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Прийняття: 16/05/2025

Рецензія: 30/05/2025

Публікація: 30/06/2025

JEL Класифікатор:

E24, I20, I25, N3



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DOI: <https://doi.org/10.53920/ES-2025-2-1>

MODELING THE EDUCATIONAL AND ECONOMIC ECOSYSTEM OF THE DIGITAL UNIVERSITY IN THE CONTEXT OF INTELLECTUAL CAPITAL FORMATION

The article provides theoretical and methodological substantiation for modeling the educational and economic ecosystem of the digital university as a strategic entity of intellectual capital formation in the context of digital transformation. The essence, structural architectonics, and functional relationships of the main subsystems of the digital university ecosystem, which include organizational, infrastructural, innovative, and business process components, are determined. It is argued that the ecosystem approach ensures the integration of educational, economic, and digital components, forming a new format of university interaction in the digital environment.

Alternative theoretical and methodological approaches to the study of digital universities are analyzed, and their limitations in covering the system dynamics of educational and economic interaction are determined. The advantages of the ecosystem model as the most relevant to the current challenges of the digital economy, which involves decentralization of management, interdisciplinarity, flexibility, and sustainability of the education system, are emphasized.

The research reveals the peculiarities of the formation and development of the digital university as a multi-level open system operating at the local, regional, national, and global levels. The main stages of the educational and economic ecosystem formation are formulated, strategic guidelines for its functioning are determined, and key principles of management based on long-term goals, efficiency assessment, and institutional adaptation are outlined.

ISSN 2786-5339 (print)

ISSN 2786-5347 (online)

The research findings show that the digital university as an educational and economic ecosystem can not only provide effective training of specialists for the digital economy but also become a key tool for the sustainable reproduction of intellectual capital. The necessity of strategic rethinking of higher education through the prism of ecosystemicity is substantiated, which allows for increasing the socio-economic efficiency of institutions in the context of digital transformations.

Keywords: digital university, ecosystem approach, intellectual capital, digital transformation, educational and economic system, digitalization, digital economy.

Наталія БОБРО

МОДЕЛЮВАННЯ ОСВІТНЬО-ЕКОНОМІЧНОЇ ЕКОСИСТЕМИ ЦИФРОВОГО УНІВЕРСИТЕТУ В КОНТЕКСТІ ФОРМУВАННЯ ІНТЕЛЕКТУАЛЬНОГО КАПІТАЛУ

У статті здійснено теоретико-методологічне обґрунтування моделювання освітньо-економічної екосистеми цифрового університету як стратегічного суб'єкта формування інтелектуального капіталу в умовах цифрової трансформації. Визначено сутність, структурну архітектуру та функціональні зв'язки основних підсистем екосистеми цифрового університету, які охоплюють організаційний, інфраструктурний, інноваційний та бізнес-процесний компоненти. Аргументовано, що екосистемний підхід забезпечує інтеграцію освітньої, економічної та цифрової складових, формуючи новий формат університетської взаємодії у цифровому середовищі.

Проаналізовано альтернативні теоретико-методологічні підходи до вивчення цифрових університетів, визначено їх обмеження щодо охоплення системної динаміки освітньо-економічної взаємодії. Підкреслено переваги екосистемної моделі як найбільш релевантної до сучасних викликів цифрової економіки, що передбачає децентралізацію управління, міждисциплінарність, гнучкість і стійкість системи освіти.

У межах дослідження розкрито особливості формування та розвитку цифрового університету як багаторівневої відкритої системи, що функціонує на локальному, регіональному, національному й глобальному рівнях. Сформульовано основні етапи формування освітньо-економічної екосистеми, визначено стратегічні орієнтири її функціонування, окреслено ключові принципи управління на основі довгострокових цілей, оцінки ефективності та інституційної адаптації.

Результати дослідження засвідчують, що цифровий університет як освітньо-економічна екосистема здатен забезпечити не лише ефективну підготовку фа-

хівців для цифрової економіки, а й стати ключовим інструментом сталого відтворення інтелектуального капіталу. Обґрунтовано необхідність стратегічного переосмислення вищої освіти через призму екосистемності, що дозволяє підвищити соціально-економічну результативність інституцій в умовах цифрових трансформацій.

Ключові слова: цифровий університет, екосистемний підхід, інтелектуальний капітал, цифрова трансформація, освітньо-економічна система, діджиталізація, цифрова економіка.

Problem statement. The digitalization of higher education is accompanied by profound transformations in the content of the educational process, and in the organization of educational and economic interaction between universities, the state, business, and society. In this context, there is an urgent task to create a holistic educational and economic ecosystem of the digital university that would not only provide the training of specialists with competencies relevant to the digital economy but also contribute to the formation of intellectual capital as a basis for sustainable development. At the same time, the current scientific discourse lacks a comprehensive approach to analyzing the digital university as an open, adaptive, economically oriented ecosystem.

It is worth noting that most universities continue to operate according to the model of a classical educational institution, which focuses mainly on the transfer of knowledge and does not always consider the dynamics of digital transformations. This leads to a lag in the speed of response to the challenges of the digital economy, imperfect integration of digital platforms, weak interaction with employers, and insufficient use of the potential of artificial intelligence, data analytics, and open information systems. There is also fragmentation in the strategic management of universities as components of regional and national innovation ecosystems.

Today, there is a growing need to form a new model of the digital university that would function as a multifunctional ecosystem, where not only training of specialists takes place but also knowledge production, interaction with digital economies, entrepreneurship development, and implementation of socially important projects. At the same time, the transformation of a traditional educational institution into a digital ecosystem requires not only the implementation of technologies but also the purposeful modeling of the structural architecture of such a system, which would consider both internal subsystems and external factors of influence.

Thus, the problem lies in the lack of a holistic approach to designing, organizing, and managing the digital university as an ecosystem capable of effectively forming intellectual capital. This requires not only new thinking in education management, but also an economic argumentation of the value of such a model for the state, business, and society as a whole. The focus should be on building a flexible, sustainable, and strategically oriented model of the educational and economic ecosystem of the digital university focused on long-term development in the digital reality.

Analysis of recent research and publications. The theoretical basis for the development of the educational and economic ecosystem concept of the digital university is based on the interdisciplinary work of domestic and foreign scholars, in particular, J. C. Smuts [1], J. F. Moore [2], P. V. Huk, O. V. Skliarenko [3], Ya. O. Kolodinska, O. V. Skliarenko, O. Yu. Nikolaievskiy [4], O. V. Skliarenko, S. M. Yahodzinskyi, O. Yu. Nikolaievskiy, A. V. Nevzorov [5], O. O. Khomenko, M. V. Paustovska, I. A. Onyshchuk [6] and others. The works of these authors explore both the classical foundations of holistic theory and modern approaches to the digital transformation of university structures and network interaction in the digital economy. In particular, the business ecosystems concept presented by J.F. Moore allows us to consider the digital university as a dynamic element of a complex economic system that functions in interaction with other actors in the digital space.

Particular attention in the scientific discourse is paid to the integration of digital services into business and educational activities, which is covered in the works of Ya.O. Kolodinska, O.V. Skliarenko, O.Yu. Nikolaievskiy [4], and O.O. Khomenko, M.V. Paustovska, I. A. Onyshchuk [6]. These publications substantiate the practical feasibility of digitalizing educational processes and implementing innovative learning tools, which directly affects the formation of the intellectual capital of universities. The effects of interaction between educational institutions, state structures, and the private sector are revealed, which confirms the feasibility of an ecosystem approach to training in the digital age.

At the same time, modern scientific publications lack a comprehensive analysis of the educational and economic ecosystem functioning in the context of the digital university as a center of intellectual capital formation. Thus, despite the existence of individual studies on the digitalization of educational processes and the development of the innovation potential of universities, there is no systematic scientific approach to the analysis of the digital university as an educational and economic ecosystem. Particular attention should be paid to

assessing the effectiveness of such an ecosystem in the context of sustainable economic development, its impact on the human resources potential of the digital economy, and the development of strategic management decisions to support and scale it.

The aim of the article is to substantiate the theoretical and methodological foundations of modeling the educational and economic ecosystem of the digital university in the context of digital transformation and to determine its role in the formation of intellectual capital as a strategic resource of the knowledge economy. The research involves analyzing the structure and subsystems of the digital university, identifying key functional links between participants in the educational and economic process, and forming a conceptual model of the digital university as an open, flexible, and innovative ecosystem. Particular attention is paid to the mechanisms of integrating digital technologies into the process of training specialists, the principles of ecosystem management, and strategic guidelines for the development of educational structures in the digital age.

Presentation of the main research material. The modern understanding of the educational and economic ecosystem of the digital university allows us to interpret it as an extremely complex, multi-level, dynamic socio-economic system that combines the educational, economic, and digital spheres through the interconnections and mutual influence of its elements into a single functioning whole [7]. It is a dynamism that is the defining characteristic of the ecosystem approach, which ensures the flexibility and adaptability of the digital university, unlike traditional holism, another basic theory of socio-economic systems research.

The holistic paradigm is based on the general theory of systems proposed by Jan Smuts, which is based on the “whole is greater than the sum of its parts” principle [1]. In the context of the educational and economic ecosystem of the digital university, this theory allows us to identify three main goals of intellectual capital formation:

- gnosiological, which involves the formation of a personality through the acquisition of complex knowledge within the educational ecosystem;
- praxeological, which focuses on the formation of highly qualified personnel through integrated digital training;
- axiological, which is aimed at forming a responsible, ethically oriented specialist through value-based education.

In contrast to the reductionist approach, which explains complex phenomena through the analysis of simpler elements, the holistic approach emphasizes the importance of connections, interactions, and interdependencies between

the elements of the university's educational and economic ecosystem, which is critical to understanding the functioning of such a system.

In the economic context, the ecosystem approach has been adapted in a “business ecosystem” format, defined as an economic environment built on the interaction of many organizations and individuals united by common goals and values. This approach was first proposed by J. Moore in 1993 by analogy with biological ecosystems and involves considering any entity not just as a separate part of a particular industry but as a component of a broader educational and economic ecosystem that covers various areas of activity [2]. Digital technologies and globalization processes increase the interaction and interdependence of the elements of such systems, which is especially relevant in the development of the digital university.

According to the researchers, in addition to the ecosystem approach, other theoretical and methodological concepts are also used to study digital universities [8]. Among the most common alternative approaches are the business model approach, the cluster approach, and the intercompany value chain approach. Their comparative analysis in the context of the digital university is presented in Table 1.

Table 1. Comparative analysis of theoretical and methodological approaches to the study of the educational and economic ecosystem of the digital university in the context of digitalization

Name of the approach	Common features with the ecosystem approach	Differences from the ecosystem approach
Business model approach	Analyzes educational and labor relations as part of the university's business system, adapts to the specific digital conditions of the institution	Considers the university as a separate organization of the digital economy, which limits the study of the broader interconnections of the educational and economic ecosystem
Cluster approach	Integrates a group of interconnected organizations and educational institutions with certain characteristics similar to ecosystems	Is limited to spatially localized groups, which narrows the possibilities of analyzing broader digital educational and economic interactions of the university
Intercompany value chain approach	Studies the formation of value creation networks within educational and labor relations focused on increasing competitiveness and end-user satisfaction	Focuses only on linear value chain relationships, whereas the ecosystem approach covers much more complex multidirectional interactions

Source: [1, 2, 7, 8]

Table 2. Peculiarities of applying the principles of the ecosystem approach to the educational and economic ecosystem of the digital university

No	The principle of the ecosystem approach	Application of the principle in the digital university
1	Management tasks are determined by social needs	Digitalization requires the transformation of educational programs and competencies to meet the demands of the digital economy.
2	Maximum decentralized management of the ecosystem	The use of digital technologies makes it possible to implement individualized learning, including self-education and self-managed educational trajectories.
3	Consideration of the impact of the digital university on other ecosystems	The quality of training of digital university specialists determines the growth of intellectual capital of regional, national, and international economic ecosystems.
4	Interrelation of the digital university functioning with economic results	Managing student and faculty workloads, creating optimal working and learning conditions ensure the sustainable development of intellectual capital.
5	Preservation of the structure and functions of the educational ecosystem	The structure of the digital university preserves fundamental educational functions, adapting them to modern conditions and implementing digital competencies and learning formats.
6	Ecosystem management is carried out within the natural functioning	The digital university expands the boundaries of the traditional educational environment through continuing education and professional development, creating flexible spatial and temporal scales of learning
7	Ecosystem management at spatial and temporal scales	The implementation of educational processes using digital technologies implies scalability and adaptability to different learning environments and economic objectives.
8	Long-term goals for ecosystem management	The digital university is characterized by non-linear development; therefore, the ecosystem management strategy should be based on long-term forecasting and flexible planning.
9	Consideration of the inevitability of change	The features of the digital university are self-organization, self-education, and self-regulation, which require the creation of flexible regulatory mechanisms in education and the economy.
10	Integration and balancing of ecosystem resources	The formation of the university's educational and economic balances should consider the rights to lifelong learning, digital literacy, and constant adaptation to new conditions.
11	Use of various forms of information	The digitalization of the university expands the possibilities of obtaining and using information, including artificial intelligence, but requires data quality control to form intellectual capital.
12	Involvement of all stakeholders in ecosystem management	The educational and economic ecosystem of the digital university involves a wide range of stakeholders, including the academic community, businesses, public authorities, investors, and technology companies.

Source: compiled by the author independently

The educational and economic ecosystem of the digital university in the context of intellectual capital formation can function at several levels: international, national, regional, and local. At the same time, thanks to digital technologies, the boundaries between these levels are becoming flexible, which is ensured by distance learning and work, as well as the digital mobility of educational process subjects. It is important to note that the educational and economic ecosystem of the digital university differs from a purely digital ecosystem, which consists of platforms, aggregators, information resources that ensure interaction and communication of all participants, as well as financial transactions and information exchange [4, P. 54].

According to the theoretical approach adapted by A. Kozhyna [9], the structure of the educational and economic ecosystem of the university consists of four internal subsystems:

- organizational (structural);
- infrastructural;
- business process;
- innovation.
- As well as two external attributes:
- spatial component – range;
- temporal component – life cycle.

Their interconnection allows for a systematic presentation of all levels and aspects of the ecosystem. Thus, each of the subsystems of the digital university ecosystem has its own basic component, which demonstrates its digital nature. The peculiarity of this ecosystem is the end-to-end digitalization of the process of intellectual capital formation at all levels of the educational and economic cycle.

The ecosystem of the digital university is based on students, teachers, employers, public authorities, innovative companies, and other stakeholders whose interaction is based on functional unity and is implemented through digital technologies, which forms a new level of intellectual capital. The interaction of the main stakeholders in the digital university involves the performance of the following functions [10;11]:

- the state – provides normative and legal regulation, forms a policy of education digitalization, supports continuous learning and development of innovations, stimulates the implementation of digital technologies in various sectors of the economy;
- enterprises and organizations – create conditions for the integration of information resources of the university and business, ensure the availability of digital platforms, and create demand for new types of intellectual capital;

- innovative companies - drive the emergence of new digital services and technologies aimed at providing innovative training of specialists in the digital university.
- The digital university ecosystem creates favorable conditions for effective interaction of participants due to the following properties:
 - flexibility in interaction and harmonization of interests of different stakeholders (students, teachers, employers, educational institutions);
 - adaptability, which implies constant updating of educational programs and processes to meet the challenges of the digital economy;
 - digitalization, which ensures openness, transparency, and accessibility of educational services;
 - implementation of technologies such as artificial intelligence, augmented reality, and automation, which are the basis for new educational and business processes;
 - creation of a fundamentally new product - intellectual capital, which is formed through the synergy of the interaction of all participants in the educational and economic ecosystem of the digital university.
- The basis for the formation of the global digital educational space is the active development of information and network technologies and their gradual implementation in the educational and economic activities of universities. The stages of the formation of the educational and economic ecosystem of the digital university are shown in Figure 1.

Under the influence of digitalization, the process of formation and use of intellectual capital of universities is transforming. The ecosystem approach allows us to determine the competence profile of a modern graduate that meets the needs of the digital economy [3, P. 110].

The strategic goal of the functioning of the educational and economic ecosystem of the digital university is the balanced development of the sectors of the digital economy through the optimal use of the university's intellectual potential at all levels of management and economic activity.

For this ecosystem to work effectively, it is necessary to optimize the mechanisms for implementing the country's socio-economic development strategy, increase the level of state support for innovative university structures, adapt the system of higher and additional professional education to the conditions of digitalization, and create appropriate digital aggregators and educational platforms.

Therefore, the ecosystem approach to studying the educational and economic ecosystem of the digital university allows us to link technological and social factors, explain new forms of interaction between artificial and natural intelligence, and determine the leading role of humans in the digital economy.

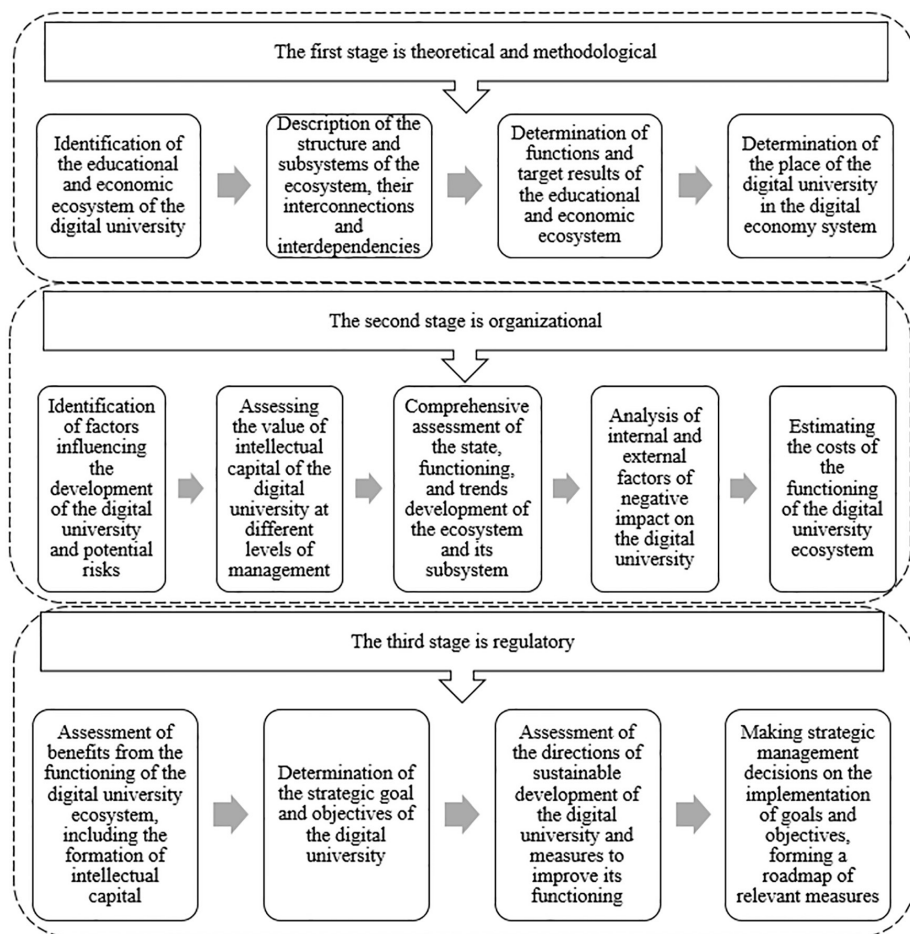


Figure 1. Stages of formation of the educational and economic ecosystem of the digital university

Source: compiled by the author independently

Conclusions and proposals. The educational and economic ecosystem of the digital university represents a complex multi-level system that harmoniously combines educational, economic, and technological factors that form the basis for the training of a new type of intellectual capital. Its dynamic nature is due

to the ability to quickly adapt to changes in the external environment, including the transformation of the labor market, the needs of the digital economy, global challenges, and local needs. Digitalization not only changes the forms of education but also restructures the logic of organizing educational processes, expanding the boundaries of the traditional university as a physical and social space.

The use of the ecosystem approach in the analysis of the digital university allows us to go beyond isolated functional subsystems and explore their interaction as a single holistic entity. This approach integrates the gnosiological, praxeological, and axiological components of the formation of a modern graduate who has not only digital competencies, but also an ethical orientation, the ability to continuously learn, and to quickly adapt to digital changes. At the same time, ecosystemicity ensures the system's openness to external influences, flexibility, and resilience to risks arising from digital transformation.

The formation of the educational and economic ecosystem of the digital university is a process that unfolds in stages and includes the theoretical and methodological substantiation of the ecosystem structure, organizational adjustment of its functioning, as well as regulatory support at the level of management decisions. Each of these stages involves an assessment of impacts, risks, performance, and strategic development guidelines. It is important that in the context of digitalization, not only universities as knowledge providers play a significant role, but also other stakeholders – business, the state, and innovative companies – who jointly form the value proposition and infrastructure for training.

Therefore, the ecosystem approach to modeling the digital university opens up opportunities for creating an innovative model of training specialists focused on the sustainable growth of human and intellectual capital in the digital economy. An important condition for the effective functioning of such an ecosystem is adherence to the principles of decentralized management, consideration of social needs, ensuring a balance between human and digital resources, and integration of the university into broader economic, social, and cultural networks. All this forms the basis for the strategic development of the university as a key institution of the digital age.

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