

ON THE DEVELOPMENT OF THE DIGITAL ECOSYSTEM IN THE FIELD OF
EDUCATION AND SCIENCE: DIGITAL TRENDS IN THE PRESENT

*SOBRE O DESENVOLVIMENTO DO ECOSISTEMA DIGITAL NO DOMÍNIO DA
EDUCAÇÃO E DA CIÊNCIA: TENDÊNCIAS DIGITAIS NA ATUALIDADE*

*SOBRE EL DESARROLLO DEL ECOSISTEMA DIGITAL EN EL ÁMBITO DE LA
EDUCACIÓN Y LA CIENCIA: TENDENCIAS DIGITALES EN LA ACTUALIDAD*



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ABSTRACT: The purpose of the research is to highlight the structural, organizational, mental, and ideological components of the digital ecosystem of the educational and scientific space. The task of the study is to analyze the integration of the digital potential of the educational system. The methodology used in the article is based on general scientific methodological approaches, mainly analytical. Synergistic and interdisciplinary principles aim to support the mutual influence of digital tools and educational and scientific guidelines. The results of the study indicate the need for a new positioning of the ICT element as a full-fledged element of the educational and scientific environment. Modern digital trends are moving from the status of innovation and popularization to the format of practical application in education and science. Thus, the digital ecosystem is gaining the status of a fundamental component of the educational and scientific sphere, ensuring the dynamism, mobility, and pragmatism.

KEYWORDS: Digital education. Innovations. ICT. Education 4.0. Science 4.0.

RESUMO: *O objetivo da investigação é destacar os componentes estruturais, organizacionais, mentais e ideológicas do ecossistema digital do espaço educativo e científico. A tarefa do estudo é analisar a integração do potencial digital do sistema educativo. A metodologia utilizada no artigo baseia-se em abordagens metodológicas científicas gerais, principalmente analíticas. Os princípios sinérgicos e interdisciplinares pretendem fundamentar a influência mútua das ferramentas digitais e das diretrizes educativas e científicas. Os resultados do estudo indicam a necessidade de um novo posicionamento do elemento TIC como um elemento de pleno direito do ambiente educativo e científico. As tendências digitais modernas estão passando do status de inovação e popularização para o formato de aplicação prática na educação e na ciência. Assim, o ecossistema digital está ganhando o status de componente fundamental da esfera educativa e científica, assegurando o dinamismo, a mobilidade e o pragmatismo.*

PALAVRAS-CHAVE: Educação digital. Inovações. TIC. Educação 4.0. Ciência 4.0.

RESUMEN: *El objetivo de la investigación es poner de relieve los componentes estructurales, organizativos, mentales e ideológicos del ecosistema digital del espacio educativo y científico. La tarea del estudio es analizar la integración del potencial digital del sistema educativo. La metodología utilizada en el artículo se basa en enfoques metodológicos científicos generales, principalmente analíticos. Los principios sinérgicos e interdisciplinarios pretenden fundamentar la influencia mutua de las herramientas digitales y las directrices educativas y científicas. Los resultados del estudio indican la necesidad de un nuevo posicionamiento del elemento TIC como elemento de pleno derecho del entorno educativo y científico. Las tendencias digitales modernas están pasando del estatus de innovación y popularización al formato de aplicación práctica en la educación y la ciencia. Así, el ecosistema digital está adquiriendo el estatus de componente fundamental del ámbito educativo y científico, garantizando el dinamismo, la movilidad y el pragmatismo.*

PALABRAS CLAVE: Educación digital. Innovaciones. TIC. Educación 4.0. Ciencia 4.0.

Introduction

The modern socio-cultural space is divided into two key trends related to digitalization:

- Ecosystems whose target vector of functioning is ultimately aimed at a single digital unified environment.
- Ecosystems in the context of the project format are united by common digital tools but retain their autonomy.

The article aims to provide a structured coverage of the organizational and ideological elements of the digital ecosystem that are characteristic of the educational and scientific space. The task of the study is to analyze the processes of integrating digital resources into the modern scientific perspective of the world and the reaction of participants in the scientific and educational community to innovative progress in these areas.

The research problem focuses on the orderliness of ICT elements in the educational and scientific paradigm of the digital ecosystem. It is important to recognize the difference between digital trends promoted in everyday life and digital trends specific to education and science. Educational standards regulate the use of digital potential in the educational process, while research activity integrates digital resources as development elements.

Furthermore, the investigation also focuses on the problem of the correlation between the traditional and innovative dimensions of education and science. In the educational space, digital trends are associated with alternative sources of learning. Scientific life presents the digital ecosystem as a driving force.

Educational and scientific transformations of a digital nature have many interpretations in the modern information technology society. The research results suggest a clear distinction between the digital ecosystem in the educational and scientific dimensions and digital activity in these areas of social activity. The digital ecosystem effectively synergizes fundamental, flexible, and digital competencies for educators and researchers.

The digital ecosystem allows updating the guidelines for the totality, mobility, and flexibility of the educational and scientific process. Interdisciplinarity aims to provide proper support for the scale of digital coverage of education and science. At the same time, the implementation of global digital trends demonstrates the competitiveness of education and science in the modern socio-cultural space.

Methodology

The article uses a set of general scientific methods, among which the analytical vector of the problem study prevails. The comparative analysis helped to identify the conceptual differences between the traditional and innovative ecosystems of education and science. The modeling method helped formulate the digital ecosystem's key characteristics in the modern global and civilizational dimension.

One of the extended approaches to the modeling methodology is the technology acceptance model (GRANIĆ; MARANGUNIĆ, 2019, p. 2572). The study of the design of learning and technology is also one of the elements of modelling a new format of educational and scientific space in the context of the functioning of the digital ecosystem (BODILY; LEARY; WEST, 2019, p. 64). The issue of the ecosystem format is fundamental to the current study, as digitalization is currently focused on the contents of education and science, leaving the question of the meanings and purpose of the digital space to be considered in the short term.

Modern scientific research, even of a highly specialized nature, cannot do without the synergistic principles of interdisciplinarity and scientific pluralism. When the problem concerns the digital space, which covers all areas of contemporary social activity without exception, the use of synergy is in demand and appropriate. Pluralistic approaches are most appropriate when considering global trends, which are undoubtedly ecosystems in education and science.

Interdisciplinarity in this study emphasizes the synergy between the educational and scientific segment and other areas of social activity in the paradigm of global and specific ecosystems. It is with the help of synergistic principles that a full interpretation of the guidelines of digital activity in education and science studied in this article is possible, namely: scale, intensity, dynamism, and flexibility.

In particular, the principles of interdisciplinarity are relevant for ecosystems of different natures in the modern world, as these structures are permeated by synergistic interactions and require methodological guidelines focused on the process' synchronization and elements in education and science (JURAEV; AROYEV, 2023). The integration of sciences is, in fact, an influential independent trend in the modern scientific perspective of the world. Combined with digital trends, the interdisciplinary digital space claims to dominate the scientific discourse.

Literature review

The issue of modern digital trends in education and science can be divided into two groups in the scientific and educational discourse:

- General digitalization trends are intertwined with practical and everyday ICT elements and manifest in scientific and educational activities.
- Formation of a unique digital ecosystem in the educational and scientific space with its own specifics of ICT use.

Digital ecosystems are seen as phenomena of modern education (OLEKSIENKO *et al.*, 2022) or as the main driving force of educational development (RAK-MŁYNARSKA, 2022). One way or another, the digital ecosystem is confidently gaining ground, both on a practical and ideological level of public perception.

There has been a radical change in emphasis on updating coverage of the digitalization of education and science during the COVID-19 pandemic and the large-scale use of ICT resources in these areas. Distance learning (KODA *et al.*, 2022) or blended learning (KOSTENKO *et al.*, 2023), multimedia resources (HRYTSENKO, 2022), and innovative learning environments (KULICHENKO *et al.*, 2022) at different educational levels – all of this required effective tools to implement continuity of education. The same problems were faced by research activity, which has primarily moved from laboratory and research conditions to other research formats.

In general, the digital ecosystem in the educational and scientific space is interpreted as a promising format for future education and science development (TSEKHMISTER, 2022). Digital resources have been a leading trend in science and education for at least the last decade, regardless of the country, region, or community (SAS, 2013). In the global evolutionary dimension, society is waiting for the transformation of Industry 4.0 into Industry 5.0.

The new paradigm will involve integrating the digital component as an alternative or auxiliary tool for traditional elements and incorporating digital resources into the everyday dimension. Under these conditions, the digital ecosystem will be a logical extension of everyday human activity in the field of education and science. This position is opposed to the current situation in which digital ecosystems in science and education are the model society seeks.

Results

The digital ecosystem is gradually gaining an important status in almost all areas of social activity. Digitalization permeates human activity, from everyday activities to professional competencies. These realities could not escape the educational and scientific sphere, as it is a source of innovative ideas and a platform where progressive ecosystems demonstrate their effectiveness and relevance.

The digital ecosystem has significant differences from the usual digitalization process. The digital ecosystem is associated with the concept of sustainable innovation development (ABAD-SEGURA *et al.*, 2020). When the status of digital resources is determined, it is mostly indicated by the practical and operational level of implementation of the digital arsenal. For education and science, it is more common to operate with strategic concepts, so the digital ecosystem format is the most suitable for structuring all digital activity processes implemented in the field of science and education.

Of course, any manifestation of modernization carries risks, as the result is uncertain (CORAL; BERNUY, 2022). While such risks are common in scientific life, education has difficulty adapting to such transformations. However, with strategic planning for the integration of digital resources into research or teaching and learning activities, the risks are minimized. And if we eliminate only scientific progress, these risks turn into a field for scientific experiments and innovations.

For the digital ecosystem, not only the level of technological development is important, but also the level of ownership and access to these technologies among participants in the educational and scientific process (KOPP; GRÖBLINGER; ADAMS, 2019). The level of fundamental digital skills forms the status of innovative digital learning (LELEKA *et al.*, 2022, p. 156-166).

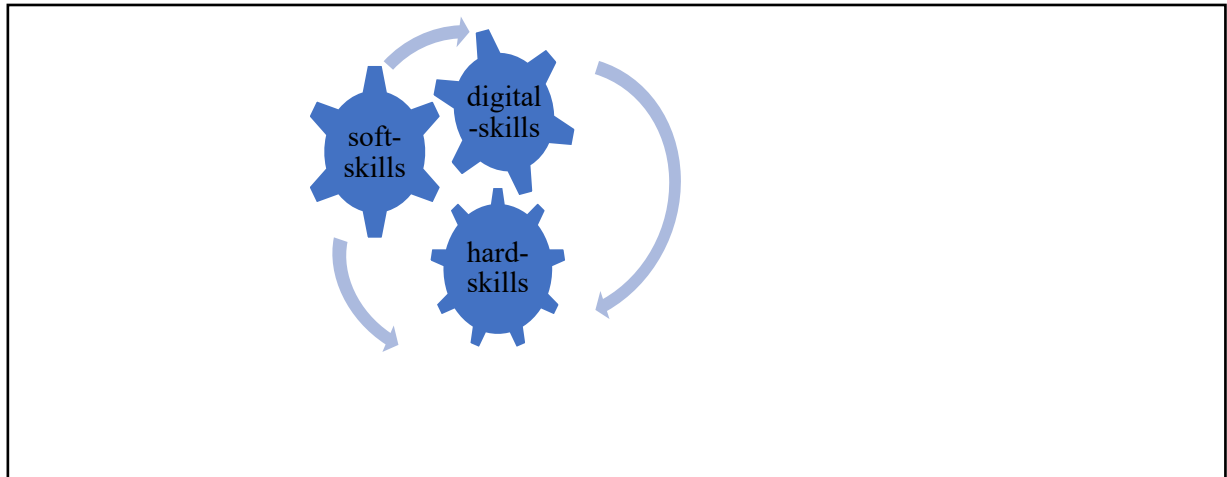
The study updates the idea that the ecosystem format is necessary not only for realizing digital potential but also for forming favorable conditions for participants in the educational and scientific process to use digital resources.

A priority for the functioning of the digital ecosystem in the research and education space is the development of digital skills among educators and researchers. Different indicators for different areas of social activity characterize the status of digital skills. In production facilities (especially large ones), digital elements are included in general algorithms on a non-

alternative basis. In education, digital tools are often used synchronously with traditional ones, mutually replacing each other.

The digital ecosystem of education and research positions digital skills in a convenient dimension (see Fig. 1).

Figure 1 – The status of digital competencies in the general paradigm of competencies in the educational and scientific sphere



Source: Prepared by the authors

This figure shows the status of skills and competencies that are typical for the educational and scientific environment. Several features are noted, namely: an equivalent role in the structural mechanisms of the industry (digital competencies are becoming as important as fundamental or flexible ones); interdependence and complementarity of competencies (in the absence of solutions in fundamental dimensions, digital skills come to the rescue and vice versa).

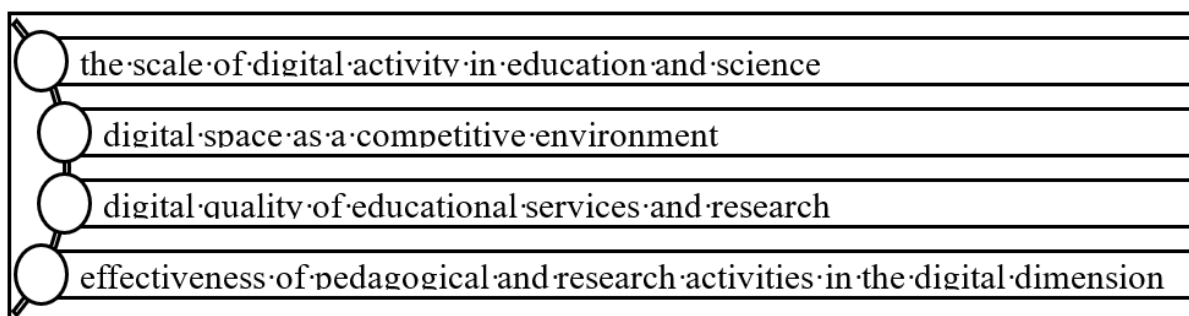
This model of education is based on dynamism and pragmatism. The digital ecosystem fully meets the requirements of the time, as it ensures both speed and flexibility in the system's functioning and shapes the effectiveness of the industry's intended purpose.

One of the features of digitalization is the totality of this process. The Industrial Revolution 4.0 has transformed approaches to organizational and structural activity without restrictions and limits (BENAVIDES *et al.*, 2020). In this context, the dichotomy of innovation and tradition is becoming more relevant. On the one hand, the digital ecosystem is building its structural elements, and on the other hand, there is a need to regulate interaction and synergy with other more traditional components.

As in any other ecosystem, its existence and functioning depend on maintaining a balance between confrontation and interaction. The digital ecosystem in education and science is faced with the need to regulate complex processes of a dialectical nature (pluralism of views, rights, and freedoms of participants in the educational and scientific process, etc).

The peculiarity is that the digital world is governed by management and control systems that are completely different from traditional ones (SUBRAMANIAM; IYER; VENKATRAMAN, 2019). Digitalization, guided by the strategic course of innovative transformations, updates several fundamental concepts of practical implementation in the field of education and science (see Fig. 2).

Figure 2 – Organizational and structural components of the digital ecosystem in the educational and scientific space



Source: Prepared by the authors

A key characteristic of the digital world is its ability to reach a large audience, regardless of place, status, or other socio-cultural indicators (AULKEMEIER; IACOB; VAN HILLEGERSBERG, 2019). The scale of the digital ecosystem reaches the point where the digital space can function effectively and autonomously, without the help or influence of traditional educational and scientific elements (VALDEZ-DE-LEON, 2019).

This all-encompassing potential of digitalization leads to increased interdisciplinarity. New powerful horizontal and vertical internal relationships are being built in the educational system or scientific paradigm. At the same time, synergies are being observed between the educational and scientific clusters and other areas of social activity.

The example of the STEM cluster points to the positive impact of digitalization on the quality of educational, pedagogical, and research elements (HRYNEVYCH *et al.*, 2021). Digitalization is not just a tool or mechanism but an integral part of an integrated science and education system. Given the current trends toward the integration of sciences, the humanities

cluster is also increasingly incorporating digital resources into its fundamental bases (ROMANUKHA; UDOVICHENKO; ZINCHENKO, 2020, p. 280).

An ecosystem, by its very nature and content, cannot be concentrated within a single industry, life chain, or body (MÁRTON, 2022). The digital ecosystem enables horizontal and vertical mobility within the industry and facilitates interdisciplinary connections with other fields (BAKHMAT *et al.*, 2022, p. 146). The digitalization of education and science is a process that is implemented outside the education and research system.

The digital ecosystem of education and science is characterized by partiality in two dimensions:

- First, digitalization is emerging in the modern world as a global paradigm in which the education and research cluster is only a subsystem.
- Second, the educational and scientific spheres are components of the socio-cultural system, and digitalization performs certain functions separately for these sectors and civilizational progress in general.

The digital learning ecosystem is formed from many hardware and software components, networking and communication, and information and broadcasting components (SARNOK; WANNAPIROON; NILSOOK, 2019). At the same time, all these elements are purely structural and organizational, which loses any meaning without a purpose. Therefore, in the following discussion, the study attempts to correlate the information technology and ideological and mental dimensions of the digital ecosystem.

Discussion

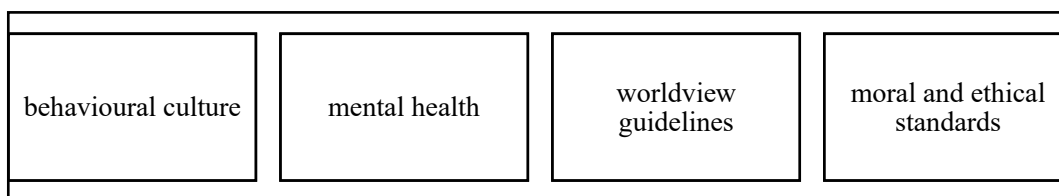
Along with purely technological deep neural networks, classic machine equipment, and scalable GPU computing (RASCHKA; PATTERSON; NOLET, 2020), the human dimension cannot be ignored in science, and especially in education.

People are becoming the dominant element in the digital ecosystem of education and science. Technology can work according to the formula in the production and economic sphere: technology for technology's sake. In education, the format is relevant: technology for man's sake. Such guidelines clearly demonstrate the primacy (or at least equality) between the content and format of the digital arsenal in the ecosystem.

Among the most resonant threats to the formation of the digital ecosystem in the educational and scientific environment are ethical risks, particularly the loss of personal data and the autonomy (rights and freedoms) of participants in this area (NGUYEN *et al.*, 2023). The technological digital space should be safe for humans, and only after fulfilling this guideline can it fulfill its purpose.

When considering the mental and ideological components of the digital ecosystem in the educational and scientific sphere, it is worth updating a number of moral and spiritual factors (see Fig. 3).

Figure 3 – Mental and ideological principles of the digital ecosystem in modern education and science



Source: Prepared by the authors

One of the factors that determines the content and purpose of digitalization in education and science is behavioral culture (TRIPATH *et al.*, 2023). The current scientific discourse emphasizes the need for digital transformation in terms of technological support and digital culture in general.

Digital culture is a priority element that determines the potential scale and intensity of digital elements. This aspect allows us to maintain parity between the person's ability to protect themselves and the aggressiveness of digital activity. In science and especially in education, this contributes to the harmonious use of digitalization with maximum benefit to humans.

One of the priority areas of the ecosystem is the concept of digital health (WANG *et al.*, 2023). In this case, not only are the medical and biological aspects of health considered, but the understanding of a healthy lifestyle is updated with the active use of ICT tools.

The world's modern scientific framework is dominated by information and digital transformation, which is changing the organizational culture of entire industries (BRANCH *et al.*, 2022). It is worth noting that while the previous Industrial Revolutions radically changed only the scientific cluster, leaving education in a conservative and sustainable dimension, the educational sector is now undergoing the same revolutionary transformations. At the same time, the human dimension allows us to maintain a balance in education and science, preventing the

technological and digital cluster from taking an unalterably dominant status in the functional and target segment of these areas of social activity.

So far, the changes in the educational paradigm have been limited to the format, but the growing role of concepts such as Artificial Intelligence and Virtual Reality may affect the purpose of education. Digitalization is an effective tool for achieving the education's mission (ALENEZI, 2021, p. 770).

Conclusion

Thus, digital trends in modern education and science are concentrated in two key dimensions:

- Operational and practical – active use of digitalization in educational and research activities.
- Strategic – formation of a digital ecosystem of education and science in which ICT elements are implemented as efficiently and safely as possible.

The main task of the modern scientific and educational discourse is to organize the digital ecosystem according to the needs and requirements of society. Two factors are fundamental for the effective functioning of the digital ecosystem in the educational and scientific environment: structural and organizational (technologies, level of mastery, scale, and intensity of use) and ideological and mental (perception of ICT, security, ethical correlation).

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