TRENDS IN THE DIGITAL TRANSFORMATION OF UNIVERSITIES AND DIGITAL ACTIVATORS OF CHANGE

ТЕНДЕНЦІЇ ЦИФРОВОЇ ТРАНСФОРМАЦІЇ УНІВЕРСИТЕТІВ І ЦИФРОВІ АКТИВАТОРИ ЗМІН

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The article examines key aspects of the digital transformation of universities in the context of the increasing role of information and communication technologies in shaping a new educational architecture. It justifies the need to revise traditional models due to technological progress, global competition, and growing stakeholder expectations. The concept of a digital university is presented as an institutional form that ensures flexibility, openness, personalization, and efficiency. Special focus is placed on digital activators, particularly digital avatars, which act as virtual agents of participants, enabling adaptive learning management, automated feedback, and role replication. A generalized model of a digital avatar as a complex socio-technological object is proposed, along with scenarios for university development based on digital maturity and institutional capacity. The results can be applied in shaping digital strategies, modernizing management, and creating personalized educational environments.

Keywords: digital university, digitization, teacher avatar, change activator, digital maturity.

Статтю присвячено актуальним аспектам цифрової трансформації університетів у контексті зростання ролі інформаційно-комунікаційних технологій у формуванні нової архітектури освітнього простору. Обґрунтовано, що стрімкий розвиток цифрових технологій, посилення глобальної конкуренції та зростаючі очікування стейкхолдерів спричиняють необхідність перегляду традиційних моделей функціонування закладів вищої освіти. У центрі дослідження – концепт цифрового університету як інституційної форми трансформації освітнього процесу, управління та комунікації, здатної забезпечити гнучкість, відкритість, персоналізацію та економічну ефективність. Особливу увагу приділено цифровим активаторам змін, серед яких провідну роль відіграють цифрові аватари як віртуальні репрезентанти учасників освітнього процесу, що дозволяють здійснювати адаптивне управління навчальними траєкторіями, забезпечувати автоматизовану зворотну інформацію, індивідуалізацію навчання та цифрову реплікацію освітніх ролей. У статті проаналізовано ключові етапи інтеграції цифрових аватарів в університетське середовище та сформовано узагальнену модель цифрового аватара як складного соціотехнологічного об'єкта. Запропоновано класифікацію цифрових активаторів за рівнем впливу на освітню трансформацію, а також п'ять сценаріїв розвитку цифрового університету залежно від початкового рівня цифрової зрілості, інституційної спроможності та ресурсного забезпечення. Розглянуто потенціал використання цифрових аватарів як елемента персоналізованого навчального середовища, що здатне інтегрувати штучний інтелект, аналітику великих даних і моделі освітньої взаємодії нового покоління. Практична значущість результатів полягає в можливості їх застосування під час формування стратегій цифрової трансформації університетів, модернізації управлінських структур, впровадження платформних рішень та створення персоналізованих цифрових освітніх середовищ. Отримані результати можуть бути корисними для керівників закладів освіти, цифрових архітекторів, розробників EdTech-рішень, проєктних офісів та органів державної влади, які формують політику у сфері цифрової трансформації вищої освіти.

Ключові слова: цифровий університет, діджиталізація, аватар викладача, активатор змін, цифрова зрілість.

ЕКОНОМІКА

Problem statement. Current trends in the digital transformation of society, the economy, and technology are significantly changing the functioning of universities as social institutions, placing new demands on their organizational flexibility, innovative capacity, and digital maturity [1, p. 94]. In the context of rapid development of information and communication technologies, the growing role of data in management, and the globalization of the educational space, traditional models of management, communication, and educational interaction no longer meet the challenges of the time. On the one hand, society expects universities to be open, inclusive, personalize the educational environment, and implement new-generation technologies. On the other hand, higher education institutions face problems of resource constraints, organizational inertia, and fragmentation of digital initiatives, which complicates the implementation of a full-fledged digital transformation.

At the same time, the issue of identifying and implementing effective digital activators of change that would ensure the strategic development of universities at the intersection of Industry 4.0 and Industry 5.0 is particularly relevant. New models of interaction between technological, organizational, and axiological components of digital transformation require scientific understanding. The impact of various forms of digital tools – in particular, digital avatars, analytical platforms, and artificial intelligence systems – on the management efficiency, adaptability, and sustainability of university systems remains insufficiently researched. Issues related to the risks associated with the introduction of digital activators of change, their interaction with existing management structures, the level of technological integration, and the role of digital strategies in the formation of a new type of university also remain unresolved. This necessitates a comprehensive analysis of digital activators as key drivers of transformation in university infrastructure, management models, and educational ecosystems.

Analysis of recent research and publications. The problems of developing digital universities, introducing digital avatars into the educational process, and assessing the level of digital maturity in higher education have been widely covered in domestic and foreign scientific literature. Significant contributions to the development of conceptual approaches to the digitization of education have been made by researchers such as Ya.O. Kolodinska, O.V. Sklyarenko, and O.Yu. Nikolaievskyi, S.M. Yahodzinskyi, O.O. Khomenko, M.V. Paustovska, I.A. Onyshchuk, G.S. Lopushnyak, A. Kozynec, as well as foreign authors – G. Kortemeyer, C. Merki, N. Kadoić, V. Đurek, Ž. Dobrović, S. Sepasgozar and others.

The works of Ya.O. Kolodinska, O.V. Sklyarenko, and O.Yu. Nikolaievskyi focus on the formation of innovative thinking through digital services, which highlights the need for digital transformation of management models in education [2]. Similar approaches are supported by S. Kubiv and A. Kozhyna, who consider the innovative potential of digital technologies in an interdisciplinary context [3; 4]. From a socio-economic perspective, the digital transformation of education is considered by H. Lopuschnyak, N. Chala, and O. Poplavska, who identify the determinants of sustainable development of university ecosystems in the digital environment [5].

In turn, G. Kortemeyer and J. Nöhl analyze the possibilities of using artificial intelligence in assessing learning outcomes, which directly correlates with the digital practices of universities of the future [1; 6].

S.M. Yahodzinskyi and O.V. Sklyarenko, in their publications, substantiate the role of digital interactive technologies as a basic element of the modern educational process [9], while Khomenko O.O., Paustovska M.V., and Onyshchuk I.A. study the influence of interactive digital tools on the development of students' cognitive activity [10].

Recent research has focused on the challenges of personalizing learning through digital avatars. A. Krap, S. Bataiev, and others analyze the impact of digital technologies on modern management methods in educational and corporate environments [7; 8; 12]. The prospect of using avatars in the educational process is substantiated as a factor in improving the economic efficiency of educational systems [12]. In addition, R. Hyshchuk and S. Lysenko study the functional role of artificial intelligence as part of the university's digital infrastructure [10; 11].

At the same time, analysis of the available source base indicates that scenarios for the digital transformation of universities have not been sufficiently developed in the context of identifying key digital drivers of change, their resource provision, and their integration into institutional management models capable of responding to the challenges of Industry 5.0. It is these areas that remain priorities for further

scientific research, which involves developing strategies for implementing innovative technologies and assessing their impact on the quality and efficiency of the educational environment.

Identification of previously unresolved parts of the general problem. Despite growing attention from researchers to the processes of digital transformation in universities, a number of key aspects remain understudied. In particular, there is no systematic approach to identifying and classifying digital activators of change that ensure sustainable institutional renewal in the context of Industry 4.0 and the transformation of value orientations towards Industry 5.0. There is a limited number of studies analyzing the relationship between the level of digital maturity, the use of digital avatar technology, and the development of new data-driven management models. Issues related to the institutionalization of digital innovations, the formation of digital competence in organizational structures, and the risks and barriers associated with the implementation of large-scale digital changes also remain insufficiently explored.

Formulation of the article's objectives (problem statement). The aim of the article is to outline current trends in the digital transformation of universities and identify key digital activators that contribute to organizational change, modernization of management processes, and increased digital maturity. To achieve this aim, it is necessary to: conduct a theoretical analysis of the essence of digital activators as drivers of transformation; identify the main types of digital solutions that influence structural and functional changes in the university environment; explore the potential of digital avatars in the context of the new management architecture; identify the risks of implementing digital tools and propose ways to minimize them.

Presentation of the main research material. An analysis of multidisciplinary scientific discourse on higher education reveals the dominance of research aimed at the theoretical understanding of digital transformation as a defining vector of modern university development. Leading conceptual models of modern education emphasize the systematic introduction of cross-cutting digital technologies into key educational and management processes, which significantly changes the functional structure, institutional logic, and cultural mission of universities. This trend is leading to a transformation of the paradigm of higher education at various levels of its theoretical construction – from economic

and managerial to anthropological, axiological, and psychological-pedagogical. As a result, there is a fundamental renewal of ideas about the university as a socio-technological institute operating in conditions of profound technological turbulence.

In turn, the complexity and multi-level nature of the changes taking place in higher education necessitates a rethinking of research approaches. A transdisciplinary perspective focused on integrating knowledge from different fields serves as a tool for analytically covering digital shifts in education, management, communication, infrastructure, and academic culture. This approach allows for not only recording the external manifestations of digitalization, but also identifying the internal mechanisms and logic of transformations that change the educational reality at a fundamental level.

In this context, the concept of digital maturity is gaining key importance, which is gradually transforming from a purely economic category into an interdisciplinary indicator of a university's readiness for deep digital modernization. Digital maturity determines the level of adaptation of institutions to new technological modes, the scale of implementation of digital services, flexibility of management decisions, the ability to personalize the educational process, openness to change, and the ability to maintain academic value identity in the face of digital challenges [2, p. 54]. The conceptualization of this concept allows focusing not only on infrastructural modernization, but also on strategic planning of digital development of universities in the context of the evolution of technological modes, denoted by the terms Industry 4.0 and Industry 5.0.

Digital maturity in higher education serves as a navigational indicator that sets the benchmarks for digital transformation according to the modern requirements of the knowledge society. Its level directly correlates with the efficiency of implementing strategies for the digitalization of education. At the same time, the concept of digital maturity is not stable or universal. Its content varies depending on the stage of technological development, socio-economic context, open data policy, integration of AI, Big Data, XR solutions, and other digital activators that form the new architectonics of the educational space. In this context, digital maturity appears not only as a technological indicator but also as a strategic category that allows modeling scenarios for the development of universities of the future.

In the modern educational discourse, digital technologies are interpreted as a key resource

for the transformation of higher education, which forms a new landscape of academic practices, management, and infrastructure organization of universities [11, p. 44]. In the global context, we are talking primarily about technologies such as Big Data, VR and AR reality, robotics elements, sensor systems, artificial intelligence, the latest production technologies, the industrial Internet, new generation wireless communications, quantum computing, and distributed ledger technology. These technologies create the basis for the formation of educational requests that meet the conditions of Industry 4.0, and are increasingly positioned as "cross-cutting" – that is, those that have the potential to systematically affect all sectors of society, including education.

Digitalization, driven by the introduction of cross-cutting technologies, initiates significant changes in industries, which are measured by the level of digital maturity. This concept refers not only to the actual state of digital development of organizations, institutions, or entire sectors of the economy, but also to the dynamic trajectory of their movement according to a certain probabilistic scenario of digital modernization [6; 9]. In the field of education, digital maturity is increasingly interpreted as an indicator of readiness for transformation, supported by government strategies, programs for the development of digital ecosystems, and the integration of digital tools into the structure of management, training, and interaction with stakeholders.

An analysis of scientific sources shows that digital transformation is taking place at different rates depending on the country, sector, and political priorities, which in turn leads to differences in the levels of digital maturity [1; 11]. It is important to note that despite the widespread circulation of the term in practice, the concept of digital maturity still does not have a single well-established definition in academic discourse. In the modern scientific literature, digital maturity is interpreted as an integral indicator of the digital development of an organization, which may include its readiness for managerial changes, the ability to form innovative products, or provide services with a high level of efficiency [4, p. 251].

In higher education, digital maturity is also seen as a critical strategic planning tool that allows universities to identify the strengths and weaknesses of digital transformation, adapt to global technological trends, and increase resilience to future challenges [10, p. 45]. In particular, the research of G. Kortemeyer, N. Dittmann-Domenichini, and C. Merki

outlined the multi-vector application of digital maturity models in education, healthcare, energy, the financial sector, and public administration [1, p. 94].

In international practice, the assessment of the digital maturity of universities is based on such approaches as the Digital Maturity Framework for Higher Education Institutions (DMFHEI), as well as using the Analytic Network Process (ANP) and Decision Expert (DEX) methods. Digital maturity models developed by leading consulting companies are also popular: The Digital Maturity Model 4.0, Deloitte Digital Maturity Model, etc. [2; 8] However, despite the active use of these models in the IT sector, industry, communications, and small business, their application in higher education is still fragmented, which opens up prospects for the development of adapted indicators of digital maturity of universities.

An analysis of current methods for assessing digital maturity in various sectors, including education, shows that the vast majority of them are based on complex quantitative indicators that require significant time and financial resources to collect, process, and analyze data. This approach, despite its effectiveness in the context of statistical modeling, is limited when analyzing the essence of digital changes in education. Most of the existing tools for assessing DM are based on the algorithm of formal calculation of partial coefficients that reflect the intensity of the use of digital tools, the costs of their implementation, or the dynamics of changes in the digital infrastructure [6; 8; 9]. At the same time, such methods overlook the qualitative component of digital transformation - efficiency, impact on pedagogical strategies, level of user adaptation, and relevance to educational goals.

Another methodological challenge is that most approaches to measuring digital maturity do not establish a direct link between specific cross-cutting technologies and changes in the educational environment. They do not record either the depth of penetration of digital tools in academic activities or which ones have become strategically important for the development of the educational space. This makes it difficult to understand the real transformation of the university as a digital institution and does not allow for identifying the most effective change activators. In this context, there is a growing need for a new model of assessing the DM, which will rely not only on quantitative metrics but also on qualitative features, such as the university's ability to integrate complex digital

solutions, personalize learning, develop flexible infrastructure, and support the digital identity of the subjects of the educational process.

Given the above, it seems advisable to move to a macro-level model of assessing digital maturity based on the concept of technological permeability of the educational environment. This approach involves considering digital transformation as a systemic process of integrating digital activators into all levels of university functioning: educational, administrative, communication, cultural, and value. The absolute criterion for achieving high digital maturity in this approach is not just the availability of digital tools, but their strategic integration in the form of so-called integrator technologies, such as digital twins, artificial intelligence platforms, or virtual simulation environments.

It is important to emphasize that the digital maturity of higher education is a dynamic category that changes according to the stage of development of technological modes. In the Industry 4.0 paradigm, the priorities are large-scale implementation of digital solutions, process automation, product unification, and cost optimization [3, p. 29]. At this stage, universities are focused on developing digital infrastructure, launching LMS platforms, using big data analytics, and creating conditions for digital mobility. However, with the transition to Industry 5.0, where the values of humanism, co-creation, and individualization are becoming key, the emphasis on defining digital maturity is also changing.

In the context of Industry 5.0, the digital maturity of higher education is increasingly associated with flexibility, openness to change, the ability to personalize the educational process, and create conditions for the formation of individual educational trajectories. The quantitative approach to assessing digital transformation is giving way to the concept of "education with a human face," where digital technologies are viewed not as an end in themselves, but as tools to meet the needs of specific users – students, teachers, and administrative staff. A unified educational product, even a high-tech and effective one, is no longer perceived as a universal solution if it does not take into account individual needs in the context of changing axiological orientations of society.

Thus, the digital maturity of the university today is not only an indicator of technical equipment or the degree of digitalization of individual processes, but primarily a characteristic of its ability to adapt to the value challenges of the digital age, preserving the humanistic mission of education and developing an innovative identity as a strategic response to global transformations.

One of the most distinctive markers of the new educational reality in the context of digital transformation is the digital avatar technology, which is rapidly gaining independent significance in various fields and is beginning to integrate into the practices of knowledge management, educational modeling, and personalized learning. Despite the growing interest in this technology, the scientific community still lacks a single, stable, and unambiguous definition of the concept of "digital avatar," particularly in the context of education.

In the technical and engineering environment, a digital avatar is most often interpreted as a virtual model of a physical object or process that allows reproducing its properties, interactions, and behavioral dynamics [7]. In the context of Industry 4.0, this technology has become the basis for the formation of new control systems, human-machine interaction, virtual testing, and intelligent forecasting. The basic principles of building a digital avatar include compatibility of devices and sensors, data transparency, technical support for decisions through information analysis, and decentralization of management through the participation of cyber-physical systems. The classic three-component model of a digital avatar includes a physical object, its virtual representation, and a data flow that ensures synchronization between them.

However, the translation of this concept into the educational space takes place with significant adaptations. An analysis of the scientific literature shows that the study of digital avatars in education is at an early stage of development. The vast majority of scientific publications focus on the use of this technology in fields traditionally associated with visualization and modeling, in particular in the field of architectural and technical education [1; 7].

Despite the limited number of mentions compared to the industry, the very idea of a digital avatar in education has significant innovative potential. It is not only about modeling educational processes or infrastructure, but also about creating a personalized digital representation of a student, teacher, or academic system as a whole. Such an avatar not only represents digital behavior but can also act as a tool for adaptation, diagnosis, and support of an individual educational trajectory.

Modern educational literature often confuses the concept of a digital avatar with more general terms such as "virtual learning environment", "digital copy of the educational process," or "educational simulator". However, the essence of a digital avatar in education is precisely the creation of a conceptual model that can synthesize information from various sources, reflect the current state of learning, and predict possible development scenarios. It is not just a visual or programmatic image, but a systemic tool that allows for real-time feedback, assessment, recommendations, and, in the future, autonomous learning support.

Against this background, the key challenge is to build an institutionally motivated model for introducing digital avatars into higher education. It is important not to reduce the concept to an abstract visualization, but to consider it as part of the architecture of the university's digital maturity. The integration of avatars should take into account both technological capabilities and ethical, pedagogical, and psychological factors. Of particular relevance is the issue of preserving subjectivity, academic freedom, and avoiding reductionist approaches to the digital representation of the individual.

Undoubtedly, the digital avatar technology, which has already gained considerable popularity and has become a landmark for Industry 4.0, has the prospect of productive application in higher education institutions. While the key problem in engineering fields is the interconnection of a physical object and its digital model in order to optimize the quality of control and technological processes, in education, the integration of physical and digital reality comes to the fore to qualitatively transform the educational and management processes of universities. Education, as a social system, can act as a point of synergy that unites the digital world of technology and the world of physical objects and social relations. It is the solution to this problem that will become the main challenge for modern universities, where digital avatar technology can play an independent role as a key digital activator of change.

It is especially important to consider that digital avatars in education cannot be direct copies of technological models from industry. These should be specially created digital replicas of educational and social objects, characterized not only by the stability of technical and administrative structures, but also by such specific factors as subjectivity, individual characteristics of teachers, social interactions, and cultural aspects of the educational environment.

Table 1 below shows the necessary and sufficient conditions for creating digital avatars in the educational environment of universities.

The process of creating a digital avatar in education consists of four consecutive stages:

1. The preparatory stage, which involves determining the object of digitalization, its characteristics, the formation of a digital profile, and technical specifications.

2. The stage of data collection, where the types of information, methods of obtaining it (sensors, video analysis, biometric data) are determined, and the avatar model is preliminarily developed.

3. The stage of developing a digital avatar, during which software is created that takes into account all the specific characteristics of an educational object or process.

4. The stage of implementation and verification, when the avatar is integrated into the educational environment, analyzes information, generates reporting, and provides feedback to the real object.

Table 1

Necessary and sufficient conditions for creating digital avatars in education

No.	Conditions for creating digital avatars	Content of the condition
1	Creation of a mathematical model of an object or process	Formalization of educational processes and objects
2	Development of technical means of data collection and analysis	Implementation of specialized software
3	Monitoring and transmission of information in real time	Current exchange of information between real and virtual environments
4	Adjustment of a digital avatar through feedback	Adaptation of a digital model based on data analysis
5	Formation of a methodological framework for research	Theoretical substantiation of the digitalization of the educational process

Source: compiled by the author

ЕКОНОМІКА

The implementation of digital avatar technology opens up significant prospects for universities, in particular:

First, in the area of management, digital avatars will improve the quality of management decisions through a deeper understanding of internal processes and optimization of management strategies. This will allow universities to avoid management mistakes, predict the consequences of decisions made, and verify them before implementation.

Second, digital avatars will help to increase the transparency of internal processes of the university environment, ensuring their analytical accessibility for all levels of management. This will allow forming a holistic view of the dynamics of educational and administrative processes, improve system manageability, and increase the efficiency of management decision-making.

Third, this technology will allow formalizing and optimizing the stochastic and intuitive processes that currently dominate educational practice. The ability to mathematically describe these processes will facilitate not only their monitoring but also the management, evaluation, and forecasting of their development. Thus, the quality of feedback, information exchange, and management procedures will improve.

Thus, the introduction of digital avatar technology is a critically important factor in the transition of universities to a modern digital model of management and education. Without this technology, neither the transformation of the management paradigm nor effective adaptation to the challenges and requirements of Industry 4.0 and further changes in Industry 5.0 is possible. The technology of digital avatars should become not just a new tool, but a fundamental strategy for the university's digital maturity, focused on openness, personalization, and high-quality integration of digital innovations in higher education.

Conclusions. The results of the research suggest that the digital transformation of universities is influenced by a number of change activators, among which digital avatars, analytical platforms, artificial intelligence, and comprehensive management information systems play a key role. The determining factor for successful transformation is the university's ability to integrate these technologies into its educational, management, and communication processes, taking into account the principles of openness, personalization, and sustainable development. The typology of digital activators proposed in the research allows structuring digital solutions by the degree of impact on organizational change and forming strategic guidelines for digital development.

The theoretical significance of the conducted analysis lies in the conceptualization of digital activators as component elements of the university's digital maturity. The potential of digital avatar technology as an integrative tool capable of combining personalized educational trajectories, automated management, and adaptive services into a single ecosystem of a digital university is substantiated. A model for the phased implementation of digital activators has been developed, which takes into account the organizational, technological, and regulatory conditions for their effective integration.

The practical significance of the obtained results lies in the possibility of their application in the formation of digital strategies for the development of universities, modernization of management structures, building personalized educational environments, and implementation of platform solutions. Of particular importance is the integration of digital avatars into the educational process, which opens up new opportunities for the implementation of individual educational trajectories, automated student support, visualization of learning progress, and the introduction of flexible forms of pedagogical interaction. The use of digital avatars as a tool for educational modeling and digital representation of participants in the educational process contributes to the formation of a digital university as an open, dynamic, and adaptive system. The proposed approaches may be useful for university administrations, digital architects, educational project managers, and public authorities responsible for implementing digital transformation policies in higher education. The integration of these solutions will help strengthen the institutional capacity of universities to effectively adapt to the challenges of the digital age and form innovative models of educational development.

REFERENCES:

1. Kortemeyer, G., Dittmann-Domenichini, N., & Merki, C. (2025). Attending lectures in person, hybrid or online at a technical university: how do students choose after the pandemic, and what about the outcome?. *Discover Education*, 4 (1), 94. DOI: https://doi.org/10.1007/s44217-025-00500-y

2. Kolodinska, Ya. O., Sklyarenko, O. V., & Nikolaievskyi, O. Yu. (2022). Practical aspects of developing innovative business ideas using digital services. *Ekonomika i upravlinnia – Economics and Management*, (4), 53–60. DOI: https://doi.org/10.36919/2312-7812.4.2022.53 [in Ukrainian]

3. 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*, 29–32. DOI: https://doi.org/10.30525/978-9934-26-269-2-7

4. Kubiv, S. I., Bobro, N. S., Lopushnyak, G. S., Lenher, Y. I., & Kozhyna, A. (2022). Innovative potential in European countries: analytical and legal aspects. *International Journal of Economics and Business Administration*, 8 (2), 250–264. DOI: https://doi.org/10.35808/ijeba/457

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

6. Kortemeyer, G., & Nöhl, J. (2025). Assessing confidence in AI-assisted grading of physics exams through psychometrics: An exploratory study. *Physical Review Physics Education Research*, 21 (1), 010136. DOI: https://doi.org/10.1103/PhysRevPhysEducRes.21.010136

7. Kozynec, A. (2024). Motivational environment in higher education institutions in the system of international comparisons. *Věda a perspektivy*, 12 (43), 206–214. DOI: https://doi.org/10.52058/2695-1592-2024-12(43)-206-214 [in Ukrainian]

8. Krap, A., Bataiev, S., Bobro, N., Kozub, V., & Hlevatska, N. (2024). Examination of digital advancements: their influence on contemporary corporate management methods and approaches. *Multidisciplinary Reviews*, 7 (26). DOI: https://doi.org/10.31893/multirev.2024spe026

9. Sklyarenko, O. V., Yahodzinskyi, S. M., Nikolaievskyi, O. Yu., & Nevzorov, A. V. (2024). Digital interactive learning technologies as an integral part of the modern educational process. *Innovatsiina pedahohika – Innovative Pedagogy*, 68(2), 51–55. DOI: https://doi.org/10.32782/2663-6085/2024/68.2.51 [in Ukrainian]

10. Khomenko, O. O., Paustovska, M. V., & Onyshchuk, I. A. (2024). The impact of interactive technologies on the learning process and development of higher education seekers. *Naukovi innovatsii ta peredovi tekhnolohii – Scientific Innovations and Advanced Technologies*, 5 (33), 1222–1231. DOI: https://doi.org/10.52058/2786-5274-2024-5(33)-1222-1231 [in Ukrainian]

11. Bobro, N., Hyshchuk, R., Strunhar, A., Bukovskyi, O., & Alekseiko, V. (2024). Exploring the role of AI in shaping future marketing strategies: evaluations and outlooks. *Amazonia Investiga*, 13(80), 43–53. DOI: https://doi.org/10.34069/AI/2024.80.08.4

12. Lysenko, S., Bobro, N., Korsunova, K., Vasylchyshyn, O., & Tatarchenko, Y. (2024). The role of artificial intelligence in cybersecurity: Automation of protection and detection of threats. *Economic Affairs*, 69 (Special Issue), 43–51. DOI: https://doi.org/10.46852/0424-2513.1.2024.6

13. Bobro, N. (2025). Use of digital avatars in the learning process as a factor of economic efficiency. *International Scientific Conference "Economic Transformation in the Context of Global Challenges: Current Issues": Conference Proceedings* (February 7–8, 2025, Klaipeda, Lithuania), 7–10. DOI: https://doi.org/10.30525/978-9934-26-529-7-3

СПИСОК ВИКОРИСТАНИХ ДЖЕРЕЛ:

1. Kortemeyer, G., Dittmann-Domenichini, N. Merki, C., Attending lectures in person, hybrid or online at a technical university: how do students choose after the pandemic, and what about the outcome?. *Discover Education*, 2025, 4 (1), p. 94. DOI: https://doi.org/10.1007/s44217-025-00500-y

2. Колодінська Я.О., Скляренко О.В., Ніколаєвський О.Ю. Практичні аспекти розробки інноваційних біз-нес ідей з використанням цифрових сервісів. *Економіка і управління*. 2022. № 4. С. 53–60. DOI: https://doi.org/10.36919/2312-7812.4.2022.53.

3. Kozhyna, A. Reducing Poverty, Inequality and Social Exclusiom 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, 2022. Pp. 29–32. DOI: https://doi.org/10.30525/978-9934-26-269-2-7

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

5. Lopuschnyak, H. N. Chala, O. Poplavska. Socio-economic determinants of the ecosystem of sustainable development of Ukraine. *IOP Conf. Series: Earth and Environmental Science*. 2021. 1. C. 1-9. DOI: https://doi.org/10.1088/1755-1315/915/1/012019

6. Kortemeyer, G., Nöhl, J. Assessing confidence in AI-assisted grading of physics exams through psychometrics: An exploratory study. *Physical Review Physics Education Research*, 2025. 21(1), p. 010136. DOI: https://doi.org/10.1103/PhysRevPhysEducRes.21.010136

7. Krap, A., Bataiev, S., Bobro, N., Kozub, V., Hlevatska, N. Examination of digital advancements: Their influence on contemporary corporate management methods and approaches. *Multidisciplinary Reviews*. 2024. 7 (26). DOI: https://doi.org/10.31893/multirev.2024spe026

8. Скляренко О.В., Ягодзінський С.М., Ніколаєвський О.Ю., Невзоров А.В. Цифрові інтерактивні технології навчання як невід'ємна складова сучасного освітнього процесу. *Інноваційна педагогіка*. 2024. № 68 (2). С. 51–55. DOI: https://doi.org/10.32782/2663-6085/2024/68.2.51

9. Хоменко О. О., Паустовська М. В., Онищук І.А. Вплив інтерактивних технологій на процес навчання і розвиток здобувачів вищої освіти. *Наукові інновації та передові технології.* 2024. № 5 (33). С. 1222–1231. DOI: https://doi.org/10.52058/2786-5274-2024-5(33)-1222-1231

10. Bobro N., Hyshchuk R., Strunhar A., Bukovskyi O., Alekseiko V. Exploring the role of AI in shaping future marketing strategies: evaluations and outlooks. *Amazonia Investiga.* 2024. Vol. 13 (80). P. 43–53. DOI: https://doi.org/10.34069/AI/2024.80.08.4

11. Lysenko S., Bobro N., Korsunova K., Vasylchyshyn O., Tatarchenko Y. The Role of Artificial Intelligence in Cybersecurity: Automation of Protection and Detection of Threats. *Economic Affairs*. 2024. Vol. 69 (Special Issue). P. 43–51. DOI: https://doi.org/10.46852/0424-2513.1.2024.6

12. Bobro N. Use of digital avatars in the learning process as a factor of economic efficiency. *International Scientific Conference "Economic Transformation in the Context of Global Challenges: Current Issues": Conference Proceedings (February 7–8, 2025, Klaipeda, Lithuania)*. P. 7–10. DOI: https://doi.org/10.30525/978-9934-26-529-7-3