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Digital Technologies as a Catalyst for the Transformation of Academic Entrepreneurship

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Abstract*. Digital technologies serve as a key catalyst in transforming academic entrepreneurship by modernizing educational processes and enhancing universities’ capacity to develop innovative ecosystems.* ***Purpose****: This study aims to establish a scientific framework for leveraging digital technologies to transform academic entrepreneurship, emphasizing their role in modernizing education, increasing resource accessibility, and fostering new forms of interaction within educational ecosystems. The research* ***methods*** *include analyzing contemporary scientific literature, modeling the socio-technical characteristics of digital infrastructure, and comparing theoretical and practical approaches to the digitalization of university activities. The* ***results*** *show that the integration of digital artifacts, infrastructure, and platforms contributes to the creation of innovative university entrepreneurial ecosystems. It has been determined that digital tools such as massive open online courses, virtual laboratories, social networks, and cloud computing contribute to the formation of new forms of cooperation between teachers, students, businesses, and stakeholders. It has been established that the digitalization of educational*

processes contributes to the democratization of access to quality education, expands opportunities for personalized learning and stimulates the development of innovative approaches to the creation of educational programs. It has been found that digital platforms create conditions for involving universities in global business and research initiatives, which increases their integration into the international space. The proposed conceptual model of digital academic entrepreneurship covers pedagogical, technical and managerial aspects that ensure the adaptation of universities to the challenges of the digital age. The ***findings*** *confirm the critical role of digital technologies in enhancing universities' competitiveness and socio-economic impact by integrating digital tools into academic entrepreneurship. The development and implementation of educational programs in digital entrepreneurship, alongside the adoption of innovative digital tools, enable the creation of modern entrepreneurial ecosystems. Future research prospects include evaluating the effectiveness of specific digital tools and their influence on the growth of regional educational and entrepreneurial ecosystems.*

Keywords*: academic entrepreneurship, digitalization, digital infrastructure, digital platforms, digitalization, digital university.*

Цифрові технології як каталізатор трансформації академічного підприємництва

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Анотація. *Цифрові технології виступають ключовим каталізатором трансформації академічного підприємництва, зумовлюючи модернізацію*

освітніх процесів та розширення можливостей університетів у створенні інноваційних екосистем. ***Мета*** *дослідження полягає у науковому обґрунтуванні використання цифрових технологій для трансформації академічного підприємництва, акцентуючи увагу на їхньому впливі на модернізацію освітнього процесу, підвищення доступності ресурсів і розвиток нових форм взаємодії між учасниками освітніх екосистем.* ***Методи*** *дослідження включають аналіз сучасних наукових джерел, моделювання соціотехнічних характеристик цифрової інфраструктури, а також порівняння теоретичних і практичних підходів до цифровізації університетської діяльності.* ***Результати*** *показують, що інтеграція цифрових артефактів, інфраструктури та платформ сприяє створенню інноваційних підприємницьких екосистем університетів. Визначено, що цифрові інструменти, такі як масові відкриті онлайн-курси, віртуальні лабораторії, соціальні мережі та хмарні обчислення, сприяють формуванню нових форм співпраці між викладачами, студентами, бізнесом і стейкхолдерами. Установлено, що цифровізація освітніх процесів сприяє демократизації доступу до якісної освіти, розширює можливості для персоналізованого навчання та стимулює розвиток інноваційних підходів до створення освітніх програм. Виявлено, що цифрові платформи створюють умови для залучення університетів до глобальних підприємницьких і наукових ініціатив, що підвищує їхню інтеграцію у міжнародний простір. Запропонована концептуальна модель цифрового академічного підприємництва охоплює педагогічні, технічні та управлінські аспекти, що забезпечують адаптацію університетів до викликів цифрової епохи..* ***Висновки*** *дослідження підтверджують значущість цифрових технологій для підвищення конкурентоспроможності університетів та їхнього соціально-економічного впливу через інтеграцію цифрових інструментів в академічне підприємництво. Розробка і впровадження освітніх програм із цифрового підприємництва та використання інноваційних цифрових інструментів забезпечують можливість формування сучасних*

підприємницьких екосистем. Перспективи подальших досліджень включають аналіз ефективності окремих цифрових інструментів та їхнього впливу на розвиток регіональних освітньо-підприємницьких екосистем.

Ключові слова: *академічне підприємництво, цифровізація, цифрова інфраструктура, цифрові платформи, діджиталізація, цифровий університет.*

A general statement of the problem and its connection with important scientific or practical tasks. The development of digital technologies is profoundly transforming the educational environment, serving as a catalyst for the evolution of academic entrepreneurship – a key driver of universities' socio-economic impact. However, despite considerable progress in adopting information and communication technologies (ICT), the integration of digital tools into academic entrepreneurship models remains a challenge, hindering the advancement of universities' innovation activities and their engagement with external stakeholders.

The relevance of this issue stems from the necessity of creating mechanisms to leverage digital platforms, infrastructure, and artifacts for developing digital entrepreneurship curricula, enhancing access to educational resources, and fostering innovative collaboration with businesses and the public. The development and implementation of these mechanisms will strengthen universities' competitiveness, amplify their contribution to regional development, and support the establishment of a modern digital ecosystem.

Analysis of recent research and publications. The relevance of studying digital technologies in the transformation of academic entrepreneurship is supported by numerous contemporary publications that explore various aspects of this topic.

For instance, domestic researchers N. Verina and O. Titko examine the conceptual foundations of digital transformation, identifying three key components: digital artifacts, digital infrastructure, and digital platforms [1]. While this model provides a valuable framework for understanding transformation processes, it does not adequately address their integration into the educational environment.

S. Kubiv, N. Bobro, and H. Lopushniak explore the innovation potential of European countries and its legal dimensions [2]. However, their study focuses on the macroeconomic level and overlooks the role of digital platforms in transforming educational institutions.

O. Skliarenko, S. Yahodzinsky, and O. Nikolaievsky examine the impact of digital interactive technologies on the educational process, specifically their contribution to enhancing the quality of education [3]. However, they do not explore their interaction with entrepreneurial models within universities.

B. Williamson, R. Eynon, and D. Potter analyze the influence of digital technologies on distance education during the pandemic, focusing on pedagogical aspects [4], but do not address their application in the context of academic entrepreneurship.

Kolodinska and Skliarenko explored the development of innovative business ideas through digital services [5], but their analysis primarily focuses on practical aspects, without considering the strategic opportunities that digitalization offers to educational institutions.

H. Lopushniak, N. Chala, and O. Poplavska examined the socio-economic determinants of sustainable development [6], yet the integration of digital tools into university ecosystems was not addressed in their research.

D. S. Sin and M. Wright investigated the social and economic impact of universities [7], but did not fully explore how digital technologies can support the achievement of this mission through entrepreneurial models.

The works of M. Kaku [8] and J. Cortes [9] focus on technological changes and their effects on work processes, but their analysis is confined to the production sector and does not address educational aspects.

C. Karpliuk examined the digitalization of the educational process in higher education, focusing on transformation processes within Ukraine’s educational space [10]. His work highlights the significance of digitalization in enhancing the educational environment, but it does not address the practical implementation of digital tools within the context of university business activities.

The literature review indicates that, despite significant progress in digital technology research, gaps persist, particularly in the integration of digital tools into academic entrepreneurship models. This article aims to address these gaps by presenting a comprehensive approach to studying digital technologies as a catalyst for transforming academic entrepreneurship.

Identification of previously unresolved parts of the general problem. Despite the recognized importance of digital technologies in transforming the educational environment, the mechanisms for their integration into academic entrepreneurship – a key component of university innovation – remain insufficiently explored. There is a limited body of research examining the role of digital platforms, infrastructure, and artifacts in fostering new forms of collaboration between universities, businesses, and stakeholders. This gap hinders universities' ability to form integrated entrepreneurial ecosystems that can unlock their socio-economic potential.

This article aims to address the identified gaps by developing evidence-based approaches for leveraging digital technologies as a catalyst for transformational processes in academic entrepreneurship.

Formulation of the objectives of the article. The purpose of this article is to provide a scientific justification for the use of digital technologies as a catalyst for the transformation of academic entrepreneurship, with a focus on their impact on modernizing educational processes, expanding access to educational resources, and fostering innovative forms of interaction among participants in educational ecosystems.

The objectives of the study are as follows:

1) To examine the key aspects of digitalization that influence the development of academic entrepreneurship.

2) To analyze the socio-technical characteristics of digital infrastructure and platforms in supporting innovation.

3) To explore the impact of digital tools on the creation of new forms of cooperation between educators, students, and businesses.

4) To justify methodological approaches for developing educational programs in digital entrepreneurship.

The proposed concept will contribute to the development of scientific and practical recommendations for universities regarding the implementation of digital technologies, aimed at enhancing their socio-economic impact and adapting educational activities to the challenges of the digital age.

Presentation of the main research material with full justification of the scientific results obtained. The development of information and communication technologies (ICTs) offers a unique opportunity to reconsider the mission and objectives of the higher education system, while significantly expanding the potential for using technology in academic entrepreneurship. ICTs democratize access to quality education and provide a broad, diverse audience for educators. The emergence of free online learning resources, such as massive open online courses (MOOCs), texts, audio materials, interactive simulations, and games, proves particularly valuable for delivering digital content both inside and outside the classroom. Additionally, free online entrepreneurship courses offer teachers and students, even those distant from well-developed entrepreneurial ecosystems, access to a wide range of support, tools, and content.

These changes create the conditions for new forms of interaction between educators, students, and businesses, fostering the development of digital academic entrepreneurship as an innovative model of educational activity. Let us now explore the concept of digital academic entrepreneurship.

N. Verina and O. Titko synthesized the concept of digital technologies as comprising three interconnected yet distinct elements: digital artifacts, digital infrastructure, and digital platforms [1, p. 720]. This classification was proposed to highlight the role of digital technologies in business processes.

A digital artifact can be defined as a digital component, application, or media content that is part of a new product or service, offering specific functions or value to the end user. In the field of information systems (IS), researchers argue that digital artifacts differ from their physical counterparts. Unlike physical objects and other

cultural records (e.g., paper documents, tape recordings), digital artifacts are characterized by their ability to be edited, interacted with, reprogrammed, and distributed through various sources [1, p. 721]. Therefore, when organizations manage the digitization process—converting analog signals into digital form and ultimately into binary code – they must adapt their approach to conducting business.

Digital infrastructure is defined as the tools and systems of digital technologies that facilitate communication, collaboration, and/or computing [2; 3]. The use of digital infrastructure is a sociotechnical process, referred to by B. Williamson [4, p. 110] as digitalization, which involves concurrent changes at the cognitive, social, and institutional levels. Specifically, digitalization makes the relationship between entrepreneurial processes and outcomes more complex and dynamic.

As digitalization underpins information technologies and organizational structures, digital infrastructures are considered socio-technical systems that encompass more than just technological components. These infrastructures rely on the active involvement of diverse and heterogeneous groups of actors in their use, operation, design, and planning. This participatory aspect makes digital infrastructure appealing to stakeholders, as the greater the involvement of participants, the more it develops and fosters innovation.

A common participation mechanism is self-adjustment, where initial users adapt the infrastructure to their specific needs. This mechanism is viewed as an entrepreneurial approach to maximizing the use of limited resources, enabling spontaneous entrepreneurial activity to drive creative innovation [5, p. 56].

Digital infrastructure, including cloud computing, data analytics, online communities, social media, 3D printing, and digital makerspaces, supports academic entrepreneurship. For instance, 3D printing, also referred to as 'additive manufacturing' or 'rapid prototyping,' enables the creation of solid, three-dimensional objects. By utilizing files from computer-aided design (CAD) systems, 3D printing allows the production of physical models, prototypes, samples, tooling components, or production parts.

Digital platforms refer to shared sets of services and the underlying architecture that supports additional offerings, including digital artifacts [6, p. 4]. They can be defined as software platforms built on an extensible code base that provides basic functionality shared across modules, which interact with it through interfaces (e.g., Apple's iOS or Google's browser).

Digital technologies are breaking down the boundaries of innovation and entrepreneurship, enabling more transparent and flexible outcomes in entrepreneurial processes. At the same time, these technologies have significantly broadened the range of participants in innovation and entrepreneurship. For example, new business models have emerged due to the expansion of digital infrastructure types, including crowdfunding systems, digital 3D printing, digital manufacturing spaces, and social media platforms.

In the context of this study, we will examine the elements of modern academic entrepreneurship theory and its trends in Table 1.

Table 1

Modern Theories and Trends in Academic Entrepreneurship

Modern theory of academic entrepreneurship (according to D.S. Sin and M. Wright)		Substantiation of the trend of academic entrepreneurship (own developments)
Ensuring the broader social and economic impact of the university ecosystem.		Democratization of access to the university ecosystem.
Startups for students and graduates; entrepreneurial students; job creation in the region.		Digital entrepreneurship training; graduate startups, global and regional development.
Students; graduates; industry cooperation on campus; academic faculty; post-docs..		Citizens; student entrepreneurs.
Accelerators; garages for entrepreneurs; student business plan competitions; creation of startups with industry representatives at universities; public and private "incubators".		Digital accelerators; focused on virtual business games; 3D virtual laboratories and spaces; online learning resources (MOOCs); experimental digital laboratories; social media technologies.

Source: proposed and finalized by the author based on [7]

It is important to note that transitioning to a new model of academic entrepreneurship within an educational organization is impossible without a shift in the management's strategic vision.

In practice, for a university to adopt this new approach, the entire institution must align with the implementation of top-down goals. However, to fully realize the benefits of this methodology, it must be embraced at all levels of the organization. Only then can the university better focus on its key stakeholders – students, parents, and employers – and remain open to change.

The most comprehensive and widely adopted approaches to quality improvement in this area are Lean and Six Sigma [9, p. 66]. Six Sigma is not only a philosophy of quality leadership but also a methodology focused on reducing variability, identifying defects, and enhancing the quality of products, processes, and services [11, p. 107]. Lean, on the other hand, aims to increase customer value while minimizing waste. Together, Lean and Six Sigma complement and enrich each other, offering a powerful combination for quality improvement.

The tools provided by Six Sigma offer universities significant opportunities to reduce costs, minimize inconsistencies and defects, and enhance customer service procedures and processes. The core of the Six Sigma methodology is the DMAIC process [12, p. 645]. For university administration to transition to the Six Sigma model, a non-traditional approach to conventional practices is required. Understanding its fundamental principles necessitates a shift in the management's approach to problem-solving – from a problem-oriented mindset to a customer-oriented one.

Rapid changes in the external environment, increased digitalization, budget cuts, declining enrollment, and growing employer dissatisfaction often compel university management to passively wait for government decisions and react to proposed changes. However, instead of merely responding to problems and dissatisfaction, the Six Sigma methodology enables university management to proactively seek ways to anticipate and prevent issues [13, p. 1230]. In this approach, the challenges faced by universities are viewed as opportunities for improvement.

The most widely used Six Sigma process methodology is DMAIC, which stands for Define, Measure, Analyze, Improve, and Control. These stages are crucial for success and must be applied at the appropriate time and place. Initially developed for manufacturing, it is now understood that DMAIC's application extends beyond industrial sectors and can be adapted to educational processes. Each stage involves specific steps [14, p. 42].

Additionally, each step is executed using a set of common, effective tools.

Thus, at the definition stage, university management clearly formulates the problem to be solved, establishes goals, and analyzes how these goals align with the institution's mission. During the measurement stage, the baseline and localization of the issues are determined. The results of this stage provide a deeper understanding of the root causes of the problems and propose potential hypotheses. After data collection, these hypotheses are tested and either confirmed or refuted. Once the root cause is identified, additional solutions can be developed and implemented to address the underlying issues.

The purpose of the next steps is to identify positive changes in comparison to the current state of the process through adaptation. Any proposed changes are tested to verify their effectiveness during the improvement phase. Long-term effects on a larger scale can be monitored over time to assess whether the institution's mechanisms are functioning.

It is important to recognize that the procedure for developing and approving educational programs is much broader than simply ensuring compliance with established standards. An educational program will be successful if it fosters sustainable partnerships with external stakeholders, thereby influencing the formation of an innovation ecosystem. External stakeholders include municipalities, other educational organizations, regional authorities, commercial and non-profit enterprises, and others. Clearly, there are significant differences in organizational structures, cultures, goals, and market behavior between educational institutions and their stakeholders.

Moreover, when organizations have been established in the market for goods and services for a long period, the process of convergence can be particularly challenging. Each organization's culture has developed to meet key goals within the framework of its strategic objectives. Given the differences in organizational structures, several structural models are possible:

1. Dialogue at the interface level involves minimal changes to the structure and culture of the interacting organizations, but requires measures to enhance understanding and efficiency. This approach may include mutual representation in governing bodies (such as the board of directors or committees of the educational organization), intensive collaboration on joint projects, and active participation in the development of regional development programs, among others.

2. Dialogue within newly created organizations, consisting of representatives from interacting organizations. Examples of such organizations include innovation incubators (IIPs), joint ventures, and technology parks.

Digital technologies are changing the way we conduct business and create new enterprises [15;16], as well as influencing the initiatives that universities are adopting to introduce new forms of academic entrepreneurship. Discussions on academic entrepreneurship should incorporate a comprehensive perspective of this new concept, addressing why, what, who, and how digital technologies are transforming the processes of academic entrepreneurship.

Digital technologies, as a pervasive phenomenon, contribute to the creation of an open and flexible environment that fosters convergence and enhances productivity. They lay the foundation for the development of new organizational forms and business models that align with the needs of the modern digital age.

The introduction of digital technologies enables universities to employ standardized tools that support academic business processes at all organizational levels. This, in turn, facilitates the integration of data and processes across the university, broadening the scope of collaboration and enhancing efficiency. New methods of information exchange and process organization are transforming

traditional configurations and relationships among participants in academic entrepreneurship.

In these conditions, researchers and students gain access to a broader audience, opening up new opportunities to generate ideas, implement innovative projects, and strengthen their role within the academic environment. Thus, digital technologies serve as a catalyst for change, driving the development and transformation of academic entrepreneurship.

Conclusions: The results of the study confirm the crucial role of digital technologies as a catalyst for the transformation of academic entrepreneurship in the digital age. The integration of digital artifacts, infrastructure, and platforms lays the foundation for the creation of new models of interaction among universities, students, business, and society. Digital tools play a key role in democratizing access to quality education, expanding the potential audience, and fostering innovative educational approaches, including through massive open online courses, interactive simulations, and other digital resources.

The study has shown that the digitalization of academic entrepreneurship can significantly impact the socio-economic landscape by fostering inclusive educational and entrepreneurial ecosystems. However, the successful realization of these opportunities requires the adaptation of strategic approaches by university management, the development of educational programs that promote digital skill-building, and the integration of innovative digital tools into the educational process.

A comparison of the research objectives and the obtained results allows us to conclude that the tasks have been successfully accomplished. Specifically, the influence of digital technologies on educational processes has been analyzed, the mechanisms for integrating digital tools have been investigated, and recommendations for the formation of new models of academic entrepreneurship have been developed. Future research prospects include a more in-depth examination of the effectiveness of specific digital tools, such as digital accelerators and collaboration platforms, as well as an analysis of their impact on the development of regional educational and entrepreneurial ecosystems.

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