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DIGITAL TRANSFORMATION OF EDUCATION AS A PREREQUISITE FOR INNOVATIVE ACTIVITY AND TECHNOLOGICAL DEVELOPMENT OF THE ECONOMY

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Abstract. The *subject* of the present study is the digital transformation of higher education as an institutional prerequisite for innovative activity and technological development of the economy. The work considers the digitalisation of universities as a mechanism for accelerating the reproduction of human capital, enhancing the quality of competence training, and reducing time lags between the generation of knowledge and its practical application in business and the public sector. The theoretical basis of the study is formed by modern approaches to the knowledge economy and innovation ecosystems, within which universities are treated as key elements of technological modernisation through education, science, knowledge transfer, and interaction with industry. The *objective* of the present study is twofold: firstly, to provide a robust theoretical and empirical basis for understanding the impact of digital transformation on innovation processes and technological upgrading in the economy; and secondly, to identify the key channels of such impact in the context of the growing role of digital platforms, artificial intelligence, and educational analytics. The *research methodology* is based on systemic, institutional and structural-functional approaches. These are supplemented by a comparative analysis of university digitalisation practices and a logical generalisation of the mechanisms of competence formation. Analytical and synthetic methods were employed to develop an integrated conceptual framework combining the infrastructural, organisational, pedagogical and managerial elements of digital transformation in higher education. The *results* obtained prove that comprehensive digital transformation has the greatest effect on innovative activity. This occurs when the architecture of the learning platform, digital resources and laboratory facilities are modernised simultaneously; when the digital competencies of personnel are enhanced; when personalisation and learning analytics mechanisms are introduced; and when sustainable models of co-operation between universities and industry are formed. The *conclusions* show that digital educational platforms and intellectual learning support tools speed up programme updates, reduce the cost of accessing knowledge and expand opportunities for continuous learning. This is important for the rapid diffusion of technologies and adapting to the labour market. The study's practical value lies in its potential to inform the development of digital university strategies aimed at increasing innovation potential, technological competitiveness and economic sustainability.

Keywords: digitaliiation, digital university, digital transformation, higher education, innovative activity, technological development, human capital.

JEL Classification: E24, I20, I25, N3

1. Introduction

The development of an innovation-driven economy necessitates a reorientation of the higher education system from the reproduction of standard qualifications to the formation of technologically relevant competencies. These competencies must ensure the rapid transfer of knowledge into production and management practices. In the context of accelerating technological change and the growing role of data, platforms and artificial intelligence tools, the competitiveness of the economy is increasingly determined not so much by the volume of resources as by the quality of human capital, institutional capacity for learning, and the pace of innovation diffusion. In this context, the digital transformation of higher education is becoming a fundamental prerequisite for institutional technological development. This is because it changes the architecture of educational

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processes, quality management mechanisms, models of interaction with industry and the logic of continuous competence renewal.

The study focuses on analysing the impact of the digitalisation of higher education on innovative activity and the technological development of the economy, through mechanisms such as training, knowledge dissemination and reducing the time lag between scientific results and their practical application. Particular emphasis is placed on digital educational platforms, blended formats, educational analytics, personalised learning paths, micro-credentials and artificial intelligence tools as ways of increasing the productivity and relevance of the educational process to innovation ecosystems.

The methodological basis consists of systemic and institutional-organisational approaches that facilitate consideration of the digital transformation of universities as a set of changes in technological infrastructure, management procedures, quality assurance practices, and interaction with industry. This facilitates the integration of the analysis of educational, economic, and technological determinants into a unified logical framework, thereby enabling the identification of causal relationships between digital educational solutions and parameters of innovation dynamics.

The paper employs analytical, comparative, and conceptual-logical methods to generalise approaches to the digital transformation of higher education, systematise its tools and mechanisms of influence on the innovativeness of the economy, and interpret relevant practices of the digital university. The empirical basis comprises contemporary scientific publications, analytical reviews, and materials from international organisations, which facilitate the identification of key trends in the digitalisation of education and their correlation with the requirements of the knowledge economy. The study's logic is structured as a sequential transition from the theoretical justification of the relationship between "digital education – human capital – innovation" to the identification of institutional mechanisms through which universities become providers of technological development.

The article combines conceptual justification and applied analysis of digital solutions in higher education, demonstrating that the digital transformation of universities is not merely an auxiliary modernisation of educational services, but rather a fundamental condition for the formation of an innovation-driven economy. Consequently, the digitalisation of higher education is regarded as an institutional conduit for accelerating technological change, enhancing labour market adaptability, and augmenting the nation's competitiveness in an economy that is progressively driven by knowledge and innovation.

2. Access to Higher Education and Innovation

A seminal aspect of the profound shifts witnessed in the domain of higher education systems in recent decades pertains to the transition from a model characterised by extensive accessibility to a paradigm of mass higher education. In contemporary approaches to the digital transformation of universities, expanding access to higher education is regarded as an institutionally significant direction, reinforced by digital platforms, hybrid formats, and the technological rethinking of educational processes (Williamson et al., 2020; Alenezi, 2021; Gkrimpizi et al., 2024; Fernández et al., 2023). Human capital development policy emphasises that increasing investment in higher education, expanding learning opportunities, and creating conditions for continuous competence development can generate long-term economic effects, in particular through increased productivity, adaptability, and innovation capacity of economic systems (OECD, 2021; UNESCO, 2023; Ordonez-de-Pablos & Bustinza, 2023).

In the context of innovative development, it is not only the quantitative expansion of the student body and the accessibility of higher education that are important, but also the substantive reorientation of educational programmes towards competencies related to entrepreneurship, management, and the ability to operate in innovation ecosystems (EUA, 2022; Marchant-Pérez et al., 2024; Natário & Oliveira, 2025). Consequently, it can be hypothesised that the parameters of innovative development are influenced by the characteristics of business education in the country, as well as the number of students enrolled in Business, Administration, and Law programmes (EUA, 2022; Marchant-Pérez et al., 2024).

For developing countries, particularly those where gender inequality is still prevalent, increasing access to higher education primarily involves making it accessible to women and including female teachers in the research process. Inclusive approaches to economic development emphasise that reducing inequality and social exclusion creates conditions that allow different groups to participate more widely in the formation of human capital, which is important for sustainable development (Kozhyna, 2022). At the same time, the digital transformation of education emphasises the importance of ongoing professional development and the active use of digital technologies in learning and academic activities. This is regarded as a prerequisite for modernising universities (Dushchenko, 2021; Trevisan et al., 2024).

On the one hand, the expansion of the higher education cohort is a response to structural and technological modernisation in the economy, the humanisation and informatics of society, and the transformation of

universities into key elements of innovation ecosystems (EUA, 2022; Taxt et al., 2022; Natário & Oliveira, 2025). Conversely, widespread access to higher education is frequently linked to quality and resource provision risks: mounting pressure on infrastructure, human resources and student funding could potentially restrict universities' research and innovation activities in the absence of suitable managerial and technological solutions (Gkrimpizi et al., 2023; Bravo-Jaico et al., 2025). The variety of approaches (often contradictory) to interpreting the consequences of expanding access to higher education emphasises the importance of studying the impact of this expansion on various aspects of innovative development in the context of the digital transformation of universities.

3. Digital Transformation and Human Capital

Digital technologies are profoundly altering the parameters of human capital formation, thereby increasing the demand for competencies related to working with data, digital tools, network interaction, and the ability to operate in conditions of technological uncertainty and rapid institutional change (Andersen, 2022; Bobro et al., 2025a; Liu et al., 2025; Qiao et al., 2024). In this context, the importance of having the ability to continuously update knowledge and master new digital solutions and integrate them into professional activities is growing, rather than the formal presence of qualifications. This is confirmed by research into higher education and innovation ecosystems (Kortemeyer et al., 2025; Khomenko et al., 2024; Safarly et al., 2024). In this context, universities are increasingly recognised as not only providers of educational services, but also as institutional actors in digital modernisation and the enhancement of human capital resilience in the context of structural shifts (Bobro et al., 2025b).

In accordance with this, an economy driven by innovation requires specialists with advanced digital literacy and skills in the use of modern technologies in production, management, and service processes. This highlights the need to rethink the functions and outcomes of higher education as an institutional mechanism for reproducing competitive human capital (OECD, 2021; UNESCO, 2023). In this logic, the concept of lifelong learning becomes systemic in nature. Individuals form personalised educational trajectories and maintain the relevance of their "portfolio" of competencies in response to changes in the labour market and technological arrangements, often combining learning with work activities. The capacity to perpetually enhance capabilities is regarded as a prerequisite for expediting the dissemination of innovation. A substantial degree of digital competencies among personnel has been demonstrated to expedite the integration of innovation into business models and operational practices (Rachinger et al., 2024; Ordonez-de-Pablos & Bustinza, 2023).

In light of these developments, universities are undergoing a shift from a predominantly "translational" model to a proactive training model. In this new model, digital technologies are not merely supplementary tools but rather constitute a system-forming element of the educational architecture. Research into the digital transformation of higher education institutions indicates that sustainable results are achieved when digitalisation simultaneously encompasses educational processes, management, communication, and institutional culture, forming an integrated digital environment (Gkrimpizi et al., 2024; Antonopoulou et al., 2023; Alenezi, 2021). Consequently, the implementation of digital solutions necessitates the establishment of a novel educational ecosystem, wherein digital platforms for learning and educational process management function as the pivotal integration nexus. In response to these challenges, universities are implementing distance and blended learning platforms, electronic libraries, course management systems, and learning analytics systems. Concurrently, they are undertaking substantial methodological, organisational, and managerial work, including updating programmes, developing digital resources, enhancing the digital competencies of personnel, and establishing procedures for ensuring the quality of digital educational services (Fernández et al., 2023; Trevisan et al., 2024).

In practice, this necessitates the systematic mastery of EdTech tools, particularly the organisation of synchronous online interaction, the application of educational analytics to inform learning decisions and personalisation. Empirical evidence has demonstrated a correlation between personalisation and the enhancement of the effectiveness and adaptability of the educational process.

The alignment of institutional changes with public policy is an important condition for scaling up the digital transformation of higher education. International approaches emphasise that the digital modernisation of education necessitates concurrent investment in infrastructure, competencies, management capabilities, and ethical frameworks for the utilisation of digital technologies, particularly artificial intelligence tools (OECD, 2021; UNESCO, 2023). In this context, national strategic frameworks for the digitalisation of education serve as a coordination mechanism aimed at creating a modern, accessible, and secure digital educational environment and aligning educational outcomes with the dynamics of technological change, which is essential for supporting the technological development of the economy. A thorough examination of contemporary scientific methodologies pertaining to the digital transformation of higher education has yielded substantial evidence to

facilitate the identification of its fundamental domains (see Figure 1).

Figure 1 summarises the key areas of digital transformation of the higher education system as a set of interrelated institutional changes. These include:

– Modernisation of digital infrastructure and resources – network provision, digital libraries, laboratory, and service environments;
– development of digital competencies of students and educators; introduction of educational technologies and platforms – distance and blended learning, MOOCs, interactive resources;
– personalisation and continuity of learning – individual trajectories, modularity, micro-credentials;
– strengthening interaction between universities and industry;
– digital management and analytics – use of data and information systems for management decisions.

4. Digital Literacy and Higher Education

The digital transformation of higher education is inextricably linked to the level of digital literacy among the population. Fundamentally, digital skills determine the ability of citizens to utilise digital educational services and the capacity of universities to expand blended and distance learning without compromising accessibility and quality. According to Eurostat, the level of basic digital skills among the population in European countries during the 2021–2025 period is characterised by steady but uneven growth dynamics. Across the leading EU countries, there has been an increase in the proportion of the population aged 16–74 who possess at least basic digital skills. This increase is evident when comparing the figures from 2021 (53.9%) and 2025 (60.4%), which correspond to an increase of approximately 12% over a four-year period (Eurostat, 2025). However, this mean value obscures substantial variations across different countries that endure throughout the entire period under scrutiny.

The highest values are consistently recorded in Northern and Northwestern Europe. In the Netherlands, the level of basic digital skills rose from 78.9% in 2021 to 83.6% in 2025, in Finland from 79.2% to 81.0%, and in Denmark from 68.7% to 81.5%. These figures indicate not only high starting positions, but also the further expansion of the population's digital competencies. Analogous trends are evident in Ireland, where the indicator increased from 70.5% to 82.8%, and in Germany, where an escalation from 48.9% to 59.6% was documented during the 2021–2025 period (Eurostat, 2025).

The majority of Central and Southern European countries demonstrate more moderate yet predominantly positive dynamics. In particular, in the Czech Republic, the proportion of the population possessing fundamental digital competencies increased from 59.7% to 70.5%, in Austria, from 63.3% to 69.8%, in Spain, from 64.2% to 66.5%, and in Portugal, from 55.3% to 59.2%. Concurrently, a number of countries have observed stagnation or a marginal decline in this indicator: in Slovenia, from 49.7% to 46.5%; in Greece, from 52.5% to 51.0%; and in Latvia, from 50.8% to 48.4%, which suggests structural limitations in the propagation of digital skills (Eurostat, 2025).

The lowest values recorded throughout the period are observed in the countries of South-Eastern Europe. It is evident that in Romania, there has been an increase in the level of basic digital skills from 27.8% in 2021 to 31.8% in 2025. A similar trend is observed in Bulgaria, where the figure has risen from 31.2% to 38.3%. Similar to these observations, Bosnia and Herzegovina has also witnessed an increase from

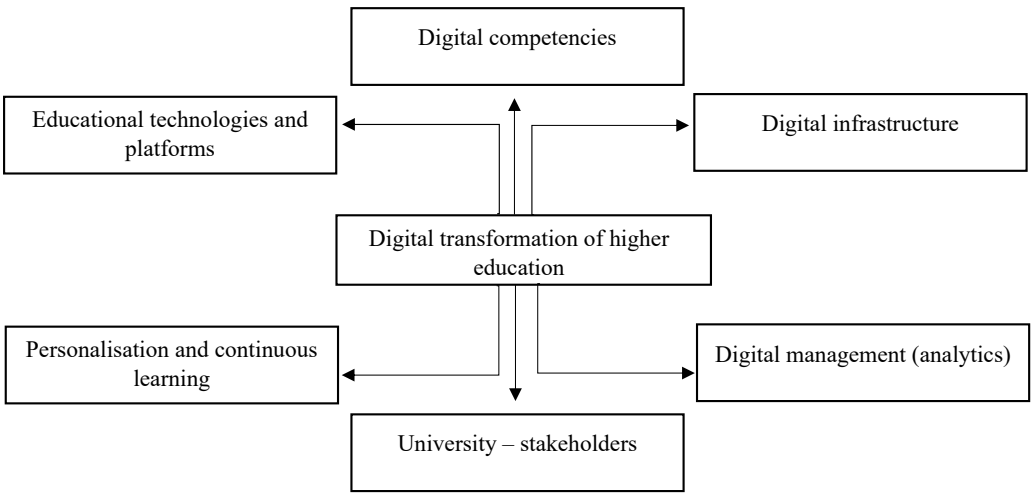

Figure 1. Key areas of digital transformation of higher education

Source: developed by the author based on Ordonez-de-Pablos & Bustinza, 2023; Fernández et al., 2023; Trevisan et al., 2024; Rachinger et al., 2024

34.7% to 36.3%. Finally, a comparable rise is seen in Turkey, where the figure has increased from 30.1% to 31.5%. Despite the positive dynamics observed, the absolute values remain significantly below the Central European level, indicating persistent disparities in the development of digital competencies (see Table 1).

In Ukraine, the proportion of individuals possessing basic digital skills rose from 52% in 2021 to 59% in 2023. This reflects the accelerating digitalisation of public services, the proliferation of remote learning formats, and the increasing importance of digital tools in everyday and professional life. Although the figure fell to 57% in 2025, an overall increase of 9.62% was recorded over the analysed period, indicating the continuation of the general upward trend. Compared to the European Union average, Ukraine is approaching Central European values, though it is still significantly behind the leading countries in terms of digital development.

Overall, the empirical data for the period 2021–2025 show that the growth of digital skills in Europe is uneven: countries with high levels of digital maturity not only maintain their leading positions, but also continue to increase the digital competence of their populations. In contrast, countries with lower initial levels demonstrate slower convergence with the EU average. In this context, achieving the EU's goal of an 80% digitally competent adult population by 2030 will require the strengthening of higher education's role as an institutional mechanism for scaling digital competencies and reducing internal structural gaps.

A significant trend is the growing importance of informal education and online learning in professional development, driven by the need to update competencies quickly in the digital economy. Many professionals now acquire new knowledge and skills through short-term online courses, training and professional certifications. According to Eurostat, approximately 30% of internet users in the European Union participated in online learning or used digital educational materials over a three-month period in 2023. This figure is more than double that recorded five years ago, indicating the rapid growth of electronic forms of education (Eurostat, 2024).

The advent of the pandemic has precipitated a substantial adoption of remote formats, compelling academic institutions to proactively cultivate blended

Table 1
Share of the population with basic digital skills, 2021-2025

Country	Years, %			2021 to 2025, %
	2021	2023	2025	
Netherlands	78,94	82,70	83,61	5,92
Finland	79,18	81,99	80,98	2,27
Norway	78,71	81,09	79,80	1,39
Switzerland	77,79	77,52	78,01	0,28
Ireland	70,49	72,91	82,82	17,49
Denmark	68,65	69,62	81,45	18,64
Czechia	59,69	69,11	70,45	18,02
Sweden	66,60	66,44	69,99	5,09
Spain	64,16	66,18	66,50	3,65
Austria	63,33	64,68	69,77	10,17
Estonia	56,37	62,61	62,52	10,91
France	61,96	59,67	65,74	6,10
Belgium	54,23	59,39	61,22	12,88
Croatia	63,37	58,95	63,38	0,02
Ukraine	52	59	57	9,62
Hungary	49,09	58,89	57,33	16,78
Portugal	55,31	55,97	59,15	6,94
Lithuania	48,84	52,91	53,80	10,15
Germany	48,92	52,22	59,55	21,74
Cyprus	50,21	49,46	55,75	11,03
Italy	45,60	45,75	54,27	19,01
Poland	42,93	44,30	50,42	17,45
Bulgaria	31,18	35,52	38,26	22,70
Serbia	41,30	33,61	42,02	1,74
Turkey	30,12	33,11	31,49	4,55
Bosnia and Herzegovina	34,65	30,08	36,25	4,62
Romania	27,82	27,73	31,84	14,45

Source: developed by the author based on Eurostat, 2025

learning and massive open online courses, which are being integrated into the formal educational infrastructure. Examples of current practices include the approach of the Swiss technical university ETH Zürich, where course chatbots perform the functions of a virtual teaching assistant. In this context, the chatbots answer students' questions based on materials from a specific discipline, provide feedback on assignments, and support routine assessment procedures under conditions of source database control and organisational constraints on data use (see Figure 2).

Concurrent with the development of "internal" digital services, universities are expanding their public educational offerings in the form of MOOCs as a tool for increasing access to modern knowledge and supporting continuous professional development, in particular through thematic online courses focused on practical competencies and applied cases (ETH Zurich, n.d.).

With regard to the digitalisation of formal educational pathways on an institutional level, the Ukrainian European University offers a noteworthy case study. The institution has developed digital services for applicants and students that facilitate seamless interaction with the university through a personalised digital account and integrated AI-based advisory tools. These innovations have been shown to reduce communication transaction costs and enhance the manageability of educational processes in blended formats (see Figure 3).

It is noteworthy that, according to estimates presented in the Online Education Market Report 2025, which was published on the Research and Markets platform, the global online education market exhibited a substantial growth, expanding from USD 68.07 billion in 2024 to USD 82.81 billion in 2025. This represents a compound annual growth rate (CAGR) of 21.7%, reflecting the heightened demand for flexible digital formats of learning and professional development (Research and Markets, 2025). This expansion can be attributed to a combination of infrastructural and socio-economic factors, including the spread of high-speed internet, increased access to mobile devices, growing demand for flexible educational schedules, and the institutionalisation of lifelong learning. It is anticipated that high growth rates will endure during the projected period. By 2029, the online education market is predicted to attain a value of 184.29 billion USD at a CAGR of 22.1%, thereby signifying the structural consolidation of digital formats within formal and informal educational systems (see Figure 2).

It can be posited that the growth of the online education market has not only a commercial dimension for higher education institutions but also an institutional and economic one. It has been argued that this change in the way human capital is reproduced reinforces the

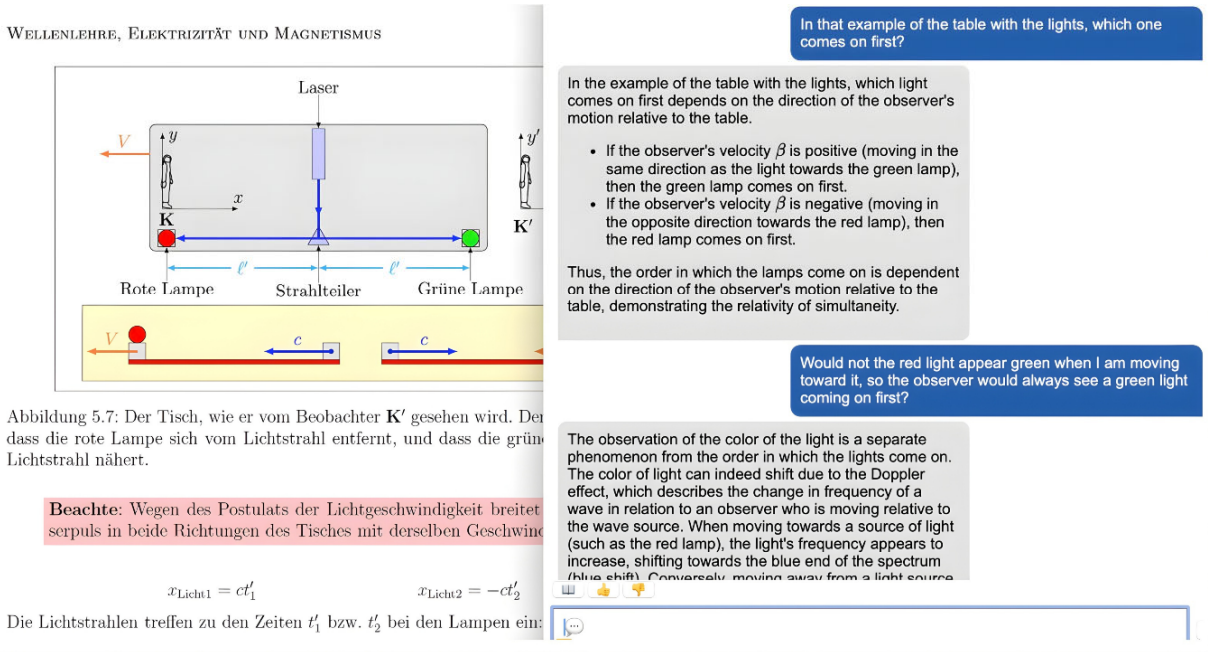

Figure 2. An example of a student interacting with an AI-based educational chatbot while working through a fragment of lecture material at ETH Zürich

Source: ETH Zurich, 2025

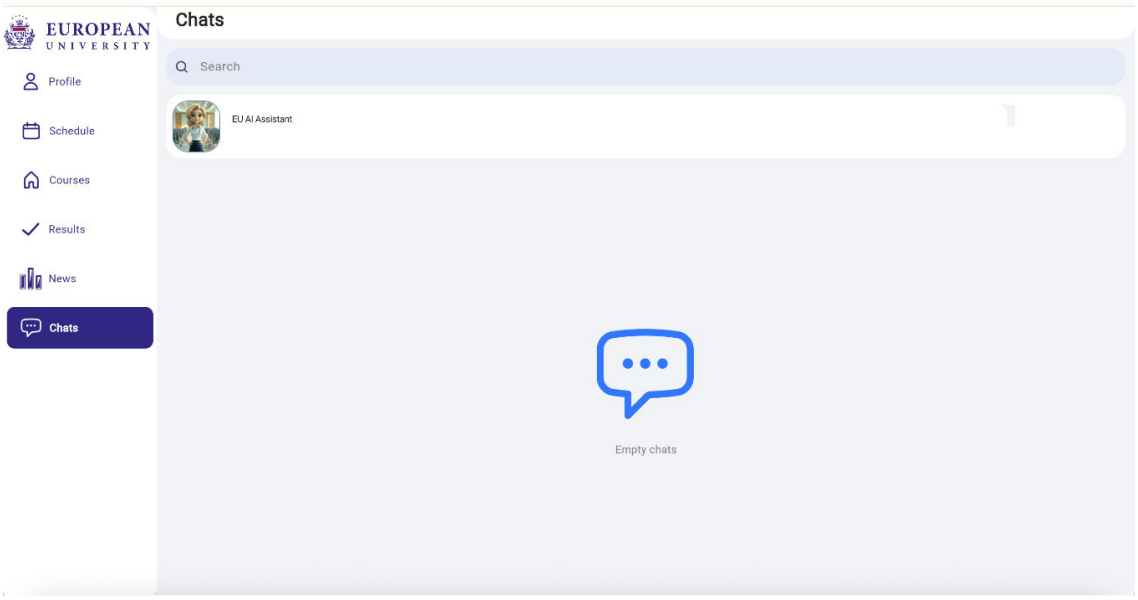

Figure 3. The chat module interface of the EUni digital platform with an integrated virtual assistant for consultations and support of learning interactions.

Source: developed by the author based on ETH Zurich, 2025

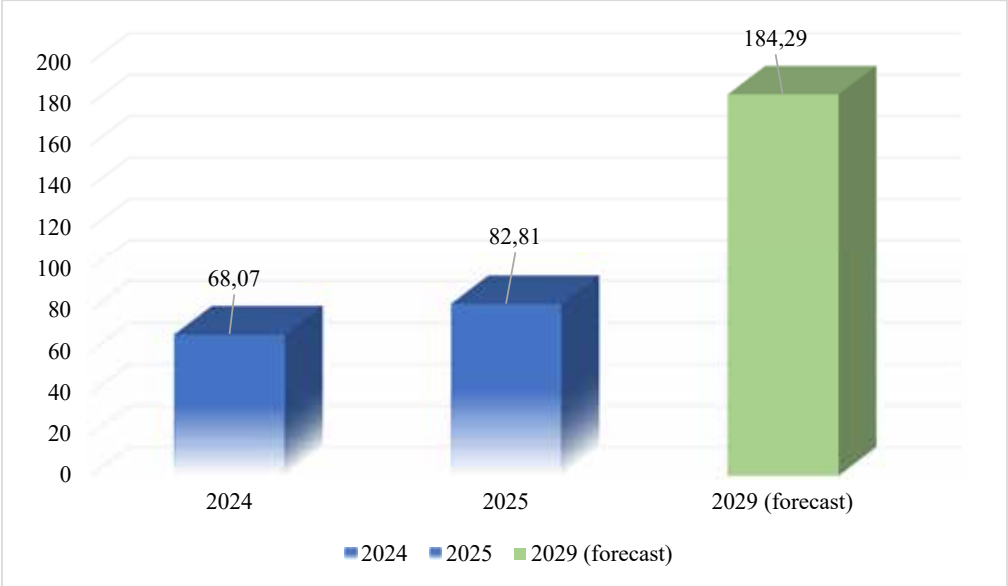

Figure 4. Dynamics of the global online education market size in 2024–2025 and forecast for 2029, billion USD

Source: developed by the author based on Research and Markets, 2025

requirement for universities to ensure continuous updating of digital and entrepreneurial competencies as a prerequisite for innovative activity and technological renewal of the economy. In response to the growing demand for flexible learning formats, universities are moving towards a multi-channel model of educational provision. Alongside traditional programmes, modular learning pathways, micro-credentials and certification products are becoming more widespread. These can be integrated into formal programmes while also meeting the labour market's need for rapid skills updating. The decisive factor is not the scale of digitalisation itself, but its institutional quality. This refers to the availability of a learning platform architecture and learning analytics, as well as quality assurance procedures for digital courses and rules for recognising online learning outcomes. It also refers to ethical frameworks for the use of artificial intelligence tools.

At the same time, the uneven distribution of basic digital skills among the population acts as a systemic constraint on scaling up such practices, determining the different starting conditions of universities with regard to student engagement in blended learning and digital services. Consequently, the digital transformation of higher education emerges as a significant economic mechanism that lowers barriers to accessing knowledge, accelerates the adoption of technological practices and supports the development of the skills base through which innovations are transferred into business processes and management decisions.

5. Conclusions

The analysis shows that the digital transformation of higher education is a systemic prerequisite for the economy's innovative activity and technological development, as it accelerates the reproduction of human capital, improves the quality of competence-based training and reduces the time gap between new knowledge emerging and it being put into practice. The institutional effects of digitalisation include increased educational accessibility, the scaling up of hybrid formats and the development of a culture of continuous skills updating. This enhances the labour market's receptiveness to technological change and promotes the adoption of innovation in production and management practices.

It has been demonstrated that the expansion of access to higher education in the digital environment can only be economically significant if the quality of the educational offering is maintained and enhanced. The pivotal factors in this regard are the competency-based reorientation of programmes, the institutionalisation of micro-credentials and modular trajectories, the utilisation of educational analytics, and the development of digital services that serve to reduce the transaction costs of interaction between students and universities and increase the manageability of educational processes. Concurrently, the heterogeneity of the population's fundamental digital competencies engenders disparate initial conditions for nations and academic institutions, thereby constraining the scope of digital formats and necessitating targeted instruments to facilitate equitable access to digital educational opportunities.

Recent studies have demonstrated that the proliferation of online education has not only resulted in the emergence of novel avenues for universities to offer educational programmes, but has also precipitated a paradigm shift in the manner in which competition for students' attention and trust is conducted. This development is indicative of a shift towards platform-based organisation of learning, standardisation of digital course quality, formalisation of procedures for recognizing online learning outcomes, and development of ethical and organisational frameworks for the use of artificial intelligence tools in the educational process. In this context, the digital transformation of higher education is regarded as a mechanism for enhancing the innovation capacity of the economy through the scaling of relevant technological and entrepreneurial competencies.

Prospects for further research are related to the development of models for quantitatively assessing the contribution of universities' digital maturity to indicators of economic innovation dynamics, clarifying the causal relationships between the population's digital skills and the effectiveness of digital educational formats, as well as designing quality indicators for digital educational services that reflect not only the technological level but also the institutional capacity of universities to ensure sustainable educational outcomes.

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