DOI: https://doi.org/10.30525/978-9934-26-540-2-32

Natalia Bobro
Candidate of Economic Sciences, Doctor of Philosophy,
Director of the Digital Department
Private Higher Education Institution «International European University»;
Director of the «NooLab & AI» Scientific Laboratory of the
Private Higher Education Institution «International European University»

DIGITAL TECHNOLOGIES IN EDUCATION AS A FACTOR OF ECONOMIC DEVELOPMENT

Summary

The article explores the role of digital technologies in education as a factor of economic development, focusing on the concept of digital maturity as a key criterion for assessing the level of digital transformation of the education sector. Introduction of pervasive technologies, including artificial intelligence, big data, virtual and augmented reality, as well as digital avatars in higher education institutions is analysed. Particular attention is paid to the economic effects of digitalisation, in particular, optimisation of educational management, increasing the accessibility and efficiency of educational services. The digital avatar technology as an innovative tool for structuring and optimising educational processes is studied. Its potential for improving management decisions, personalising learning and adapting educational institutions to rapid technological change is considered. The paper analyses international models and methodologies for assessing the digital maturity of education, and substantiates the need to develop specialised approaches that take into account the unique social and economic characteristics of the educational system. The findings contribute to a deeper understanding of digital education as a driving force for economic modernisation, emphasising the role of higher education institutions in shaping innovation potential and training competitive personnel. The publication proves that the successful digital transformation of education will determine not only the competitiveness of universities, but also their ability to achieve long-term economic and social development in the context of Industry 4.0 and 5.0.

Introduction

Digitalization of education is one of the key factors of socio-economic development in the context of global technological change. The integration of digital technologies into the learning process creates new opportunities to increase the accessibility, efficiency, and inclusiveness of educational services, which has a direct impact on economic modernization. At the same time, this process is accompanied by challenges related to ensuring the quality of educational programs, adapting to rapid technological innovations, and the need to form digital competencies in teachers and students.

In the current scientific discourse, the digital transformation of education is viewed through the prism of such concepts as the digital maturity of educational systems, the integration of artificial intelligence into the educational environment, the implementation of digital avatars and personalized learning trajectories. These aspects determine not only the strategic guidelines for the development of educational institutions, but also form the economic efficiency of their activities.

It is important to note that the concept of digital maturity of education, which was originally used mainly in the economic context, is becoming increasingly relevant for the educational sphere. It reflects the level of integration of digital technologies into the learning process, organizational management, and research, which directly affects the competitiveness of educational institutions in the global space.

Despite the active development of digital education, many aspects of its transformation remain insufficiently studied. In particular, the scientific literature fragmentarily covers the issues of the impact of digital technologies on the economic sustainability of educational institutions, the effectiveness of using digital avatars to manage educational processes, and mechanisms for adapting the educational system to the challenges of Industry 4.0 and 5.0.

The aim of this research is to analyze the role of digital technologies in education as a factor of economic development, to determine the level of digital maturity of educational institutions, and to substantiate the key vectors of their digital transformation. The paper also considers the issues of integrating digital avatars into the educational environment, assessing the socio-economic effects of digitalization, and identifying imperatives for regulating digital education.

Thus, the research is aimed at revealing the theoretical and practical aspects of the digital transformation of education, analyzing its impact on economic modernization, and identifying promising areas for the development of the educational system in the context of technological revolutions.

Chapter 1. Digital maturity of education

The digital transformation of education, which is a systemic and irreversible process, requires a conceptual understanding of its essence and development vectors through the prism of methodological analysis of technological revolutions. The institutional specificity of education implies that digital technologies have variable effectiveness depending on their functional purpose and the level of integration into the learning process. Deepening digital modernization of education is accompanied by reformatting the interaction between educational institutions, government agencies, and end users of educational services according to the logic of global technological change [1; 2].

The study of theoretical methodological and practical aspects of the digitalization of education is a subject of interdisciplinary scientific interest, covering both academic and public discourses. One of the key conceptual approaches in the study of digital transformation is the analysis of digital maturity (DM) of education as a criterion for the adaptation and sustainability of educational systems in the context of technological change [3, p. 52].

The DM of education acts as a conceptual focus, a starting point for defining, identifying, and understanding the nature and essence of digital transformations in modern society and the educational environment. The theoretical understanding of the DM of education allows to reduce the whole set of digital issues, challenges, and topics to one key problem: the need to understand and assess the role and place of digital transformation of modern society and education in the context of the general logic of current and future technological revolutions, defined as Industry 4.0 and 5.0.

The concept of digital maturity, which emerged in the course of theoretical discussions about Industry 4.0, initially referred exclusively to the economic and managerial aspects of market economy development. Subsequently, it began to be used in the educational context [4, p. 1223]. The very notion and theoretical concept of DM can play a significant role in determining the key guidelines in the process of finding optimal strategies for the digital transformation of education.

Determining the level, nature, and essence of the DM actually sets the goals, objectives, and stages of education development and its subjects on the path of mass digitalization of the sector. The DM acts as a kind of compass, guided by which educational actors will form their own trajectory towards a certain digital ideal. The success or failure of the entire state strategy of large-scale digitalization of national education depends on the level of the achieved DM.

Having emerged within the framework of the Industry 4.0 concept, the notion and concept of DM will not remain unchanged in the context of the development and transformation of economic modes under the influence of the following technological revolutions. The working hypothesis is based on the belief that each stage of development and formation of digital technologies, starting with Industry 4.0 and subsequent Industries X.0, will have its own image of digital maturity of education.

In the modern scientific discourse, digital technologies are considered as a set of innovative tools, including Big Data technologies, virtual and augmented reality, robotics elements, sensor systems, artificial intelligence, advanced manufacturing technologies, industrial Internet, wireless communications, quantum computing, and distributed ledger systems [5, p. 41]. These technological components determine the parameters and vectors of development of the educational environment in the context of Industry 4.0.

Within the scientific literature, these technologies have been classified as “penetrating” due to their ability to seamlessly integrate into all key areas of socio-economic activity, including education [1; 3]. The impact of these technologies on various sectors is considered through the prism of digitalization, and the level of their adaptation and efficiency is assessed through the concept of digital maturity. The latter, in turn, is interpreted as a systemic indicator that reflects not only the current level of digital development of enterprises and industries, but also their prospective trajectory of digital transformation according to possible scenarios of technological upgrades.

The digitalization of education is attracting the attention of government agencies, which is leading to the development of special programs aimed at stimulating the implementation of digital technologies in various sectors. The main list of digital technologies that play a key role in the digital transformation of industries is defined

in a number of state strategic programs of national development. International digital transformation programs include:

- Industrie 4.0 (Germany) [6];
- Made in China 2025 (China) [7];
- Manufacturing USA (USA) [8].

Certain technologies are also integrated into the national strategies for the development of artificial intelligence in countries such as China, the United States, the European Union, the United Kingdom, Germany, France, etc. [9].

These programs are directly related to the theory and practice of Industry 4.0, aimed at the technological modernization of economic and social systems through digital innovation.

An analysis of the available literature clearly confirms that the digitalization of industries in different countries is occurring with different intensities, which leads to different levels of digital maturity. Despite the widespread use of the term "digital maturity" in applied practice, it still does not have a well-established, generally accepted definition in the scientific discourse. There are different interpretations of it in open sources.

In particular, digital maturity is understood as "a key indicator of the level of a company's digital development", which can be expressed in readiness for management changes, the ability of an enterprise to offer optimized products to customers or effectively provide and control public services. At the same time, E. Tocto-Cano, S. Paz Collado, JL. López-Gonzales, JE. Turro-Chaparro interpret digital maturity as a tool widely used in software development, which has become widespread in such industries as education, healthcare, energy, finance, public administration, and other sectors [10].

International studies of the digital maturity of economic sectors focus on its assessment using conceptual models, in particular, the "digital maturity assessment model" or the methodology for determining priority elements in the digital maturity framework for higher education institutions (DMFHEI). Methods of analyzing the digital maturity of universities are also used, in particular Analytic Network Process (ANP) and Decision EXpert (DEX) [11, p. 109].

It should be noted that most models for assessing the digital maturity of enterprises have been developed by international researchers, and an analysis of the literature of recent years confirms the active use of these methods in the field of IT, manufacturing, small business, telecommunications, and other sectors. Among the well-known approaches are The Digital Maturity Model 4.0 and the Digital Maturity Model (developed by Deloitte) [9]. It is important to note that despite the growing demand for digital maturity assessment results in industrial sectors, the education sector has not yet been sufficiently researched in this regard.

This gap in research necessitates the development of specific methods for assessing the digital maturity of education, taking into account its unique features, including the role of digital technologies in the learning process, management of educational institutions, and organization of research. In our case, the digital maturity of education in the period of Industry 4.0 is defined as an integral characteristic of the implementation process and the use of penetrating technologies in key educational

processes. It reflects the level of adaptation of education to the conditions of digital transformation, the degree of effective use of digital tools, and their impact on the educational ecosystem.

The absolute criterion for achieving the maximum level of digital maturity of education in the context of Industry 4.0 is not only the implementation of individual digital technologies, but also the use of integrator technologies, in particular digital avatars, which provide comprehensive management of educational processes and their synchronization with economic and social demands [12, p. 65]. The following analysis is based on the assumption that each technological mode (starting with Industry 4.0), which creates a number of challenges and expectations for education, corresponds to a certain level of digital maturity of the educational system.

The main challenge of Industry 4.0 is the need for effective implementation and use of penetrating technologies in order to:

- maximum automation and unification of educational and production processes;
- radical reduction of costs for the production of goods and services;
- maximum satisfaction of market demand for high-quality products at the lowest price by digitalizing dangerous and monotonous processes.

Industry 5.0, in turn, is creating a new paradigm focused on harmonizing the interaction between humans and technology. The main challenge of this technological mode is the transition from mass production of standard technologies and goods to their personalization and individualization, which forms new requirements for educational strategies, teaching methods, and professional training.

The digital maturity of education in the future era of Industry 5.0 will be significantly different from the digital maturity of education in the period of Industry 4.0. If earlier the main assessment criteria were the scale of digital technology implementation, standardization, and automation of educational processes, in the new environment, individualization, personalization, and adaptability of educational solutions will become a priority. The education of the future will increasingly focus on creating unique learning trajectories that take into account the personal characteristics, professional interests, and requests of each student.

The focus of digital maturity of education will shift from the number of implemented digital technologies as the main criterion to assessing the mechanisms of their effectiveness in meeting the request of customers and consumers for personalized and individualized educational products and services. Industry 5.0 does not deny or reject the technological achievements of Industry 4.0, but offers a reassessment of value orientations based on the integration of penetrating technologies into educational practice.

Within Industry 4.0, humanistic values of education and individual consumer requests are to some extent inferior to the desire for technological efficiency and the creation of maximally unified educational products at the lowest price. In Industry 5.0, the main criterion for the digital maturity of education will be the compliance of digital technologies with new social value orientations that provide for the formation of education with a “human face”.

A unified educational product, no matter how high-quality, affordable, and technologically efficient, will eventually lose mass appeal in the global education

market. In the context of revolutionary changes in the value and goal orientations of Industry 5.0, demand will shift to unique educational solutions that meet the requests of each individual and society as a whole.

Thus, the immanent characteristics of the technological revolutions that form Industries 4.0 and 5.0 determine a fundamental difference in the interpretation of the digital maturity of education in these ages. Within the framework of modern Industry 4.0, digital maturity of education is defined primarily as *a characteristic of the implementation processes and effective use of digital technologies, which is expressed by their penetration and relevance of integration into the educational environment. Instead, in the context of the future Industry 5.0, the digital maturity of education is gaining importance as a comprehensive indicator that reflects the scale and depth of digital technology integration based on customized and personalized approaches to educational processes.*

Chapter 2. Digital avatar in the educational environment

One of the most striking markers of the new educational reality is the digital avatar (DA) technology, which is gradually gaining more autonomy and sustainability in various fields. At the same time, a unified and unambiguous understanding of the essence of this concept in social and technological environments has not yet been formed in scientific discourse.

The most general and practically generally accepted definition of a digital avatar in the engineering and technological context is formulated as a set of mathematical models and algorithms that describe a certain object. Although the application of the digital avatar concept in social systems is more complex and ambiguous, such avatars of various physical objects have long been successfully integrated into the engineering and management practices of Industry 4.0.

It is worth noting that in 2011, when the concept of Industry 4.0 was first introduced in Germany, German experts formulated its basic principles:

Compatibility is the ability of different devices, sensors, and people to interact with each other via the Internet of Things (IoT):

– Transparency is the result of such interaction, when digital copies of real objects, systems, and processes are created in the virtual environment, accurately reproducing all changes in their physical analogs. Due to this, complete information about the functioning of equipment, “smart” products, production systems, etc. is accumulated.

– Technical support is the use of computer systems to help people make decisions by collecting, analyzing, and visualizing all data related to the functioning of digital avatars.

– Decentralization of management decisions is a transfer of some management functions to cyber-physical systems to increase the efficiency and flexibility of production and educational processes.

It is generally accepted that the concept of a “digital avatar” was introduced into scientific circulation by Dr. M. Grieves of the Florida Institute of Technology (USA) in collaboration with NASA expert J. Vickers [11, p. 110]. According to M. Grieves, the conceptual model of a digital avatar includes three main components:

– physical objects in real space;
– their digital analogs in the virtual environment;
– data and information flows that provide interconnection between physical and virtual objects.

With the growing integration of this technology into the industrial sphere, many interpretations of it have emerged and continue to expand. Without going into a detailed analysis of all the variations, it is worth noting that in a general sense, *a digital avatar means a technology for creating a virtual copy of an object or process for its research and optimization*.

Leaving aside the analysis of the specifics of this technology's application in industry, the main focus is on its prospects and social effects in the context of education. The analysis of existing international and national research allowed to outline the key thematic areas and problematic aspects of the implementation of digital avatars in the educational environment.

The number of references to digital avatar technology in education in international sources, compared to industry, remains relatively small. For example, researcher S. Yahodzinskyi considers the use of digital avatars in distance learning in the field of architecture, noting that this technology is part of a "set of five new digital technologies that use virtual and augmented reality" and opens up new opportunities for learning [13, p. 77].

In turn, A. Kozynets and V. Shpylyova, analyzing the implementation of digital avatars in engineering education, note that the integration of this technology into the educational process can contribute to the dissemination of new knowledge among students, teachers, and business representatives, as well as increase motivation to learn [14, p. 217].

It should be emphasized that most publications devoted to digital avatars in education and indexed in the WOS international citation database are mostly dated to 2024, and the earliest recorded research is dated only to 2018. This is probably due not so much to the lack of demand for this technology in the educational environment as to the lack of obviousness of the existing experience of its implementation. As a result, there is still little research devoted to digital avatars in education.

The key aspect of using digital avatar technology in education is that it is not aimed at reducing or leveling human potential in the learning process. Concerns that digital technologies could completely replace teachers and traditional teaching methods are one of the main obstacles to the implementation of promising digitalization initiatives, particularly in education.

Recently, scientific journals have begun to publish articles on the use of digital avatars in education. However, most of them focus not so much on a comprehensive analysis of the advantages and disadvantages of this technology in the educational environment as on general considerations of the usefulness of the educational process digitalization as such.

In the literature, there are interpretations of a digital avatar as a "digital educational environment of higher education institutions" [15] or "high-quality digital space of the university" [16], which, in fact, does not explain the essence of this technology. Some researchers use a similar concept of "virtual avatar," which is understood as a

digital representation of the real educational process, taking into account all its characteristics. At the same time, this interpretation does not correspond to the original concept of a digital avatar as a reference model based on which a highly accurate digital copy of a certain process or object is created.

The topic of the digital avatar in education is also considered in the context of analyzing methods of evidence-based management and processing of educational data. However, in such works, this concept is mentioned only superficially, without a detailed consideration of its functional purpose and goals of integration into the education system. Therefore, current research only partially covers the potential of the digital avatar, leaving open questions about its practical application in the learning process.

So, does the promising and productive digital avatar technology in Industry 4.0 have an effective future in education? In engineering, according to M. Grieves' concept, the key is to establish the relationship between a physical object, product, technology, and the information underlying them in order to optimize quality control, technological and managerial decisions [11]. In the educational environment, the issue of education transformation in the context of global digitalization and network technologies, which form a new format of the educational process as a leading social institution of modern society, is of fundamental importance.

Education in the new digital reality can serve as an integration mechanism between the world of digital, virtual objects and technological solutions and the world of physical objects that exist in the space of social interactions, meanings, and human relations. The task of combining these two dimensions – physical and virtual – is one of the key challenges of the modern education system. Digital avatar technology can play a fundamental role in solving this task.

Digital avatars in education cannot be simple analogs of "digital twins" in industry, created for technical products or devices. Educational digital replicas should reflect the specifics of social objects, which, on the one hand, have technical and administrative stability of design, and on the other hand, include all aspects related to the human factor.

Among the promising areas of creating digital avatars in education are the development of digital replicas of such educational objects and systems as students and teachers, structural units and educational institutions, as well as various activities within research and educational institutions. For the successful implementation of this concept, it is necessary to identify the necessary and sufficient conditions without which the creation of digital avatars in education is impossible.

The methodology for designing digital educational reality should take into account not only technological aspects but also the specifics of the social object for which the digital avatar is created. A comprehensive approach to the development of such systems will allow not only to integrate digital technologies into the educational process, but also to ensure effective interaction between the digital and physical components of modern education.

Digital avatar of an educational object can be created under the following conditions:

– Building a mathematical model of an object or phenomenon for which the digital avatar is being developed. All processes should be described in the language of mathematical formulas and algorithms.

– Development of the necessary technical tools for collecting, processing, and storing data on a social object, which requires specialized software.

– Real-time information collection, which involves constant updating and correction of data transmitted to the digital avatar.

– Implementation of a mechanism for digital avatar adaptation, which allows for its refinement and provides feedback from a real social object.

– Formation of a theoretical and methodological base for the study of digital technologies in education and their further analysis.

The necessary steps in creating the digital avatar in education include several key stages. At the preparatory stage, the object or process for which the digital avatar is being developed is determined. All its internal and external characteristics are analyzed, after which an electronic passport is formed, containing the necessary documentation, technical specification, mathematical models, and other parameters.

At the data collection stage, the types and amounts of information required to create the digital avatar are determined. Methods for collecting, processing, and storing this data are established, which may include readings from sensors, video cameras for analyzing eye movements while reading, room temperature, keyboard typing speed, etc. After that, a digital model design is developed.

At the development stage, a software system is created that reflects all the defined characteristics of the object. The digital avatar should correspond to the structural and functional features of the real object, reproducing its parameters in the virtual environment.

At the stage of implementation, verification, and adjustment, the created digital avatar is put into operation. It begins to analyze and process the data received, compare it with standard parameters, and identify discrepancies and problems. Using artificial intelligence algorithms, the system makes appropriate decisions and generates analytical reports for developers on the operation of the real object, the digital analog of which it is.

Summarizing the conditions and stages of creating digital avatar technology allows to outline its potential capabilities and prospects for the sphere of education. In particular, an important aspect is the management potential of this technology, which can significantly increase the efficiency of managing individual departments and business processes, as well as the activities of the educational institution as a whole.

The implementation of the digital avatar avoids the traditional “trials and errors” approach, minimizing the risks of management decisions. Due to this, the technology provides disclosure and structuring of internal processes in the sphere of education, making them more transparent and understandable. Verification of administrative decisions based on digital modeling allows to assess their potential consequences, which improves the quality of educational management and contributes to a more accurate forecasting of the development of educational institutions.

In the information sense, educational social objects are often characterized by insufficient transparency of internal processes, which complicates their objective assessment. Even direct supervisors may not have a complete picture of the real state of affairs in the institution or its structural units. As a result, management decisions and administrative orders do not always have the expected effect. The main reason for this phenomenon is the fragmentation and incompleteness of information about the educational environment, which complicates the analysis of its functioning and the development of effective development strategies.

The use of the digital avatar allows to create mathematical models of educational processes, which contributes to their structure, system analysis, and increased decision-making efficiency. The use of this technology makes the internal dynamics of the educational system more transparent for all participants in the management process. This allows not only to better understand the structure and patterns of functioning of educational organizations, but also to optimize their management, ensuring a high level of adaptability to changing conditions.

Another important aspect is the stochastic and intuitive nature of the processes that take place in educational practice. This is due to the social nature of education as a complex system that includes multi-level interactions and unpredictable factors. At the same time, the implementation of technology capable of mathematically describing these processes opens up opportunities for their optimization.

Due to the analysis of Big Data, it will be possible not only to observe, but also to effectively manage the educational environment, assess current trends, and predict future changes. A clear understanding of internal processes will allow for the formation of accurate algorithms for making managerial and administrative decisions, which will help to increase the efficiency of educational management. The use of the digital avatar will significantly improve the quality of information feedback, increase management efficiency, and provide a more adaptive model for administering educational processes.

In this context, it becomes obvious that the transformation of the education system according to the requirements of Industry 4.0 is impossible without the widespread implementation of digital technologies, in particular, the digital avatar. This technology acts as a strategic tool for the transition from local educational reality to a network one, serves as a modern methodology for modernizing management and administration, and also creates a basis for designing, structuring, and visualizing the latest teaching methods in the digital age.

Chapter 3. Social imperatives for regulating the education development

Modern education is one of the priority areas of national policy, playing the role of a key driver of society modernization, public administration, and economy. The main driving force of this transformation is Industry 4.0, which puts forward a number of strategic and practical tasks for the educational sphere, on the successful solution of which the socio-economic development of the country depends.

Industry 4.0 is characterized by the widespread implementation of digital services that transform traditional educational models and contribute to the formation of a new social reality both at the individual level and within the state system as a whole.

National strategic programs are aimed at modernizing key sectors of the economy, including education, by updating the material and technical base, integrating digital services, improving the system of training professional personnel, and revising the forms, content, and teaching methods.

The digital transformation of education is an integral part of the overall digital strategy aimed at radical changes in the functioning of the economy and society [17, p. 110]. The educational system is facing the need to critically rethink its role, available resources, and strategic prospects in the context of digital challenges. These processes expand the horizons of opportunities for society and every citizen, providing access to new forms of learning, development, and professional self-realization These processes expand the horizons of opportunities for society and every citizen, providing access to new forms of learning, development, and professional self-realization.

At the same time, the massive implementation of digital technologies is accompanied by a number of social risks that are actively discussed in scientific circles. Excessive digitalization under certain conditions can create threats to human rights, security, and personal interests of citizens [18, p. 721]. In such a situation, it is important to take targeted measures that predict the potential risks of digital transformations in education, assess their social consequences, and implement digital technologies only if they are reasonably feasible and in the public interest.

It is impossible to completely eliminate all the risks and threats of the digital transformation of education, but minimizing them is the only rational strategy. One of the key ways to reduce these risks is to take into account social imperatives during the large-scale digitalization of the educational sphere. Social imperatives are a set of mandatory requirements aimed at balancing interests, meeting the needs, and ensuring the security of the individual, society, and the state in the process of digital transformation of education according to modern educational policy [19, p. 261].

The main social imperatives for the development of education in the digital age, which ensure a balance of interests of all stakeholders, are:

– high level of digital literacy of participants in the educational process, taking into account their age characteristics and individual knowledge needs;

– personalization and continuity of the educational process, which is implemented through digital services and provides an opportunity for self-study and self-development of each student;

– practice-oriented learning that involves students in interaction with the real sector of the economy, production, and business;

– training of highly qualified personnel capable of quickly adapting to changes in the labor market, quickly retraining, and developing creative thinking;

– modern regulatory framework that protects the interests and rights of citizens, society, and the state, as well as ensures security in the digital educational environment.

Adherence to these principles will contribute to the effective development of digital education, its compliance with modern challenges, and the creation of favorable conditions for the harmonious combination of technological progress and social values.

Taking into account these social imperatives can minimize the negative consequences of the education digitalization. Launching curricula and courses that take into account the age and individual characteristics of the target groups, on the one hand, significantly increases the level of digital literacy of both students and teachers, and on the other hand, contributes to the formation of personalized, practice-oriented approaches to learning.

The development of a system of individual educational trajectories and the concept of lifelong learning is made possible by the active implementation of digital technologies. These technologies contribute to the implementation of the principles of self-education and self-development for every student, regardless of age, place of residence, or previous level of education.

Structural transformation of the economy based on the real sector of production and business requires active involvement of enterprises in the training of graduates of educational institutions [20; 21]. Familiarization of future professionals with industry specifics, corporate culture features, and practical aspects of enterprise activities helps to form specialists focused on the real needs of the modern labor market.

The human resources potential of young professionals entering the labor market is determined by their flexibility, creativity, ability to work in teams, and quick retraining according to changes in the employment structure. It is these qualities that make graduates a driving force for socio-economic transformation.

All digital transformation processes taking place in society should be regulated by an appropriate legal framework. Regulatory acts should ensure the protection of the rights, interests, and safety of every citizen in the context of digitalization of the educational environment and social activities in general.

Conclusions

Digitalization of education is a key factor in economic development that determines the competitiveness of national education systems in the global space. A study of the digital maturity of education as a conceptual framework for the digital transformation of educational institutions confirms that the level of integration of digital technologies directly affects the quality of educational services, their accessibility, and efficiency. The use of artificial intelligence, Big Data, virtual reality, and other penetrating technologies contributes to the modernization of the educational process and optimization of management decisions in higher education.

A separate role in the digitalization process is played by the implementation of digital avatar technology, which opens up new opportunities for personalizing learning, modeling learning processes, and increasing the adaptability of educational institutions to changing conditions. The analysis of existing models of digital maturity indicates the need to develop specific methods for assessing the digital maturity of education that take into account its unique social and economic aspects. The implementation of digital avatars allows to increase the efficiency of educational process management, improve information exchange, and ensure transparency of decision-making.

At the same time, the digital transformation of education is accompanied by a number of challenges and risks that require systemic regulation. These challenges include preserving academic quality, preventing the digital divide, ensuring cybersecurity, and forming digital competencies for all participants in the educational process. That is why an important task of state policy is to develop effective mechanisms to support digital education that combine technological progress with social responsibility and guarantees of equal access to quality knowledge.

Therefore, digital technologies play a key role in reforming the education system and its integration into the economic space of Industry 4.0 and 5.0. The transition to personalized and adaptive digital education contributes to the creation of new learning models focused on the individual needs of students. In the future, the digitalization of education will determine not only the effective functioning of universities and educational institutions, but also their ability to drive socio-economic development in the face of constant technological change.

References:

1. Kolodinska Ya.O., Sklyarenko O.V., Nikolaevskyi O.Yu. (2022) Praktichni aspekty rozrobky innovatsiinykh biznes-idei z vykorystanniam tsyfrovykh servisiv [Practical aspects of developing innovative business ideas using digital services]. *Ekonomika i upravlinnia*, no. 4, pp. 53-60. DOI: https://doi.org/10.36919/2312-7812.4.2022.53. (in Ukrainian)
2. Huk P.V., Sklyarenko O.V. (2022) Ekonomichna dotsilnist modernizatsii pidpryiemstv z vykorystanniam avtomatyzovanykh system [Economic feasibility of enterprise modernization using automated systems]. *Ekonomika i upravlinnia*, no. 2, pp. 103-112. DOI: https://doi.org/10.36919/2312-7812.2.2022.103. (in Ukrainian)
3. Sklyarenko O.V., Yahodzinskyi S.M., Nikolaevskyi O.Yu., Nevzorov A.V. (2024) Tsyfrovi interaktyvni tekhnolohii navchannia yak nevidiemna skladova suchasnoho osvitnoho protsesu [Digital interactive learning technologies as an integral part of the modern educational process]. *Innovatsiina pedahohika*, no. 68(2), pp. 51-55. DOI: https://doi.org/10.32782/2663-6085/2024/68.2.51. (in Ukrainian)
4. Khomenko O.O., Paustovska M.V., Onyshchuk I.A. (2024) Vplyv interaktyvnykh tekhnolohii na protses navchannia i rozvytok zdobuvachiv vyshchoi osvity [The impact of interactive technologies on the learning process and the development of higher education students]. *Naukovi innovatsii ta peredovi tekhnolohii*, no. 5(33), pp. 1222-1231. DOI: https://doi.org/10.52058/2786-5274-2024-5(33)-1222-1231. (in Ukrainian)
5. Dushchenko O. (2021) Suchasnyi stan tsyfrovoi transformatsii osvity [The current state of digital transformation of education]. *Fizyko-matematychna osvita*, no. 28(2), pp. 40-45. DOI: https://doi.org/10.31110/2413-1571-2021-028-2-007. (in Ukrainian)
6. Industrie 4.0 (Germany). (n.d.). Official Industry 4.0 Strategy. Industrie 4.0 Platform. Available at: https://www.industrie40award.com (accessed February 25, 2025)
7. Made in China 2025 (China). (n.d.). National Strategy for Industrial Modernization. The State Council of China. Available at: https://english.www.gov.cn/2016special/madeinchina2025 (accessed February 25, 2025)
8. Manufacturing USA (United States). (n.d.). Advancing Manufacturing Innovation. Manufacturing USA Initiative. Available at: https://www.manufacturingusa.com (accessed February 25, 2025)
9. Deloitte Digital Maturity Model. (2021). Framework for Assessing Digital Maturity in Businesses and Education. Deloitte Insights. Available at: https://www2.deloitte.com (accessed February 25, 2025)

10. Tocto-Cano E., Paz Collado S., López-Gonzales J.L., Turpo-Chaparro J.E. (2020). A Systematic Review of the Application of Maturity Models in Universities. *Information*, vol. 11(10), p. 466. DOI: https://doi.org/10.3390/info11100466.

11. Grieves M., Vickers J. (2017). Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems. In Kahlen F.-J., Flumerfelt S., Alves A. (Eds.). Transdisciplinary Perspectives on Complex Systems, pp. 85-113. DOI: https://doi.org/10.1007/978-3-319-38756-7_4.

12. Bobro N.S. (2024) Tsyfrova platforma yak suchasna orhanizatsiina innovatsiia [Digital platform as a modern organizational innovation]. *Investytsii: praktyka ta dosvid*, no. 1, pp. 63-66. DOI: https://doi.org/10.32702/2306-6814.2024.1.63. (in Ukrainian)

13. Yahodzinskyi S.M. (2015) Hlobalni informatsiini merezhi u sotsiokulturnii perspektyvi: monohrafiia [Global information networks in a sociocultural perspective: monograph]. Kyiv: Agrar Media Grup, 276 p. (in Ukrainian)

14. Kozynets A., Shpylyova V. (2023). Suchasni formy i metody motyvatsii pratsivnykiv sfery vyshchoi osvity [Modern forms and methods of motivating employees in the higher education sector]. *Herald of Khmelnytskyi National University. Economic Sciences*, vol. 314(1), pp. 212-219. DOI: https://doi.org/10.31891/2307-5740-2023-314-1-32. (in Ukrainian)

15. Karpliuk S.O. (2019) Osoblyvosti tsyfrovizatsii osvitnoho protsesu u vyshchii shkoli [Features of digitalization of the educational process in higher education]. *Informatsiino-tsyfrovyi osvitnii prostir Ukrainy: transformatsiini protsesy i perspektyvy rozvytku: Materialy metodolo-hichnoho seminaru NAPN Ukrainy*, pp. 188-197. (in Ukrainian)

16. Kozhyna A. (2022) Reducing Poverty, Inequality and Social Exclusion in European Countries Based on Inclusive Approaches to Economic Development. *Economics and Management of the National Economy, The Crisis of National Models of Economic System*, pp. 29-32. DOI: https://doi.org/10.30525/978-9934-26-269-2-7.

17. Williamson B., Eynon R., Potter J. (2020) Pandemic politics, pedagogies and practices: digital technologies and distance education during the coronavirus emergency. *Learning, Media and Technology*, vol. 45(2), pp. 107–114. DOI: https://doi.org/10.1080/17439884.2020.1761641.

18. Verina N., Titko J. (2019) Digital transformation: conceptual framework. *In Contemporary Issues in Business, Management and Economics Engineering*, pp. 719-727. DOI: https://doi.org/10.3846/cibmee.2019.073.

19. Kubiv S.I., Bobro N.S., Lopushnyak G.S., Lenher Y.I., Kozhyna A. (2020) Innovative potential in European countries: analytical and legal aspects. *International Journal of Economics and Business Administration*, vol. 8(2), pp. 250-264. DOI: https://doi.org/10.35808/ijeba/457.

20. Lopushnyak H., Chala N., Poplavska O. (2021) Socio-economic determinants of the ecosystem of sustainable development of Ukraine. *IOP Conference Series: Earth and Environmental Science*, vol. 915, pp. 1-9. DOI: https://doi.org/10.1088/1755-1315/915/1/012019.

21. Kaku M. (2019) Robots, artificial intelligence, and the future of work. Environmental Health and the US Federal System: Sustainably Managing Health Hazards, p. 254.