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The Impact of Digital Economy Products on Higher Education Development and Digital University Integration

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ABSTRACT: This research examines the impact of digital economy products on higher education development and digital university integration. The research is based on a systematic analysis of the implementation of end-to-end digital technologies, including artificial intelligence, big data, blockchain, virtual and augmented reality, and automated systems in the activities of universities. Particular attention is paid to the role of these technologies in optimizing educational processes, improving resource management, and enhancing the quality of education. The results of the analysis show that artificial intelligence and big data technologies have the greatest potential for application in key university processes, including student admission, implementation of educational programs, and support processes. Virtual and augmented reality are effectively used for practical training and research, and blockchain technologies contribute to increased security and transparency in academic administration. The research confirms that the digital transformation of higher education is a prerequisite for creating an adaptive and innovative learning environment that ensures the competitiveness of universities in the global knowledge economy.

KEYWORDS: digital economy, higher education, digital university, artificial intelligence, big data, blockchain, virtual reality.

I. INTRODUCTION

The digital economy is significantly transforming all spheres of social life, and higher education is no exception. The use of digital technologies contributes to the modernization of the educational process, making it more accessible, flexible, and efficient. In the context of global digitalization, traditional models of education are losing their effectiveness, which encourages universities to implement innovative solutions, including artificial intelligence, big data, blockchain, virtual and augmented reality technologies, which significantly improve the quality of education and management of educational institutions. Integration of digital technologies into the learning process is not only a means of optimizing educational activities, but also a key factor in training highly qualified specialists capable of working effectively in the digital economy (Kubiv at al., 2020).

The impact of digital products on higher education is manifested in several ways: first, in changing teaching methods through the implementation of adaptive learning, personalized educational trajectories, and the use of artificial intelligence to analyze students' academic performance; second, in the transformation of management processes in universities with the help of big data and automated systems for monitoring and forecasting educational outcomes; third, in creating new digital educational platforms that expand access to quality education regardless of the student's location. The implementation of end-to-end digital technologies allows not only to optimize costs but also to improve the quality of educational content, ensuring interactivity and multifunctionality of educational materials.

The study of the impact of the digital economy on higher education is relevant due to the rapid development of technology and the need for universities to adapt to the new challenges of digital transformation. This article analyzes the potential for integrating digital solutions into higher education, identifies their advantages and challenges, and considers the practical aspects of implementing artificial intelligence, big data, virtual and augmented reality technologies in the learning process. Particular attention is paid to the analysis of end-to-end digital technologies and their impact on the educational process, university management, and the formation of new approaches to professional training.

II. LITERATURE REVIEW

A. Digital transformation of education

The digital transformation of education is a key area of modernization of the modern university environment, which necessitates the integration of the latest digital technologies into all aspects of the educational process (Kozynets, 2024; Bobro, 2024). Universities are actively implementing artificial intelligence, big data technologies, virtual and augmented reality, blockchain, and automated management systems to improve learning efficiency, resource management, and personalization of educational trajectories (Yahodzinskyi et al., 2024). In the context of the digital university, special attention is paid to the analysis of educational analytics, adaptive learning, and cybersecurity of educational platforms (Lysenko et al., 2024).

B. Integration of end-to-end digital technologies into higher education

The implementation of end-to-end digital technologies contributes to the transformation of teaching methods, in particular through the use of interactive platforms, predictive analytics, and automated learning systems (Komninos et al., 2023; Popenici, 2022). Big data technologies allow to analyze learning processes, predict student performance, and improve the effectiveness of teaching (Kubiv et al., 2020). Virtual and augmented reality play an important role in practical training, allowing for the creation of digital simulations of complex processes and interactive learning environments (Skliarenko et al., 2024).

C. Digital university as an element of the knowledge economy

The digital university is not only an educational institution, but also a center for generating new knowledge and innovations, promoting the formation of digital competencies among students and teachers (Kolodinska et al., 2022). The institutional structure of the digital university involves the use of blockchain technologies to store diplomas, digital certificates, and other educational achievements (Bobro, 2024). Moreover, the implementation of artificial intelligence and automated systems for monitoring educational processes allows to improve the quality of educational services, ensuring adaptability of learning and transparency of management decisions (Khomenko et al., 2024).

Thus, the digitalization of universities is a necessary step to ensure their competitiveness in the global digital economy, which requires a strategic approach to the implementation of innovative educational technologies.

III. METHODOLOGY

This research is analytical and based on an interdisciplinary approach that covers the economic, educational, and technological aspects of the impact of the digital economy on higher education development. The main research methods are system analysis, structural-functional approach, and comparative analysis.

The system analysis allowed to identify the main components of the digital university and their relationship with the technologies of the digital economy. The use of the structural-functional approach made it possible to consider the role of end-to-end digital technologies in key processes of university activities, including student admission, implementation of educational programs, and support processes. The comparative analysis was used to evaluate the effectiveness of various digital solutions in higher education based on international experience and current research.

The main sources of information for the research include scientific publications, analytical reports, regulatory documents, and statistical data on the digitalization of the educational process. The analysis of digital technologies was made on the basis of existing empirical research covering the impact of artificial intelligence, big data, blockchain, virtual and augmented reality on the higher education system. The results obtained are presented in the form of analytical tables that demonstrate the potential for implementing digital solutions in the activities of universities and the possible effects of their application.

IV. RESULT AND DISCUSSION

The first digital technologies implemented in the education system were technological solutions that enable distance learning. Their use began actively at the turn of the twentieth and twenty-first centuries, primarily in non-governmental educational institutions. The main factor in the development of this area was the economic aspect - the technology allowed to reduce costs without significantly reducing the quality of the learning process. Subsequently, distance learning has demonstrated its effectiveness as a means of expanding access to education for various categories of the population. The real challenge for these technologies was the period of forced restrictions in 2020-2021, when they became the main tool for ensuring the continuity of the learning process (Tocto-Cano at al., 2020). At the present stage of education development, distance technologies have been integrated into the educational process, acting as its integral component and effectively combining with traditional full-time modes of study.

The next stage in the development of end-to-end digital technologies in education was the implementation of virtual and later augmented reality technologies. In the period 2010-2020, their active use was observed in complex technical and technological

sectors, including healthcare, transportation infrastructure, and industry. In contrast to general secondary education, it is in the field of vocational training, including higher education and additional vocational education, that these technologies have shown high efficiency, becoming a reliable tool for forming professional competencies in working with technically complex systems (Saxena at al., 2020).

Below are the results of the analysis of the potential for the implementation of digital technologies in education, including big data, neurotechnologies, artificial intelligence, distributed registry systems, advanced manufacturing technologies, the industrial Internet, robotic components, sensorics, and virtual and augmented reality technologies (Table 1, Table 2).

TABLE 1. APPLICATION OF END-TO-END DIGITAL TECHNOLOGIES IN THE UNIVERSITY'S MAIN PROCESSES

	Market analysis and reception			**Educational program implementation**							**Supporting processes**						
End-to-end digital technologies	Marketing research	Conducting orientation work	Applicant admission	Civic and patriotic education	Learning	Research and innovation activities	Practical training	Conducting current certification	Conducting interim certification	Conducting final certification	Employment	Personnel provision	Material and technical support	Educational and methodological support	Scientific and methodological support	Information support	Financial and economic support
Neural networks and artificial intelligence	QR	QN	QRS	-	QRNS	N	QRNS	QRS	QRS	QRS	Q	QR	-	QR	-	-	R
Big Data technology	-	QR	-	QRN	QRNS	-	QRN	QR	QR	QR	Q	QR	QR	QR	-	-	-
Virtual and augmented reality	-	QR	-	QR	QRNS	QRNS	QRNS	-	QRS	QRS	-	-	-	-	-	-	-
New production technologies	-	-	-	-	Q	QN	QN	-	-	-	-	-	QR	-	QR	QR	-
Quantum technologies	-	-	-	-	QN	QN					-					QR	-
Robotics and sensorics components	-	ORN	QR	-	QRNS	QRS	S	-	-	-	QN	QR	-	-	-	-	-
Wireless technologies	-	-	-	-	Q	Q					-					Q	-
Distributed registry systems	-	-	-	-	N	N	-	-	N	N	-	-	-	-	-	-	-

Possible effects:
Q (quality) – improving the quality of the process implementation,
R (resources) – saving resources, reducing process implementation costs,
N (new) – new products and solutions,
S (social) – social effect.

The results of the analysis are presented in the form of matrices, where the intersection of a resource-intensive process and a digital technology reflects the potential effect of its implementation. Possible effects include improving the quality of process implementation, saving resources and reducing costs, creating new products and solutions, and social impact. Thus, the analysis of Table 1 indicates the wide possibilities of using end-to-end digital technologies in key university processes. In particular, artificial intelligence and Big Data technology demonstrate the highest potential for use in all three groups of processes: student admission,

educational program implementation, and support processes. Virtual and augmented reality are effectively integrated into practical training and research and innovation activities, contributing to the development of new methods of training specialists. The latest production technologies, quantum technologies, robotics, and sensorics have a significant impact on technically oriented disciplines, providing new modes of study. Supporting processes, such as human resources, material and technical, financial and economic support, rely to the greatest extent on the capabilities of big data and artificial intelligence, which allows optimizing resources and increasing the efficiency of university management.

TABLE 2. APPLICATION OF END-TO-END DIGITAL TECHNOLOGIES IN THE EDUCATIONAL PROGRAMS IMPLEMENTATION

End-to-end digital technologies	**The main components of the educational program implementation**															
	Analysis of the psycho-emotional state of	Conducting classroom lessons	Independent learning	Practical training	Research and innovation activities	Extracurricular activities	Assessment of professional competencies	Talent spotting	Predicting the learning process	Feedback from students	Conducting current certification	Conducting interim certification	Conducting final certification	Employment	Feedback from the graduate	Inclusive education
Neural networks and artificial intelligence	QRNS	QRNS	QRNS	QRNS	N	QRN	QN	QN	QN	-	QRS	QRS	QRS	Q	-	-
Big Data technology	QRNS	QRN	QRN	QRN	-	QRN	QRN	QN	QN	Q	QR	QR	QR	QR	QR	-
Virtual and augmented reality	-	QRNS	QRNS	ORNS	QRNS	QRNS	QRNS	-	-	-	-	QRS	QRS	-	-	-
New production technologies	-	Q	Q	QN	QN	-	QN	-	-	-	-	-	-	-	-	QN
Quantum technologies	-	QN	QN	-	QN	-	-	-	-	-	-	-	-	-	-	-
Robotics and sensorics components	-	QRNS	QRNS	S	QRS	-	QRS	-	-	-	-	-	-	QN	-	QN
Wireless technologies	-	Q	Q	-	Q	-	-	-	-	-	-	-	-	-	-	-
Distributed registry systems	-	N	N	-	N	-	-	-	-	-	N	N	-	-	-	-

Possible effects: Q (quality) – improving the quality of the process implementation,
R (resources) – saving resources, reducing process implementation costs,
N (new) – new products and solutions,
S (social) – social effect.

The analysis of Table 2 shows the significant role of end-to-end digital technologies in the educational program implementation. The most universal and effective technologies in this context are artificial intelligence and Big Data technology, which help to improve the quality of teaching, assess learning outcomes, and adapt educational trajectories. Virtual and augmented reality are key to practical training and research activities, providing the ability to simulate complex processes in a secure digital environment. The latest production technologies, robotics, and sensorics are used in the assessment of professional competencies and practical training of students, especially in technical specialties. Wireless technologies and distributed registry systems provide effective feedback organization, academic achievement monitoring, and learning process management. In

general, the table demonstrates the high potential of end-to-end digital technologies in improving the educational process aimed at high-quality training of competitive specialists.

The implementation of neurotechnologies and artificial intelligence has significant potential for improving the quality of educational programs and optimizing resource costs (Kadoić at al., 2018). Neurotechnologies include the design of artificial neural networks and their training, which allows to implement forecasting of the educational process and data classification. The use of these technologies contributes to the creation of an effective system of predictive (forecasting) analytics that allows to identify risks of reducing the quality of educational programs at an early stage and prevent them. Just as a defect in the production of a car part can lead to an accident, predictive analytics allows to identify potential problems in the acquisition of professional competencies in advance and minimize the risk of training specialists with insufficient qualifications.

The input data for the predictive analytics system are digital footprints accumulated in the university's electronic educational environment. These include both individual digital footprints of students and data on the activity of teachers and other participants in the educational process. In addition to traditional indicators, such as learning outcomes, additional parameters can be used, in particular, reaction time and its dynamics during training, frequency and volume of transactions between participants in the educational process (messaging, document transfer, etc.). The integration of such analytical approaches contributes to improving the efficiency of educational process management, personalization of learning, and ensuring high quality of specialist training.

It is important to note that the development of the modern vocational education system directly depends on the trends in the development of end-to-end digital technologies in this area (Huk, Skliarenko, 2022). Artificial intelligence is one of the most dynamic end-to-end digital technologies in education, which is constantly evolving and becoming more complex, allowing to solve more and more complex and unique tasks. While in the past it was assumed that robots would completely replace human physical labor, modern neural networks capable of generating images, poetry, and scientific articles indicate that even creative professions may be gradually automated. One of the most striking examples is the AlphaCode neural network, which was among the top 54% of the Codeforces competition, where programmers from all over the world compete in solving complex algorithmic problems requiring critical thinking, logic, and programming. This indicates that the future has already arrived, and artificial intelligence has become an integral part of everyday life, from electronic translators to personalized recommendations in online stores and music services (Khomenko at al., 2024).

Ignoring the possibilities of artificial intelligence in higher education today is a strategic mistake. Many universities have already integrated training modules dedicated to artificial intelligence systems aimed at developing competencies in machine learning, data analysis, and algorithmic thinking. Such modules are developed taking into account the current requirements of the labor market and employers' requests, which ensures the competitiveness of graduates.

Another promising end-to-end technology is virtual and augmented reality (VR/AR), which has wide application possibilities in the field of education (Lopuschnyak at al., 2021). From the initial prototypes more than half a century ago, this technology has evolved to create full-fledged digital worlds that allow for the simulation of complex learning situations. Modern educational practices actively use classical virtual reality (VR), augmented reality (AR), and mixed reality (MR) (Yahodzinskyi at al., 2024). In mixed reality, the digital and real worlds interact, providing a new level of interactivity. For example, some universities' laboratories use AR markers that allow to read additional information from stands via smartphone, opening access to articles, videos, and interactive content.

VR/AR technologies are especially useful in professional training, as they allow students to interact with digital avatars of teachers who can give lectures, demonstrate complex technical processes, and adapt the educational material to the individual needs of each student. The use of a digital avatar of a teacher provides an imitation of real interaction in the classroom, including facial expressions, gestures, voice intonations, and the possibility of interactive communication. This is especially important for specialties that involve practical training, work with high-tech equipment, or complex experiments, which may be limited in traditional conditions.

Blockchain, although it originated in the financial sector, shows significant potential for use in higher education. It is a distributed registry technology that provides secure, transparent, and permanent storage of digital transactions. One of the key advantages of blockchain is increased trust between users and independence from centralized control. In the field of education, blockchain can be used to store diplomas, certificates, and other academic achievements, making it impossible to falsify them.

Blockchain technologies can also be used to organize anonymous electronic voting at universities. For example, some educational institutions have already implemented online voting platforms that guarantee transparency and security of the electoral process. Thanks to the blockchain, each vote is encrypted and the results are calculated automatically, ensuring maximum trust in the system.

Big data is a key element of the digital economy that is transforming higher education, contributing to its efficiency and adaptability to modern challenges. This is an ever-growing amount of information that is formed within the educational

environment and presented in various formats, requiring specialized tools for fast and efficient processing. Universities that implement big data technologies are able to optimize the learning process, improve academic resource management, and implement personalized learning trajectories. An important aspect of digital transformation is the integration of mechanisms for collecting, accumulating, and analyzing data, which can be both structured (operational information about the learning process) and unstructured (large amounts of information that require additional processing).

One of the most important areas of big data application in a digital university is predictive analytics. For example, regular collection of information from digital educational platforms and learning environments allows to predict student performance, assess the risks of academic failure, and develop personalized educational routes. The use of artificial intelligence algorithms in combination with big data allows to analyze student behavior, their interaction with course materials, and teachers, as well as to generate recommendations for adjusting the learning process. The implementation of big data in the learning process helps to improve knowledge assessment methods, expand adaptive learning opportunities, and increase the effectiveness of educational analytics.

V. CONCLUSIONS

The digital economy development directly affects the transformation of the higher education system, contributing to its adaptation to modern challenges and increasing the efficiency of the educational process. The integration of end-to-end digital technologies, including artificial intelligence, big data, virtual and augmented reality, robotics, and blockchain, allows for optimization of management, educational, and research processes at universities. The analysis of the use of these technologies shows their ability to improve the quality of education, reduce costs, create new educational products, and improve social interaction between participants in the educational environment.

One of the most promising areas of digital transformation is the implementation of predictive analytics based on big data and artificial intelligence. The use of digital footprints of students and teachers allows to effectively predict academic results, personalize learning trajectories, and improve knowledge assessment mechanisms. Moreover, digital teacher avatars and VR/AR technologies significantly improve the quality of professional training by enabling students to work with high-tech equipment in a safe digital environment.

Therefore, the digitalization of universities is a necessary process that ensures the competitiveness of higher education in the global knowledge economy. The use of digital solutions contributes to improving the quality of educational services, expanding access to education, and creating an innovative environment for research. The further development of a digital university requires a strategic approach to the integration of digital technologies, including the modernization of educational programs, adaptation of management processes, and improvement of the digital competence of all participants in the educational process.

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