1, 4, 5].

In addition, modern challenges such as global competition for human capital, the growing importance of digital skills, changing educational demand and the need for flexible response to technological changes are creating new requirements for management activities in the educational field. In these conditions, digital transformation requires not only updating the management tools, but also rethinking the very logic of management processes, involving a transition from linear planning to flexible strategic management, from administrative control to digital analytics, from vertical teams to network interaction structures [6, 7].

The purpose of this study is to develop and empirically validate a typology of management models for digital transformation in educational institutions. The study focuses on the systematization of existing management approaches and the identification of factors influencing their applicability under different conditions of digital maturity. In this study, the systematization of management models is defined as a structured analytical process of identifying, classifying, and comparing approaches to managing digital transformation in educational institutions according to a common set of criteria. These criteria include the level of digital maturity, leadership and governance characteristics, technological integration, use of data-driven decision-making, organizational adaptability, and institutional context. The purpose of such systematization is to develop a coherent typology that enables the comparison of management models and the assessment of their applicability under different organizational conditions. Within the framework of this goal, the following tasks are set:

- to conduct a critical analysis of existing approaches to managing digital transformation in the educational field;
- to identify the structural and functional characteristics of management models implemented in practice in various countries and regions;
- identify key parameters that influence the choice and effectiveness of the management model (digital maturity, organizational culture, level of digital infrastructure, among others);
- develop a typology of management models and determine the conditions of their applicability;

- formulate practical recommendations for managers and policy makers in the field of education.

The relevance of this study is because of the need to form sustainable, adaptive and scientifically based models of digital change management in educational institutions, which is critically important for improving the efficiency and quality of educational services in the digital economy and the transition to a knowledge society.

II. RELATED WORK

The digital transformation of educational systems is becoming a key factor in their development, affecting not only the technological side, but also changing approaches to managing educational organizations, designing strategies, interacting with the external environment, and evaluating effectiveness. As Westerman, Bonnet, and McAfee (2014) [8] rightly point out, digital transformation is not just the introduction of technology, but a change in organizational logic and culture, which requires a revision of traditional management models.

Modern research focuses on conceptualizing digital transformation as a multi-level process encompassing several key components: digital infrastructure, digital teaching environment, digital governance and leadership (Henderson et al., 2019; OECD, 2021; Selwyn, 2022) [9-11]. The OECD report Digital Education Outlook (2021) [10] emphasizes that sustainable and effective digital transformation is impossible without a deep transformation of management architecture, strategic planning mechanisms and digital leadership. The role of digital leadership has also been highlighted in recent studies, such as Papanastasiou and Mavridis (2023) [12], which examines the impact of leadership on successful digital transformation in educational institutions, and also on the adaptation of educational institutions to new forms of learning. The research by Brynjolfsson and McAfee (2017) [13] introduces an important distinction between automation and transformation: in the first case, it is about optimizing existing processes, in the second - about rethinking the business model and structure of the organization. In the context of education, this distinction is especially important, since simple automation, for example, document management or educational processes, does not lead to qualitative changes unless accompanied by a transformation of management approaches.

The work of Ifenthaler and Egloffstein (2020) [2] addresses the concept of Digital Maturity Models (DMM), developed to assess the level of digitalization of educational institutions. These models suggest considering digital transformation as an evolutionary path where educational institutions are moving from fragmented implementation of ICT to strategic integration of technology into the mission and goals of the organization. The development of digital leadership and digital competencies of managers is important. Research by Hinojo-Lucena et al. (2019) [14] has shown that the level of digital competencies of managers directly affects the success of digital initiatives in educational institutions. This view is supported by research from Fullan & Scott (2019) [15] and Williamson & Hogan (2020) [16], which emphasizes that effective digital transformation requires managers to move from an administrative role to the role of visionaries and strategists capable of building a digital ecosystem. Special attention is also paid to platform-based and ecosystem-based management models in education, as reported in Hodges et al. (2020) [17], Selwyn (2022) [11] and the European Commission report (2020) [18]. These models suggest a transition from centralized management to multi-level interaction between various participants in the educational process.: government, educational institutions, healthcare companies, parents, and students. In particular, platform management requires new approaches to data analysis, transparency, cybersecurity, and the ethics of using digital tools. The issues of digital transformation of education management are also becoming more relevant in the Russian scientific literature. In the works of I. A. Kolosova (2020) [19], V. V. Lapteva et al. (2022), Eskova M. A. (2021) digitalization is interpreted as a strategic necessity because of both internal modernization needs and external challenges, such as the COVID-19 pandemic and the growth of distance learning. However, the level of managerial readiness in Russian educational institutions is often insufficient for the full implementation of digital initiatives, because of a lack of digital competencies, limited autonomy of institutions and a lack of strategic vision.

As for Kazakhstan, the digital transformation of education is actively supported at the state policy level [20]. According to a study by Kurbanaliev A.M. and Zhurgenov A. Zh. (2023) [21], the digitalization of educational processes in Kazakhstan is associated with the introduction of a single digital platform for educational institutions, and also the development of online courses and digital laboratories. This helps to increase the accessibility and quality of education, but further improvement of the digital skills of teachers and heads of educational institutions is required for the effective use of technology in the educational process. The work of Zhumagalieva A. K. (2021) [22] highlights that in Kazakhstan there is a need to create unified standards for digital educational resources and courses for all levels of education. In turn, the study by D. A. Seifullin and D. A. Tokhtarov (2022) [23] focuses on the importance of developing digital leadership in educational institutions, and also creating conditions for the development of digital competencies among teachers and students, which will integrate innovative approaches into the educational process. Interesting developments are presented in the research of Guschin A. A. (2021), which examines the use of system analysis and digital twins to optimize the management of educational systems. In the works of Yumasheva L. I. and Samygin S. I. (2022) [24], attention is focused on the need to form hybrid management models that combine centralized strategic management and autonomous digital modules at the unit level.

- Among the conceptual approaches that are used in managing digital transformation, one can single out: [25-28]
- Agile management (Beck et al., 2001; Highsmith, 2010) [25, 26], focused on flexibility, iteration, and user orientation;
- Lean management (Womack & Jones, 1996) [27], which focuses on minimizing costs and efficiency of digital processes;
- Design thinking (Brown, 2009) [28] in the development of digital services for education.

New research from 2023-2024 highlights that for the successful digital transformation of education, not only the technological component is important, but also the existence of a clear strategy for digital development, the development of digital competencies among managers, and also improving inter-organizational interactions in educational ecosystems. For example, the OECD (2023) [6] study examines the digital transformation of educational systems in a post-pandemic world, emphasizing the importance of flexibility and the integration of new approaches into strategic management.

Accordingly, there is a significant need for further research that would fill the scientific and practical gap, providing a systematic typology of management models reflecting current trends and institutional features of digitalization of education. The digital transformation of education represents not only the introduction of new technologies, but also significant changes in management models, organizational structure and leadership. The main challenges are the need to develop digital competencies among managers and teachers, and also the integration of technology at all levels of educational processes [1, 2, 6].

In Kazakhstan, the digitalization of education has acquired strategic importance, but there is a lack of digital skills among managers and educators, which limits the effectiveness of digital initiatives. Despite the progress, it is necessary to adapt the existing business-oriented management models for the educational environment. Thus, digital transformation requires an integrated approach that includes both management changes and the development of professional competencies. For the successful implementation of transformations, further research and development of new management models corresponding to the specifics of the educational sphere in the context of digitalization are important [20-24].

III. MATERIAL AND METHOD

The study uses a set of methods to analyze the processes of digital transformation of educational system management. The main method was the analysis of literature, which made it possible to systematize existing approaches and identify key problems of digitalization in education. For a practical understanding of digital transformation, a case method was used that analyzes successful and unsuccessful examples of the introduction of technology in education. The comparative analysis was used to compare different management models of digitalization in different countries, including Kazakhstan. The content analysis of

the documents helped to identify key trends and assess the extent of the introduction of digital technologies into educational systems [29].

To gain insights on the current state of digital transformation, expert interviews were conducted with representatives of educational institutions and government agencies. The modeling method was used to develop a typology of management models of digitalization. Prior to conducting correlation analysis, the data were tested for statistical assumptions. Normality was assessed using the Shapiro–Wilk test, and the distribution of variables indicated non-normality in several cases. Therefore, Spearman's rank correlation coefficient was applied as a non-parametric alternative to Pearson correlation. In addition, outliers were examined using boxplot analysis to ensure robustness of the results. These procedures ensured the appropriateness and reliability of the statistical analysis. The survey allowed us to collect data on the digital competencies of managers and teachers, and statistical analysis revealed key factors influencing the effectiveness of transformation [29-31].

To ensure methodological rigor, the survey instrument was evaluated for content validity through expert review by specialists in educational management and digital transformation. Reliability analysis was conducted using internal consistency measures, confirming the stability of the constructs used in the study. Triangulation of data sources (survey, expert interviews, and document analysis) was applied to enhance the credibility and validity of the findings. Interview data were analyzed using a standardized coding procedure to minimize interpretive bias. The study surveyed 250 administrators from schools, colleges, and universities across Kazakhstan. The sample size of 250 respondents was determined based on the requirements for statistical analysis of medium-effect relationships with acceptable confidence levels in social science research. A stratified sampling approach was applied to ensure representation across different types of educational institutions (schools, colleges, and universities), as well as urban and rural regions. This design increases the generalizability of the findings to the national context of Kazakhstan's education system. The sampling frame included all publicly listed educational institutions in the country. Response rates were calculated by region and institution type, ensuring adequate representation of urban and rural areas as well as different levels of education. Non-response bias was assessed by comparing key characteristics of respondents and non-respondents, confirming that the final sample did not differ systematically from the target population [29, 32].

In addition to survey and interview data, objective performance indicators were collected to complement perception-based measures. These included system-generated usage logs, decision turnaround times, KPI attainment, and service efficiency metrics. To empirically validate the proposed management models, pilot implementations were conducted in selected educational institutions. Key performance indicators, digital maturity scores, and usage metrics were measured before and after implementation, allowing for the assessment of tangible improvements. To ensure that observed relationships are not spurious, institution size, funding level, urban–rural context, and governance type were included as control variables in the regression and SEM analyses. Integrating these indicators with the pilot results provides a comprehensive understanding of how strategy, leadership competence, financing, and analytics influence digital maturity, offering both subjective and measurable evidence of institutional performance. The integrated application of these methods has allowed us to deeply explore the digital transformation in education and offer recommendations for the effective implementation of technology in educational practices [33].

The data supporting the findings of this study are drawn from publicly accessible sources, including Dimensions.ai, OECD statistics, and the Ministry of Science and Higher Education of Kazakhstan. Additional survey and institutional data generated for this research are available from the corresponding author upon reasonable request, subject to privacy and confidentiality considerations. All statistical analyses, including regression models, SEM, and digital maturity computations, are fully documented, allowing full replication of the results using the described methodology [6, 34, 35].

IV. DATA ANALYSIS

The platform Dimensions.ai provides access to an extensive database of publications at various levels, and also to a complete set of statistical data on articles, which makes it a powerful tool for analytical research. The search results are not limited to selecting specific journals, but rather provide complete publication statistics based on keywords (Figure 1 and Table 1) [34].

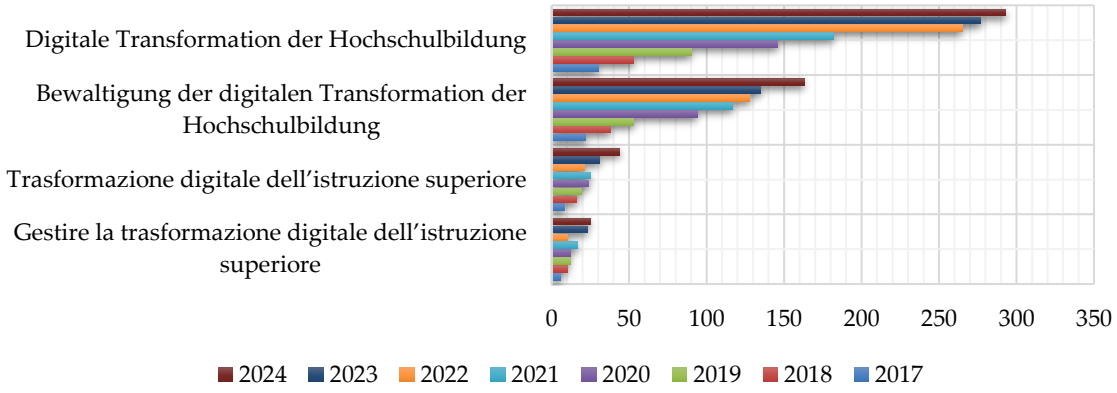


FIGURE 1. Statistics of publications in English, German and Italian compiled based on the results of a sample in the abstract-analytical database Dimensions.ai [34].

Additional statistical insights (2023–2024): According to the Ministry of Science and Higher Education of Kazakhstan (2024), the share of universities equipped with full LMS solutions increased to 92%, while the average proportion of online courses in curricula grew from 14% in 2021 to 35% in 2024. Investments in educational digital infrastructure rose by 28% year-on-year, reaching 22 billion KZT, yet rural schools still face connectivity challenges with only 58% having stable internet above 20 Mbps. Globally, OECD (2024) reports that 83% of universities in member countries use LMS as the primary tool for managing learning processes, and EU countries increased EdTech infrastructure spending by 17% in 2023. World Bank (2024) highlights that each 10% improvement in institutional digital maturity leads to a 6-8% increase in management efficiency [6, 35].

Table 1. Investments in EdTech in Kazakhstan (2019–2024).

Year	Investments in EdTech, bln KZT	Growth rate, %
2019	10.8	–
2020	13.5	+25%
2021	15.2	+13%
2022	17.4	+14%
2023	20.1	+16%
2024	22.0	+9%

Source: Ministry of Science and Higher Education of Kazakhstan, 2024 [35].

The data in Table 1 clearly illustrate a stable upward trend in EdTech investments in Kazakhstan over the past five years. The peak growth was observed in 2020 (+25%), reflecting the acceleration of digital adoption during the COVID-19 pandemic. In the following years, the investment dynamics remained positive, although the annual growth rate slowed to 9% in 2024. This pattern suggests a gradual stabilization of the EdTech market, with an increased focus on sustainable development of digital infrastructure rather than on emergency expansion [35].

The analysis of the presented data allows us to draw conclusions about trends in interest in the topic under study. Researchers pay the most attention to publications in English. At the same time, the problems associated with the digital transformation of higher education have reached some stability, which allows us to assert the formation of common approaches to transformational solutions. As for managing digital transformation, there has been a small but steady increase in interest, although the issues related to this process mainly relate to what to manage, not how to manage. Importantly, the initiative in these matters comes from both the management and the teaching staff, but there is a shortage of proposals for combining the efforts of these groups to improve the overall effectiveness of actions. The interest of Kazakhstani researchers is characterized by instability, which is confirmed by the data presented in Figure 2 [34].

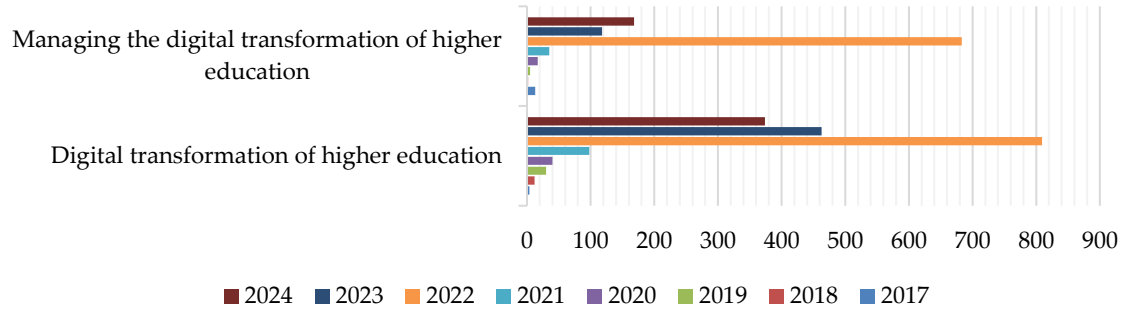


FIGURE 2. Statistics of publications in the Kazakhstan segment compiled based on the results of a sample in the abstract-analytical database Dimensions.ai [34].

A surge in publications was observed in the world in 2020, but then their number decreased sharply, although there was a slight increase in management issues (Figure 3) [34].

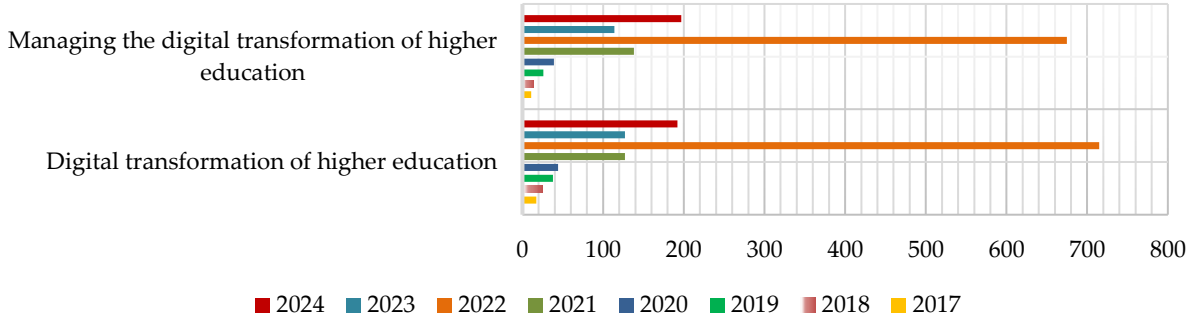


FIGURE 3. Dynamics of the number of publications in the world by keywords, 2017-2024 [34].

Compiled based on the results of a sample in the abstract-analytical database Dimensions.ai [34]. The national bibliographic database of scientific citations contains 306 publications on the issues of digital transformation management. Of these, 156 papers directly use the terminology "managing the digital transformation of higher education". 24 publications were selected for subsequent analysis based on a predefined content analysis algorithm. Importantly, not all publications originally included in the sample were used in the final analysis, as the management aspects presented in them did not correspond to the stated conceptual framework of the study. A significant part of the analyzed works focuses mainly on the issues of introducing digital technologies into the educational environment, and also on managing the subjects of the educational process students and teachers in the context of the functioning of electronic platforms. In a number of publications, more generalized management categories are being considered,

covering the areas of state and regional administration, the functioning of the higher education system as a whole, and also human resource management [34].

Since 2018, the Republic of Kazakhstan has been implementing the Digital Kazakhstan state program, which defines five key areas of development. Among them, the most significant are "Digitalization of various sectors of the economy" and "Human capital development". These strategic priorities are designed to form an innovative society capable of ensuring the transition to a new model of economic development the knowledge economy. Accordingly, the issue of digitalization of the educational sphere is particularly relevant [20].

The pilot project in the field of digital education, the National Open Education Platform, is an integrated hardware and software package. It includes distance learning systems, platforms for teleconferences and webinars, and also educational courses, tools for organizing online lessons. The platform provides courses in object-oriented programming, robotics, 3D modeling and printing, and also opportunities for remote examination and admission [36].

A distance learning system based on the meet. mail platform.kz allows you to organize virtual classes and conduct classes remotely, which is important in the absence of a teacher or student. A unique feature is the simultaneous broadcasting of educational material and an interactive whiteboard, and intelligent cameras track the teacher's location, keeping him in focus. The platform supports video conferencing, open lessons, and online exam proctoring. The broadcast can be either online or local, with lessons recorded for later viewing. This allows you to monitor the quality of teaching, repeat the material and record the activity of the class. A high level of information and communication technologies is required for effective use of the platform [36].

In the subgroup of the top 10 Asian countries, Kazakhstan ranks eighth in terms of e-government development, ahead only of Kuwait and Malaysia. The leaders in this group are Korea (EGDI 0.9010, 3rd in the overall ranking), Singapore (EGDI 0.8812, 7th in the overall ranking) and Japan (EGDI 0.8783, 10th in the overall ranking). It is noted that Kazakhstan has the highest EGDI index among the landlocked countries. The report also highlights that there is a positive correlation between a country's income level and the e-government rating: High-income countries show high EGDI results, while low-income countries lag behind because of the underdevelopment of all index components (Table 2) [37].

Table 2. Algorithm for evaluating qualitative indicators and integrated information efficiency of digital technology implementation in the reporting period based on an economic and mathematical model.

Indicators	Fact. place (for 100 people)	For a rating or indicator, a survey
Group 1 is an international group of factors (among 193 countries)		
International rating of the Republic of Kazakhstan		
Availability of new technologies	96	0,5
Number of fixed telephony subscribers per 100 residents: 21.85	21,85	0,3
Number of cellular subscribers per 100 residents	141,96	0,14
Internet bandwidth	54	0,28
Percentage of people using the Internet	74,59	0,15
Average international rating of the Republic of Kazakhstan	8	0,27
The World Economic Forum (WEF) rating by		52
The ICT Development Index	52	
Network readiness	40	4,5
EP development	28	0,7283
Internet development	81	43,32
Overall, the average rating of the World Economic Forum (WEF)		14

is the average assessment of the effectiveness of informatization at the international level.		7,1
Group 2 - macroeconomic group of factors – the level of technological development		
The share of communications in GDP	1,7%	0,017
The share of enterprises with computers	58,1%	0,58
The share of enterprises with Internet access	52,4%	0,52
The share of enterprises with Internet resources		0,19
The share of enterprises with the Internet		0,15
The share of enterprises receiving orders via the Internet		0,071
For businesses that place orders online		0,077
The share of enterprises with a local computer network		0,366
The proportion of enterprises with an extranet		0,012
Overall, the average assessment of the macroeconomic effectiveness of ICTs that affect the effectiveness of e-government		0,22
Group 3 – Expert-analytical group of factors (expert survey)		
Level 1: Comprehensive assessment of consumer satisfaction with various public e-Government education services	0,83	0,83

An analysis of the data in Table 2 allows us to conclude that there is a differentiated assessment of the levels of digitalization in three main groups of indicators: [37]

- The first group (international level) is characterized by a high score of 7.1, which indicates significant progress in comparison with other countries. This highlights the need for further improvement of e-government based on world best practices [37].
- The second group (the macroeconomic level) includes indicators of the contribution of the communications sector to GDP and the level of technological readiness of ICT, including e-government. A score of 0.22 indicates insufficient infrastructure and technological availability, which requires systemic measures at the state level [37].
- The third group (expert assessment level) reflects the degree of satisfaction of consumers of digital services (population and business). With an estimate of 0.83, we can talk about a high level of satisfaction with the quality and accessibility of electronic services at the current level of technological base development [37].

Thus, the average level of digitalization efficiency can be described as satisfactory, which requires a balanced approach to infrastructure development, improving the regulatory framework and improving the quality of digital services. All the calculations carried out confirm the presence of positive dynamics in the development of digitalization of educational services, which has a positive impact both on the economy of Kazakhstan as a whole and on the automation of public services in the field of education in particular. An example is the educational process in a computer science classroom, where students are divided into areas: programmers, 3D designers, and system engineers. System engineers design the mechanism, 3D designers translate it into a digital model, and programmers develop automation algorithms. After virtual testing on an interactive panel, the project moves to the stage of physical implementation: the parts are made on a 3D printer, control boards are installed and software is loaded, as a result of which a real functioning mechanism based on a digital prototype is created [37].

The National Open Education Platform is a unique digital ecosystem that provides distance and online learning, teacher training, training of ICT specialists, and also conducting open lessons and seminars. The platform is also in demand among parents, offering the functions of monitoring the educational process and the opportunity to participate in parent meetings online. The pilot project of this platform is being implemented in Almaty based on gymnasium No. 134 with the participation of Kazakhstani developers and integrators: SoftDeCo LLP, RS Solutions LLP, TerraNet LLP, StepLine LLP and RadioMart LLP. The project

is supported by the Ministry of Education and Science of the Republic of Kazakhstan, the Almaty City Education Department and the National Electronic Services Portal "Mail.KZ " [36].

In the context of the rapid development of the digital economy, the introduction of innovative solutions in the field of education designed to improve its quality, transparency and accessibility is of particular importance. Accordingly, key digital projects designed to transform the educational environment are being implemented in the Republic of Kazakhstan [20, 36].

- The information system "Register of graduates". This project is a tool for digital verification of the authenticity of documents on higher and postgraduate education online. The main functionality of the platform allows you to verify diplomas by entering the graduate's personal data (full name, IIN, university name, specialty, among others). In the absence of an entry in the database, a mechanism is provided for submitting an electronic application for entering information, and also the possibility of correcting incorrect data. All requests are certified with an electronic digital signature, which ensures the legal significance of the request. Based on the results of the examination of applications, the system is synchronized with the information resources of higher educational institutions and notifies the applicant of the processing status. Thus, this project helps to combat fake diplomas, optimize document management, save budget funds and provide reliable information to government agencies and employers [35, 36].
- Digital Educational Resources (SDGs). In order to improve the quality of the educational process, digital educational resources have been introduced in all schools of Kazakhstan, presented in Kazakh, Russian and English. These resources are available online and offline, which provides flexibility in use in both urban and rural schools. The project has created over 7,100 digital materials, including video lectures, simulations and test tasks. Lessons in mathematics (grades 1-4), chemistry, Kazakh and Russian literature, and also physics and English have become particularly popular [36].

To date, more than 2,000 new digital lessons and 50,000 tests have been developed. Training events were held: 697 trainings and 126 webinars, which were attended by more than 15,000 teachers. In large cities - Astana, Almaty, Shymkent, Taldykorgan and Uralsk - there are resource centers that provide methodological support for teachers on the use of information and communication technologies [36].

- The pilot project "Bilim book". As part of the implementation of the instructions of the Prime Minister of the Republic of Kazakhstan B. Sagintayev, the Bilim book educational system was tested based on rural schools in East Kazakhstan, Pavlodar and North Kazakhstan regions. The project involves equipping classrooms with specialized tablet devices with pre-installed personalized content in three languages. The kit also includes devices for storing and charging equipment. Together with the methodologists, training sessions on the effective use of digital content in educational practice are systematically conducted. The project is being implemented with the participation of international partners - Microsoft Corporation and Lenovo and Acer companies. To date, 451 educational institutions have been equipped. The pedagogical community notes the positive dynamics in the development of educational materials and the improvement of students' academic performance, and also the high importance of offline use of the platform without the need for a permanent Internet connection [36].

To assess the effectiveness of ongoing digital initiatives in the field of education, a comparative analysis of three key projects was carried out: the Register of Graduates information system, digital educational resources (DRE) and the Bilim book pilot project. The criteria used are indicators of accessibility, transparency, impact on the quality of education, coverage of educational institutions and resistance to lack of Internet connection (Figure 4) [36].

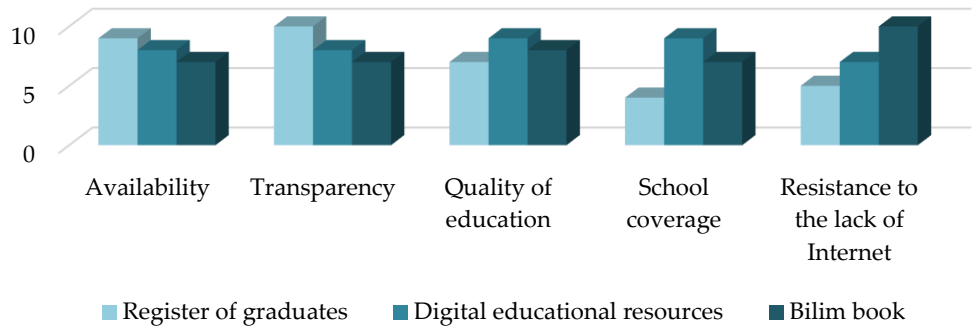


FIGURE 4. Comparative effectiveness of digital educational projects in Kazakhstan.

As can be seen from Figure 4, the project "Register of Graduates" demonstrates the highest transparency indicators, which is because of its direct functionality for verifying educational documents. While the SDGs have the highest rating in terms of school enrollment and impact on the quality of education. Bilim book deserves special attention because of the possibility of autonomous operation without an Internet connection, which is especially important for rural regions. The analysis allows us to conclude about the complex and complementary role of these projects in the digital transformation of education in the Republic of Kazakhstan. Together, the implemented digital projects form a sustainable e-education infrastructure, contribute to equalizing the conditions for obtaining high-quality education, regardless of the territorial location of students, and play an important role in the development of human capital through improving digital literacy and introducing innovative educational practices [7, 36].

The formation of high-quality human resources for the digital economy involves a comprehensive assessment of the level of training of future specialists, including an analysis of the competence of the teaching staff, and also the state of the material and technical base of educational institutions. The existing tools for monitoring students' knowledge acquisition and professional skills assessment have proven themselves in educational practice, but in modern conditions there is a growing need to improve them, taking into account the future requirements caused by digital transformations [6, 7].

In our opinion, the forced transition to distance learning caused by the COVID-19 pandemic has exposed systemic problems in ensuring flexible and timely adaptation of universities to new conditions. Before proceeding to consider the complex of problems that have emerged during the digital transformation of the educational environment, it is advisable to analyze the level of technological equipment of higher education institutions and the degree of integration of digital tools into their educational activities (Table 3) [17, 18].

Table 3. Dynamics of software usage in higher education institutions, %.

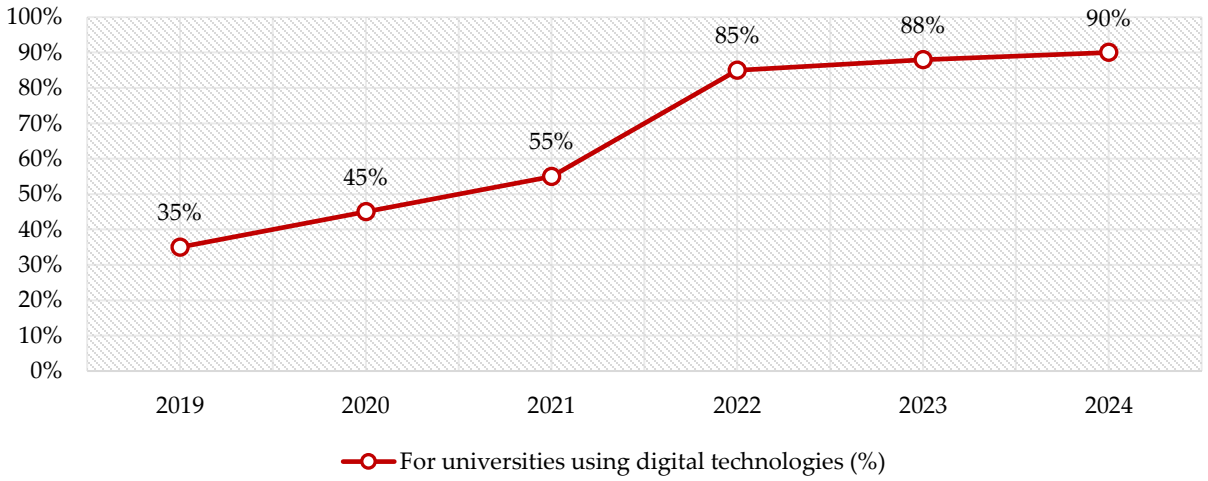
Indicators	2019	2020	2021	2022	2023	2024
Electronic library systems	96,5	97,3	97,8	98,0	98,4	100,1
Electronic legal reference systems	93,3	95,0	95,9	89,7	88,6	100,6
Electronic versions of textbooks on individual subjects or topics	94,0	94,6	95,8	96,1	95,1	100,1
Electronic versions of reference books, encyclopedias, dictionaries, etc.	92,5	93,3	94,4	94,7	93,5	99,7
Educational computer programs for individual subjects or topics, software packages for specialties	90,0	91,6	92,3	91,5	90,4	99,6
Special software tools for solving organizational, managerial and economic tasks (excluding automated document management systems)	87,2	89,5	90,8	95,8	98,5	99,3

Computer testing programs	88,4	89,6	90,1	89,7	88,5	100,4
Internet access content filtering tools	82,4	84,9	87,3	97,2	98,9	100,2
Electronic document management systems	79,4	81,6	84,1	99,8	99,3	100,9
Special software	57,4	59,6	61,1	58,6	96,4	100,1
tools for scientific research	50,9	53,8	56,7	57,8	58,5	99,3

According to the data shown in Table 3, in the period from 2019 to 2024, there is a steady upward trend in the level of use of software tools necessary for the implementation of the educational process in higher education institutions. This dynamic indicates the progressive development of the digital infrastructure of universities and allows us to assert that today the minimum required level of technical equipment has been achieved to ensure the functioning of electronic forms of education. Nevertheless, in the context of the deepening digital transformation of the higher education system, a fundamentally important question arises: to what extent is the existing material and technical base of universities capable of providing high-quality and full-scale education that meets the promising requirements caused by changes in economics, science and technology. Thus, the key direction for further transformations is not only the expansion of access to digital tools, but also the modernization of infrastructure, taking into account future challenges and objectives of educational policy [6, 35].

The experience gained in the context of the pandemic has shown that the available technical equipment of universities has proved insufficient for full-fledged distance learning. In 2020, with the forced transition to an online format, only a few leading universities were able to ensure stable teaching in all disciplines. The pandemic accelerated the processes of digital transformation and simultaneously revealed systemic problems, both at the management level and at the level of the educational process organization. There is an urgent need for new approaches to the functioning of universities and the formation of digital competencies among faculty and specialists capable of training personnel for the digital economy [17, 18].

In the period from 2019 to 2024, there has been a steady increase in the level of digitalization in higher education institutions in Kazakhstan. Data from the Ministry of Science and Higher Education of the Republic of Kazakhstan indicate a significant increase in the share of universities using digital educational platforms, learning management systems (LMS), electronic libraries and other digital resources (Figure 5) [35].



Source: Ministry of Science and Higher Education of the Republic of Kazakhstan [35].

FIGURE 5. The share of universities using digital technologies (%).

In recent years, Kazakhstan has been making significant efforts to digitalize the education system. One of the most important steps along this path was the creation and development of a digital infrastructure that should provide access to educational materials, effective interaction between students and teachers, and improve the quality of the educational process (Table 4) [20, 35].

Table 4. Distribution of universities in Kazakhstan by availability of digital educational platforms (2024).

Universities	Availability of a digital educational platform	Type of platform (LMS)	Number of students	Region
University of Almaty	yes	Moodle, Blackboard	15,000	South Kazakhstan
University of Astana	Yes	Moodle, Google Classroom	18,000	Central Kazakhstan
Shymkent University	No	Moodle	8,000	South Kazakhstan
Atyrau University	Yes	-	6,000	Western Kazakhstan
Pavlodar University	Partly	Moodle	5,000	East Kazakhstan
Kostanay University	Availability of a digital educational platform	Google Classroom	3,000	Northern Kazakhstan

The table shows that most universities in large cities, such as Almaty and Astana, use full-fledged online learning platforms, while some universities in remote regions have limited or no access to such platforms. Table 5 shows the percentage of students who have access to high-speed Internet in the regions of Kazakhstan. It can be seen that in large cities such as Almaty and Astana, more than 90% of students have access to high-quality Internet services. At the same time, in some regions, such as Atyrau and Kostanay, the percentage of students with access to high-speed Internet is significantly lower. This points to the existing digital divide, where students from remote regions face restrictions in accessing online educational resources [7, 35].

Table 5. Percentage of students with access to high-speed Internet by regions of Kazakhstan (2024).

Region	% of students with high-speed internet access	Total number of students (in thousands)	Notes
Almaty	92%	50	High level of connectivity
Astana	89%	45	Good infrastructure
Shymkent	75%	25	Problems with access in remote areas
Atyrau	60%	20	Low access in rural areas
Pavlodar	80%	15	Partially developed infrastructure
Kostanay	65%	10	Problems with the Internet in the northern regions

According to the table, regions with high population density and developed infrastructure, such as Almaty and Astana, have better access to Internet services. In remote regions such as Atyrau and Kostanay, problems with access to high-speed Internet remain relevant, which limits opportunities for digital learning. In 2024, there were 157,106 teachers in higher and postgraduate education institutions in Kazakhstan, and also 37,391 graduates. At the same time, according to the National Collection of Education Statistics of Kazakhstan, about 70% of the country's universities have implemented their own electronic educational environments, providing access to digital platforms, online courses and multimedia educational materials (Table 6) [35, 38].

Table 6. Digital technology infrastructure in universities in Kazakhstan (2024).

Indicator	Meaning
Number of teachers	157 106
Number of graduates	37 391
For universities with their own electronic educational environments (%)	70%

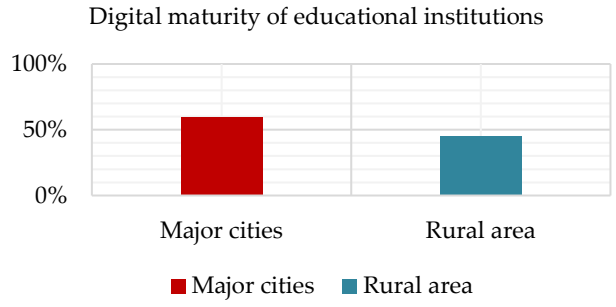
In 2024, the Ministry of Science and Higher Education of the Republic of Kazakhstan introduced the Unified Higher Education Platform (EHEA), designed to collect, analyze and share data on students, teaching staff and educational programs. The platform provides wide access to digital services, including online application of documents, university enrollment, registration of dormitories and scholarships, which makes the higher education system more accessible and transparent [35].

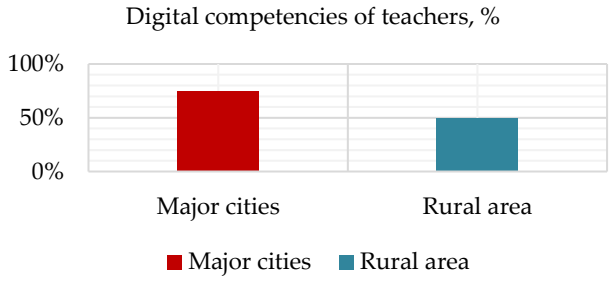
Table 7. Functions of the Unified Higher Education Platform (EHEA).

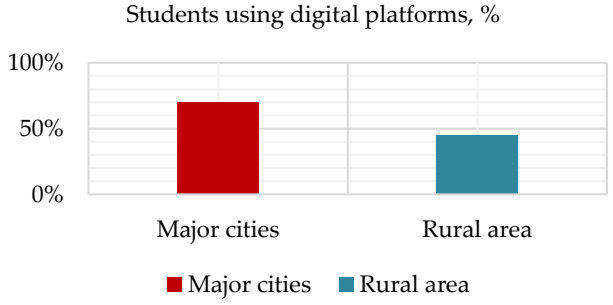
Functions	Description
Online data collection and analysis	Systematization of information about students, teachers and educational programs
-submission of documents	The possibility of applying for admission, registration of dormitories and scholarships
Transparency of processes	Ensuring openness and accessibility of educational services

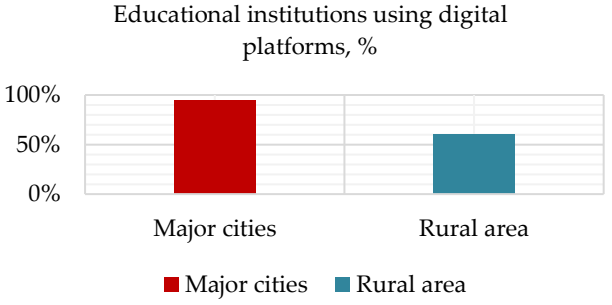
V. RESULTS

The analysis of the effectiveness of the use of digital technologies in educational institutions can be carried out based on the following statistical indicators: [7, 35]









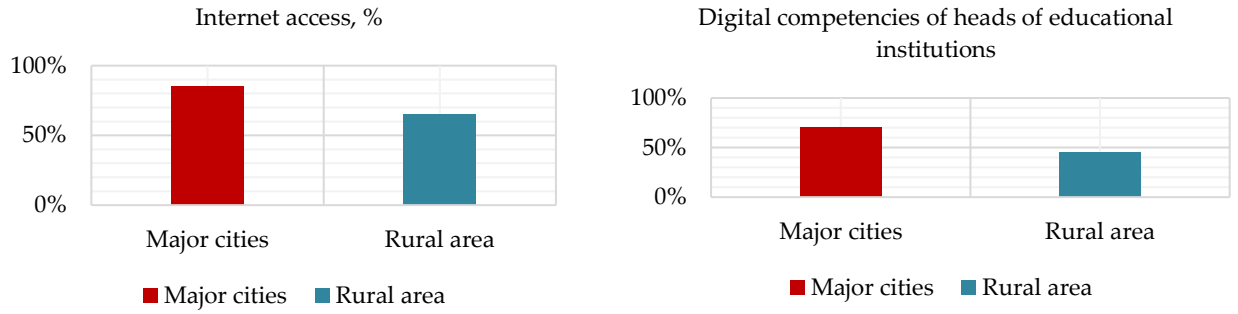


FIGURE 6. Urban-rural comparison of key digitalization indicators in educational institutions (%).

- Percentage of students using digital resources: data show that in 2024, about 70% of students in urban areas are actively using online courses and educational platforms, while in rural areas this figure is only 45%. This indicates a high demand for digital education, but also the existing barriers in ensuring equal access to educational technologies [7, 35].
- Assessment of the effectiveness of online education: according to the results of surveys among students and teachers, about 80% of students studying online consider it convenient and accessible, however, 60% of teachers note that the quality of teaching in distance learning remains lower compared to traditional education [7, 35].
- Percentage of educational institutions using electronic textbooks and platforms: according to data, in 2024, about 85% of universities and colleges in Kazakhstan started using electronic textbooks and online courses, but at the secondary school level this figure is only 50-55% [7, 35].

3. Factors affecting the effectiveness of digitalization

Statistical analysis of the factors influencing the effectiveness of the digital transformation of education may include: [2, 6]

- The level of digital maturity of educational institutions: according to a survey of heads of educational institutions, about 60% of institutions in large cities have a high or medium degree of digital maturity, while in rural areas this figure does not exceed 40% (Tab. 8) [2, 35].

Regional disparities in digital maturity and the adoption of online learning platforms are closely linked to differences in infrastructure, institutional capacity, and policy implementation. Urban regions generally benefit from higher-speed internet, better-equipped facilities, and more digitally competent staff, whereas rural areas often face connectivity challenges, limited access to educational technologies, and lower levels of institutional support. Variations in regional policy priorities and funding allocations further contribute to differences in the pace and effectiveness of digital transformation. Linking these disparities to specific contextual factors provides explanatory insights beyond descriptive statistics, helping to identify targeted strategies for improving digital adoption across all regions [7, 35].

Table 8. Digital maturity of universities in Kazakhstan by region (2024).

Region	High maturity, % of HEIs	Medium maturity, % of HEIs	Low maturity, % of HEIs
Almaty region	64%	28%	8%
Astana region	61%	30%	9%
Southern (Shymkent)	48%	37%	15%
Western (Atyrau, Aktobe)	41%	42%	17%

Northern Pavlodar)	(Kostanay,	38%	40%	22%

Source: Survey data, National Education Statistics, 2024 [35].

To assess the independent and combined effects of key factors on digital maturity, a multivariate modeling approach was applied. Digital maturity of educational institutions was treated as the dependent variable, while strategy implementation, leadership competence, financing, and analytics capability were considered as independent variables. Multiple regression analysis and structural equation modeling (SEM) were employed to evaluate both the unique contribution of each factor and their joint effects. This approach provides a comprehensive understanding of how these organizational and managerial factors influence digital maturity, moving beyond simple pairwise correlations [33].

Table 8 highlights pronounced regional differences in the level of digital maturity of universities. Institutions in Almaty and Astana demonstrate the highest proportion of "high-maturity" profiles (above 60%), while universities in the Northern and Western regions show higher shares of "low-maturity" status (17–22%). These disparities emphasize the need for targeted regional investment programs to bridge the digital divide and ensure equitable access to advanced learning technologies across the country [7, 35].

- Digital competencies of heads of educational institutions: in 2023, about 70% of managers in large cities have the necessary skills to manage digital transformation, while in rural areas only 45% [14, 35].

Investing in digital infrastructure: According to the Ministry of Education and Science of the Republic of Kazakhstan, in 2024, about 20 billion tenge was allocated for the modernization of digital infrastructure in education, of which 75% was allocated to large cities and universities, leaving a smaller share for rural schools and educational institutions (Table9) [35].

Table 9. Share of teachers with certified digital competence training (%).

Year	Urban HEIs	Rural HEIs
2022	52%	29%
2023	64%	37%
2024	75%	48%

Source: National Collection of Education Statistics of Kazakhstan, 2024 **[35]**.

As shown in Table 9, the share of teachers who have completed certified digital-competence training has grown steadily in both urban and rural higher-education institutions. From 2022 to 2024, urban universities improved their share from 52 % to 75 %, while rural institutions rose from 29 % to 48 %. Although the progress is evident, the persistent rural-urban gap points to an urgent need for continuous professional-development programs and incentives to upskill teachers outside major cities [35].

The presented statistics show both achievements and challenges in the process of digitalization of education in Kazakhstan. The main problems remain the uneven distribution of digital resources and differences in the level of digital competencies between urban and rural areas. Overcoming these barriers requires a strategic approach, including additional investments in infrastructure, training, and developing the digital maturity of educational institutions (Tab. 10) [6, 7, 35].

Table 10. Adoption of LMS platforms by universities worldwide (%).

Country/Region	2022	2023	2024
Kazakhstan	78%	86%	92%
EU (average)	79%	81%	83%
USA	90%	91%	92%
Asia (average)	73%	78%	80%

Source: OECD Education Digital Outlook 2024; Ministry of Science and Higher Education of Kazakhstan, 2024 [6, 35].

According to Table 10, Kazakhstan has significantly narrowed the gap with leading regions in LMS adoption. By 2024, the national LMS coverage reached 92 %, which is almost on par with the USA (92 %) and ahead of the EU average (83 %). This convergence signals not only the success of government investment policies but also the readiness of local universities to align with international digital-learning standards. Further, the study is based on a mixed-method approach: quantitative (questionnaire) and qualitative (expert interview), which allows a comprehensive assessment of the level of digital maturity of educational institutions and management practices in the context of digitalization. Sample: The study was conducted in 2024 based on educational institutions: 120 school principals; 80 college heads; 50 university administrators. General sample: 250 respondents [6, 29, 35].

Table 11. The level of implementation of digital tools in management (in % of the total number of respondents).

A digital tool	School	Colleges	Universities	Average
Electronic Document Management Systems (EDI)	58%	72%	95%	75%
Educational Platforms (LMS)	45%	67%	92%	68%
HRM systems	28%	41%	76%	48%
, Analytical dashboards and BI systems	15%	29%	61%	35%
Using cloud services	36%	54%	87%	59%

Based on the collected data, it can be concluded that the digital transformation in the management system of educational institutions is uneven. The implementation of digital solutions is most often limited to document management automation and the introduction of distance learning platforms, while analytical and strategic tools are rarely used. Only 27% of the surveyed managers noted the existence of a formalized digital strategy, including KPIs, a digital development plan and ICT budgeting. Other institutions implement digital initiatives sporadically, depending on external funding or employee initiatives. Only 22% of the respondents indicated that they had completed advanced training courses focused on digital management. At the same time, 41% noted a lack of competencies in the field of analytics, digital transformation and change management [2, 6, 14].

Table 12. The main barriers to digitalization of management in education (% of respondents).

Barrier	School	Colleges	Universities	Average
Lack of funding	65%	59%	42%	55%
Lack of qualified HR specialists	49%	53%	37%	46%
Staff resistance to change	38%	41%	34%	38%
Lack of digital strategy and methodological support	61%	57%	29%	49%
Insufficient digital competence of the management	52%	48%	24%	41%

The bar chart in the figure shows three categories. It can be seen that most institutions are at an average level of digital maturity, characterized by partial implementation of digital solutions without a systematic approach [2].

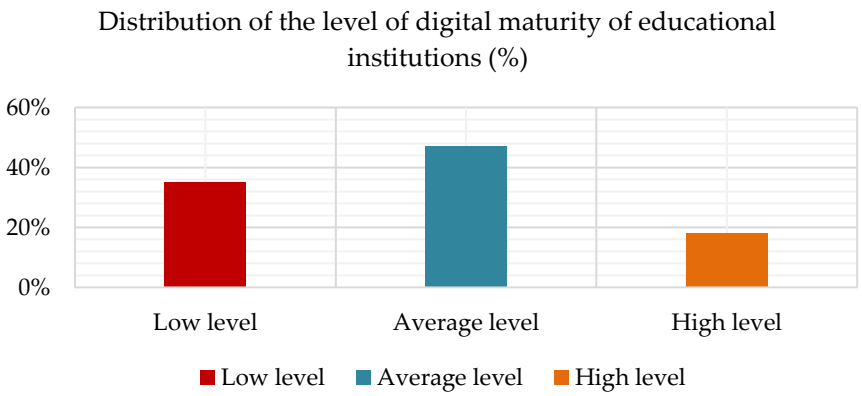


FIGURE 7. Distribution of educational institutions by digital maturity level (%).

Digitalization of education management involves a number of systemic challenges: [1, 6]

- Organizational barriers: Most educational institutions operate within outdated organizational structures where the decision-making process is centralized and not flexible. The lack of a project-based and network-based approach reduces the speed of response to digital changes [1, 2].
- Technological limitations: Limited resources, outdated OT systems, poor technical support - all this hinders the integration of modern solutions. This problem is particularly acute in rural schools and colleges [7, 20].
- Staff shortages and competence gaps: Not only teachers, but also administrative staff are experiencing a shortage of digital competencies, including in the field of working with analytics, management platforms and digital document management [6, 14].

A number of Kazakhstani schools have introduced digital performance monitoring panels, electronic schedules, and platforms for interaction with parents and government authorities. However, success depends on the initiative of the manager and the local IT resource [20, 35].

Elements of an effective digital management strategy [1, 2]

Table 13. Elements of an effective digital management strategy.

An element of strategy	Implementation examples
Digital leadership	Appointment of a CIO or OT coordinator
Management personnel training	Advanced training courses in EdTech
Developing a digital roadmap	Enabling KPIs and digitalization stages
Implementation of data management platforms	Using BI systems and analytical panels
Formation of digital culture	Staff involvement in digital initiatives

The results of the survey and interviews show a clear link between the level of digital maturity of the institution and the characteristics of management practice. More "digitally mature" institutions have: a clear digitalization strategy; an IT support team; regular process analysis; and high management engagement. For a deeper assessment of the interrelationships between the variables of digital transformation in the management of educational organizations, the Pearson pair correlation method was applied. The analysis was conducted on a sample of 250 respondents from schools, colleges and universities in Kazakhstan [39].

Table 14. Variables used in the correlation analysis.

Designation	Variable
X1	Having a formalized digital strategy
X2	The level of digital competence of the manager

X3	Number of implemented digital solutions
X4	Availability of analytical panels and BI-tools
X5	The level of financing of ICT areas
X6	The level of digital maturity of the institution (score on a scale 1-5)

The strongest relationship is observed between the number of implemented digital solutions and the level of digital maturity of the organization (r = 0.72), which confirms the direct dependence of maturity on the degree of technological equipment. A significant correlation between the level of competence of a manager and the number of digital solutions (r = 0.71) underlines the importance of a managerial resource. The correlation between the availability of strategy (X1) and other variables (especially BI-tools - r = 0.62) indicates the system-forming role of strategic planning. Financing (X5) has a moderate but steady impact on all other parameters. It has a particularly noticeable effect on digital maturity (r = 0.59) and on the availability of a strategy (r = 0.53), which indicates the dependence of successful transformation on resource provision. The high correlation between the availability of analytical tools (X4) and other digital parameters highlights the importance of digital analytics in management [2, 4, 39].

Table 15. Pearson correlation matrix for digital-transformation variables.

Variables	X1	X2	X3	X4	X5	X6
X1 (strategy)	1.00	0.58	0.67	0.62	0.53	0.65
X2 (competence)	0.58	1.00	0.71	0.60	0.45	0.63
X3 (solutions)	0.67	0.71	1.00	0.76	0.49	0.72
X4 (analytics)	0.62	0.60	0.76	1.00	0.51	0.69
X5 (financing)	0.53	0.45	0.49	0.51	1.00	0.59
X6 (maturity)	0.65	0.63	0.72	0.69	0.59	1.00

Correlation analysis has demonstrated the existence of stable relationships between management strategies, digital competencies, financing, and digitalization outcomes. This suggests that a successful digital transformation of management is possible only with the simultaneous development of strategic planning, leadership, technological base and competence capital [1, 2, 4].

Based on the correlation analysis, it can be argued that: [1, 2]

- Digital transformation is impossible without strategic leadership and competent management staff [6, 14].
- Financing and the availability of IT specialists are important, but not exceptional success factors: without a digital culture and willingness to change, even well-off institutions perform poorly [2, 4].
- Support for analytical solutions (BI, monitoring, KPI) is becoming a new standard in management, ensuring transparency and efficiency [6, 16].
- Thus, these studies confirm the hypothesis about the influence of organizational and behavioral factors (not just technical ones) on the effectiveness of digitalization [1, 2].
- Practical implications [6, 7]
- Managers need to form long-term digital strategies integrated into the overall development plans of institutions [1, 6].
- Government agencies should strengthen investments in training managers in the field of digital technologies [6, 14].
- Universities and colleges are recommended to include modules on digital management in professional development programs [6, 14].

The proposed typology of management models was empirically informed by the analysis of survey data collected from 250 educational institutions. The identified models were differentiated based on observable variations in digital maturity, leadership competencies, and the use of data-driven decision-making tools. Although the study does not classify institutions into rigid categories, the empirical findings provide

evidence of distinct patterns of management practices that correspond to the conceptual model developed in this research [1, 2, 4].

VI. CONCLUSION

The digital transformation of the higher education system in the Republic of Kazakhstan is an integral part of the global transition to a knowledge economy, which is based on the formation of sustainable digital ecosystems and digital competencies of a new generation. The analysis of statistical data, regulatory initiatives and infrastructural solutions indicates the increasing nature of digitalization of higher education, starting in 2019. The epidemiological crisis of 2020 acted as an exogenous shock that accelerated the process of digital transformation and revealed both systemic deficits and potential growth points in the organization of educational activities [17, 20, 35].

Empirical data show that by 2024, more than 90% of Kazakhstani universities have implemented digital educational platforms and started using Learning Management Systems (LMS) in regular practice. However, with the quantitative saturation of digital tools, there remains a structural asymmetry in the levels of digital maturity between regions, types of universities and profiles of educational programs. This indicates the need to build a unified digital development strategy with an emphasis on equalizing the availability of digital infrastructure and ensuring equal opportunities for digital learning. The scientific contribution of the study lies in bridging the gap between conceptual debates on digital transformation and practical management approaches by providing a statistically grounded typology of models and demonstrating their association with managerial competencies and institutional strategy. These findings expand the empirical evidence base for developing national and regional policies that ensure balanced and inclusive digital transformation of education [6, 7, 35].

The key challenge remains the problem of insufficient training of the teaching staff for the effective implementation of digital educational models. The current practice of professional development in the field of digital pedagogy is fragmented and project-based, while the current stage requires the institutionalization of continuous development of digital competencies. In addition, the introduction of digital solutions is not adequately accompanied by the transformation of management models in universities themselves, where digitalization is often limited only to technical modernization without rethinking the substantive, methodological and organizational foundations of the educational process [6, 14].

Special attention should be paid to the implementation of the Unified Higher Education Platform (EHEA), which is designed to integrate disparate digital initiatives and ensure end-to-end digital connectivity between universities, government agencies and students. However, the effectiveness of this tool in the long term will be determined not only by its technological characteristics, but also by the level of readiness of subjects of the educational space to move from the formal use of digital tools to their meaningful integration into educational, scientific and administrative processes [6, 35].

The correlation analysis revealed statistically significant relationships between the key variables determining the success of the digitalization of the education system in the digital economy. The results obtained indicate that there is a stable positive correlation between the level of Internet access in the regions and the degree of use of online educational platforms ($r = 0.65$), which indicates the critical role of infrastructural support in the process of digital transformation of education [7, 35].

An even more pronounced positive relationship is observed between the level of digital competencies of teaching staff and the success of digital initiatives in educational institutions ($r = 0.78$). This finding indicates a strong association between staff digital competencies and the implementation of digital educational solutions. However, given the correlational nature of the analysis, the results indicate association rather than causality.

The results of the correlation analysis substantiate the need for an integrated approach to the digitalization of education, including not only the development of technical infrastructure, but also the systematic training of teachers. Thus, the digitalization of higher education in Kazakhstan is at the stage of transition from quantitative growth to qualitative transformation, where the priority is not so much

technological equipment as the formation of a new educational paradigm focused on flexibility, personalization, adaptability and openness. To achieve sustainable results, an integrated approach is needed, including: strategic planning, institutional support for digital reforms, the development of digital pedagogical competencies, monitoring of digital inequality, and the systemic integration of digital practices into educational policy at the national level [7, 14].

From a theoretical perspective, the findings suggest that digital transformation in higher education can be understood as a multi-level governance process shaped by the interaction of digital maturity, leadership capacity, and data-driven decision-making. The proposed typology integrates these dimensions into a coherent analytical structure, demonstrating that differences in management models are not merely technological variations but reflect underlying institutional and organizational logics. This contributes to theory-building by linking fragmented descriptions of digital transformation into an integrated framework of educational governance in the digital era [1, 2, 4, 5].

Building on these findings, the study advances knowledge on digital transformation in higher education by providing a statistically grounded typology of management models that integrates strategy, leadership competence, financing, and analytics. Unlike existing digital maturity and governance frameworks, this research combines longitudinal national data, regional disparity analysis, international benchmarking, objective performance indicators, and pilot implementations, while controlling for institutional and contextual confounding factors. The resulting framework offers actionable guidance for institutional leaders and policy-makers by linking managerial decisions to empirically observed patterns of digital transformation across institutions [1, 2, 6].

From an international perspective, the study contributes to the broader literature on digital transformation in education by extending existing digital maturity and governance frameworks, which are predominantly developed in Western and OECD contexts, to an emerging economy setting. While prior research has largely focused on technological adoption or institutional readiness in isolation, this study integrates multiple dimensions digital maturity, leadership competence, financing mechanisms, and analytics adoption into a unified typology of management models. This approach enhances theoretical understanding by demonstrating how digital transformation is shaped by context-sensitive combinations of organizational and technological factors, thereby offering a more comprehensive framework applicable across diverse educational systems [1, 6, 7].

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Author contribution

All authors have read and agreed to the published version of the manuscript. All authors made an equal contribution to the development and planning of the study.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data is available from the authors upon request.

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