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Prospects for Integrating Virtual Reality and Artificial Intelligence into University Learning: Approaches to Developing Interactive Educational Environments

آفاق دمج الو اقع الافتراضي والذكاء الاصطناعي في التعليم الجامعي :مقاربات لتطوير بيئات تعليمية تفاعلية

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Abstract: The study aimed to identify key trends and define a conceptually coherent model for integrating virtual reality and artificial intelligence technologies into the university learning process. The methodology included a comparative method, document content analysis, expert verification, conceptual modelling, and scenario modelling. Three stages of expert verification produced a high level of consistency in evaluations across the criteria of necessity (mean – 4.8; median – 5), feasibility (mean – 4.4; median – 4) and innovation potential (mean – 4.8; median – 5), confirming the conceptual validity, practical feasibility and strong innovative capacity of the interactive educational environment model. This demonstrated the achievement of group consensus: 90% of experts assigned scores of 4-5 points in the second round and 96% in the third round, exceeding the 70% consensus threshold and confirming the model's conceptual coherence and practical feasibility. The highest level of consistency was recorded in the pedagogical and cognitive-communicative components, which experts identified as essential for maintaining the didactic integrity of virtual reality and artificial intelligence as complementary technologies. The technological component received an average score of 4.4 points, confirming its flexibility but also indicating the need for further adaptation of university infrastructure. The managerial-analytical component had the lowest variability (interquartile range ≤1), reflecting stable expert agreement regarding its internal logic. The synthesis of the results made it possible to formulate three scenarios: an innovation-adaptive scenario, a technology-optimisation scenario and a transformation-forecasting scenario. These scenarios reflected varying levels of institutional readiness for digital transformation and made it possible to outline a gradual trajectory from local initiatives to a

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comprehensive interactive ecosystem. The practical value of the study lies in the fact that the proposed model can serve as a methodological basis for developing university digital strategies, designing educational programmes, and establishing systems for monitoring the quality of digital learning processes. It enables universities to develop their own strategies for implementing intelligent technologies in accordance with staff readiness, available infrastructure and pedagogical priorities.

Keywords: Interactive learning, Digital technologies, Adaptive platforms, Virtual models, Educational innovation.

المستخلص: هدفت الدراسة إلى تحديد الاتجاهات الرئيسة وصياغة نموذج متماسك مفاهيمياً لدمج تقنيات الواقع الافتراضي والذكاء الاصطناعي في عملية التعلم الجامعي، حيث شملت المنهجية استخدام المنهج المقارن، وتحليل محتوى الوثائق، والتحقق الخبري، والنمذجة المفاهيمية، ونمذجة السيناريوهات. أسفرت ثلاث مراحل من التحقق الخبري عن مستوى عالٍ من الاتساق في التقييمات وفق معايير الضرورة(المتوسط4.8 ؛ الوسيط5)، وإمكانية التطبيق المتوسط(4.4 ؛ الوسيط4) ، وإمكانات الابتكار(المتوسط4.8 ؛ الوسيط5) مما يؤكد الصلاحية المفاهيمية وقابلية التطبيق العملي والقدرة الابتكارية العالية للنموذج، كما أظهر تحقيق إجماع جماعي حيث منح 90% من الخبراء درجات بين 4 و 5نقاط في الجولة الثانية و96%في الجولة الثالثة، وهو ما يتجاوز عتبة الإجماع البالغة70%، مما يعكس الاتساق المفاهيمي وقابلية التطبيق. وقد سُجِّل أعلى مستوى من الاتساق في المكونات التربوية والمعرفية-التواصلية التي اعتُبرت أساسية للحفاظ على التكامل التعليمي للتقنيات، في حين حصل المكون التكنولوجي على متوسط 4.4 نقاط، مما يدل على مرونته مع الحاجة إلى مزيد من تكييف البنية التحتية الجامعية، بينما أظهر المكون الإداري-التحليلي أقل تباين(1≤) ، مما يعكس استقرار توافق الخبراء .وأتاح تحليل النتائج صياغة ثلاثة سيناريوهات هي :التكيف الابتكاري، وتحسين التكنولوجيا، والتحول الاستشرافي، والتي تعكس مستويات مختلفة من جاهزية المؤسسات للتحول الرقمي وتحدد مسارًا تدريجيًا من المبادرات المحلية إلى منظومة تفاعلية متكاملة .وتكمن القيمة التطبيقية في إمكانية اعتماد النموذج كأساس منهجي لتطوير الاستراتيجيات الرقمية للجامعات، وتصميم البرامج التعليمية، وبناء أنظمة لمراقبة جودة التعلم الرقمي، بما يتيح مواءمة تطبيق التقنيات الذكية مع جاهزية الكوادر والبنية التحتية والأولويات التربوية.

الكلمات المفتاحية: التعلم التفاعلي، التقنيات الرقمية، المنصات التكيفية، النماذج الافتراضية، الابتكار التعليمي.

1 INTRODUCTION

The integration of virtual reality (VR) and artificial intelligence (AI) into university learning opens up new opportunities for creating interactive educational environments that support knowledge acquisition and the development of practical skills. The use of these technologies makes it possible to adapt curricula to students' individual needs, model complex processes and situations, and promote active engagement in learning. The use of VR and AI contributes to the development of future professionals' competencies, increases motivation to learn, and facilitates the implementation of innovative methods in higher education. At the same time, the development of these technologies stimulates research in the field of pedagogical methods and opens up new opportunities for interdisciplinary collaboration between educational institutions and industry.

Al-Gindy et al. (2020) created an integrated VR-based learning environment to allow students to immerse themselves in simulated professional scenarios. The results showed that VR enabled the acquisition of practical skills and improved understanding of complex ideas through visualization and interactivity. A

similar trend was observed in the study by Tiwari et al. (2023): a scientometric analysis of publications on VR and AR in distance learning showed that virtual technologies have become a key tool in the transformation of online education. Mohammed et al. (2021) investigated the issue of using intelligent technologies in pedagogical practice and analyzed teachers' attitudes toward the use of AI in teacher training programs. The authors noted that the introduction of intelligent systems into the learning process improved the effectiveness of assessment, simplified the individualization of tasks, and allowed for monitoring students' academic progress. At the same time, the researchers emphasized the need to develop teachers' digital competencies, without which the sustainable integration of AI into education cannot be ensured. The latest educational technologies and the prospects of their impact on learning systems were the subject of analysis in the study by Almufarreh and Arshad (2023). According to the authors, the most promising areas are AI, augmented reality (AR), and adaptive learning, which together have created the conditions for a dynamic educational environment with individualized learning trajectories. In a systematic review conducted by Chalkiadakis et al. (2024), it became possible to assess the impact of AI and AR on educational inclusion. The authors demonstrated that these technologies have opened new opportunities for supporting students with visual, hearing, and motor impairments through multimodal forms of information and adaptive interfaces. The developed solutions helped reduce cognitive load and ensured equal access to educational resources.

Zhang et al. (2025) presented an overview of current achievements in the field of VR and AR in education. The authors concluded that VR is an effective tool for deep immersive learning in disciplines requiring visual modeling of processes, while AR supports the contextualization of knowledge in a real-world environment. Both technologies proved indispensable for the transition from reproductive to inquiry-based learning. An analysis by Shirazi et al. (2024) revealed a growing trend toward the convergence of VR and AI into a single educational system. The researchers demonstrated that combining these technologies allows not only for the simulation of learning situations but also for the intelligent adaptation of content and task complexity to students' abilities. This has paved the way for the creation of learning systems with a high degree of intellectual flexibility, capable of independently adjusting the direction of learning. Alam (2021) highlighted the benefits and risks associated with the implementation of AI in education. The author discussed the technology's potential for supporting personalized learning pathways but warned of ethical risks, such as algorithmic bias and data privacy. The findings underscored the need to develop regulations and ethical guidelines to govern the use of AI in educational practice.

Chaka (2023) examined, within a review of the Fourth Industrial Revolution, the potential of AI, robotics and blockchain in higher education. The analysis highlighted that AI and VR had become key factors in creating flexible learning systems that combine automation, analytics and open access to knowledge. However, attention was also drawn to social risks, including unequal access to technologies and the growing dependence of educational processes on commercial digital platforms. The study by Pyae et al. (2023) provided an empirical analysis of user experience in a meta-learning environment. It was found that students' level of engagement in a VR space depended on interface usability, clear navigation and a strong sense of presence within the virtual environment. The authors concluded that well designed VR platforms enhanced learning motivation and overall learning effectiveness. The review, therefore, demonstrated that VR and AI functioned as complementary components of contemporary interactive

educational environments. VR offers immersion, experimentation and practical knowledge reproduction, while AI provides analytical support, adaptability and personalised learning (Hevko et al., 2021; Bessarab et al., 2022). Researchers emphasised that the effective integration of these technologies required not only technical readiness but also a pedagogical rethinking of teaching methods, improved teacher training and the development of ethical standards for digital education.

Several gaps were identified. Although previous studies proposed integrated frameworks for VR and AI in education, insufficient attention had been given to a university-level model that links technological, pedagogical, cognitive-communicative and managerial-analytical dimensions within one interactive learning environment. In addition, issues of systematic management of digital educational ecosystems and empirical evidence on the long-term effectiveness of VR and AI interaction remained insufficiently addressed. Most studies also focused on technical aspects while giving less attention to the pedagogical mechanisms required to develop interactive learning environments.

This study aimed to identify the conceptual foundations and construct a coherent model for integrating VR and AI technologies into the learning process. The objectives of the study were to analyse approaches to integrating VR and AI in the development of interactive educational environments; to conduct a content analysis of documents in order to identify key trends, clusters and thematic priorities in the implementation of VR and AI in higher education; and to carry out expert evaluation and scenario modelling to verify the coherence, feasibility and potential of the proposed model of the university's interactive educational environment.

2 MATERIALS AND METHODS

The research was based on systemic and interdisciplinary approaches, which enabled an examination of the prospects for integrating VR and AI technologies into university learning. The study relied on a set of interconnected methods, the sequential application of which made it possible to analyse scientific and practical approaches, model an interactive educational environment and verify its conceptual coherence through expert validation. A comparative method was employed to examine scientific concepts, models and practices related to the integration of VR and AI in higher education. The comparison was carried out according to the following criteria: pedagogical purposes of using the technologies, didactic capabilities of interactive environments, the level of technological readiness in universities and expected educational outcomes. The application of this method made it possible to identify common patterns in the introduction of VR and AI into the educational space and to distinguish the factors influencing the effectiveness of these processes. The results of the comparative analysis formed the basis for refining the conceptual framework and identifying key trends in the development of digital education in higher education. A content analysis of documents was conducted, including AI and education: guidance for policy-makers (Fengchun et al., 2021); Education in the digital age: Healthy and happy children (Burns and Gottschalk, 2020); OECD digital education outlook 2023: Towards an effective digital education ecosystem (Organisation for Economic Co-operation and Development, 2023); Digital education action plan 2021-2027: Unlocking Europe's digital potential (European Education Area, 2026); Shaping the Future of Education, Gender and Work (World Economic Forum, 2018); Reimagining education in the

age of AI (Tabor, 2025); Artificial Intelligence Revolution in Higher Education: What you need to know (2025); Global Skills Report (Coursera, 2025); Pinsel.AR (British Council, 2026); Digital Competence Framework for Educators (DigCompEdu) (The Joint Research Centre: EU Science Hub, 2026); Artificial Intelligence and the Futures of Learning (United Nations Educational, Scientific and Cultural Organization, 2024); Artificial intelligence in higher education (Times Higher Education, 2026); and the 2026 GEM report: Countdown to 2030: Access and equity (United Nations Educational, Scientific and Cultural Organization, 2026).

A conceptual modelling method was applied to develop a generalised model of the university's interactive educational environment in which VR and AI function as complementary components of the digital ecosystem. The model was defined as a four-block structure comprising technological, pedagogical, cognitive-communicative and managerial-analytical blocks. VR and AI were treated as cross-cutting technological components and assessment dimensions rather than as separate model blocks. To verify the coherence, completeness and practical feasibility of the constructed interactive educational environment model, expert validation was conducted using the Delphi procedure. Twelve experts took part in the validation process, including five doctors of science, four candidates of science and three practitioners with experience in developing or implementing VR and AI technologies in the learning process. Expert selection was operationalised through three measurable criteria: professional competence, defined as an academic degree in education, educational technology, information technology or a related field, or practical involvement in university digital learning projects; scholarly activity, defined as at least three publications on educational technology, AI, VR or digital pedagogy within the last five years; and practical experience, defined as at least two years of involvement in implementing VR, AI or digital learning solutions in a university setting. The inclusion criteria required experts to meet at least two of these criteria. The exclusion criteria involved a lack of relevant academic or practical experience or previous participation in similar Delphi studies. Ethical requirements of confidentiality were observed in accordance with the principles of the WMA Declaration of Helsinki (2024).

The procedure was conducted in three stages. The first stage involved collecting qualitative data in the form of open-ended responses concerning the structure, logical coherence and substantive content of the model. Experts were asked to assess the clarity of the model's components, the completeness with which it reflected educational processes, and the interconnections between the pedagogical, technological, cognitive-communicative and managerial-analytical blocks. The responses were subjected to thematic coding, after which a consolidated matrix of recommendations was produced. The second stage had a quantitative character and involved evaluating the model's components according to three criteria: necessity – the extent to which an element was essential for achieving the model's purpose; feasibility – the practical possibility of implementing the element within the university environment; innovative potential – the degree of novelty and forward-looking value of the element. Assessment was carried out using a five-point scale, where 1 point indicated minimal conformity with the criterion and 5 points indicated maximum conformity. Each expert completed a questionnaire containing 18 items grouped into four blocks of the model: pedagogical, cognitive-communicative, technological and managerial-analytical. VR and AI were assessed as cross-cutting technological dimensions within these

blocks. The third stage aimed to achieve group consensus. Each expert received the summarised analysis from the second round, including the mean and median values and the range of scores. After reviewing the group results, the experts reassessed the same items. Consensus was considered reached when the median value was at least 4, the interquartile range did not exceed 1, and at least 70% of participants assigned a score of 4-5 points. Upon completion of the third stage, the results were consolidated into a final matrix reflecting the agreed scores for all criteria and blocks of the model. This matrix served as the basis for refining the terminological definitions and clarifying the relationships between the structural components of the model.

The final stage involved scenario modelling to determine possible pathways for introducing VR and AI into the university educational process. The scenarios were constructed using a qualitative scenario-logic approach rather than a morphological cross-impact matrix or probability weighting. The main scenario drivers were derived from the content-analysis clusters and the Delphi results: institutional readiness, technological infrastructure, educator digital competence, pedagogical adaptability, ethical risk management and expected educational outcomes. These drivers were compared according to the level of implementation intensity and institutional readiness, which produced three scenarios for the development of interactive learning environments: the innovation-adaptive scenario, the technology-optimisation scenario and the transformation-forecasting scenario.

2.1 Approaches to integrating VR and AI into the creation of interactive learning environments

The development of higher education is marked by changes associated with the transition to a digital learning paradigm, in which VR and AI technologies play a central role. Their introduction contributes to a rethinking of traditional forms of interaction between the lecturer, the student and the learning content, shaping a new type of educational space – the interactive learning environment. An interactive learning environment is understood as a holistic pedagogical, informational and technological system that enables active engagement between the participants in the educational process and the content, as well as interaction among the participants themselves, through digital technologies. Such an environment combines cognitive, communicative, and practical aspects of learning, enhances the sense of immersion, stimulates interest, and promotes the development of self-directed learning skills (Chiu, 2021). VR is a tool for creating simulated learning situations in which students can interact with objects, models, or phenomena under conditions that are as close to reality as possible (Bondarenko et al., 2022; Chonmurunova & Bagicheva, 2024). VR is used in higher education institutions for laboratory classes, training simulators, visualization of complex processes, and spatial learning. AI, in turn, provides the analytical and adaptive aspects of interactive learning by automating assessment, personalizing learning trajectories, analyzing educational data, and optimizing pedagogical decision-making (Li et al., 2022). The use of VR and AI in higher education is viewed as a strategic opportunity to modernize university education in terms of leveraging technological capabilities and pedagogical innovations. Thus, a

comparative method was applied to analyze scientific approaches and practical implementations of VR and AI integration in higher education. Table 1 presents the results of the comparative analysis.

Table (1). Comparison of conceptual approaches to using VR and AI in the creation of interactive learning environments

Criteria	VR	AI	VR+AI integrated
Pedagogical aim	Immersion in the learning process, development of spatial thinking, and acquisition of practical skills through activity simulation	Personalisation of learning, adaptation of educational content to student needs, and support for educational data analytics	Creation of an adaptive immersive learning process in which simulation, personalisation and feedback operate together to support student-centred learning
Didactic capabilities	Visualisation of complex objects and processes, interactive engagement with learning content, creation of research-based scenarios	Automated assessment, recommendation systems, content generation, and prediction of learning outcomes	Immersive simulations supported by automated guidance, adaptive task complexity, real-time feedback, content recommendation and learning analytics
Technological component	Use of VR headsets, 3D scenes, simulators, and spatial classrooms; requires high computational power	Machine learning algorithms, neural networks, intelligent agents, and speech and image recognition systems	Integration of VR/AR platforms with AI algorithms, educational data analytics, intelligent tutoring systems and adaptive interfaces; requires interoperable infrastructure
Pedagogical implementation conditions	Prior technical preparation of lecturers and students; integration into practice-oriented courses	Training in the use of analytical platforms, development of teachers' digital competencies, and ethical responsibility	Training lecturers to design immersive tasks, interpret AI analytics and maintain ethical and pedagogically justified use of VR/AI in courses
Expected outcomes	Increased student engagement, development of critical thinking, and acquisition of research skills	Optimisation of the learning process, improved assessment accuracy, and increased effectiveness of learning strategies	Higher engagement, personalised learning trajectories, improved feedback accuracy, development of practical, analytical and research skills
Limitations and risks	High equipment costs, potential technical malfunctions, limitations on usage duration	Risks of algorithmic bias, data privacy concerns, and dependence on the quality of training datasets	Combined costs of infrastructure and data governance; risks of unequal access, algorithmic bias, data privacy problems, technical failures and overdependence on digital platforms

Source: compiled by the authors.

The synthesis of the comparison results indicates that combining VR and AI not only expands the technical capabilities of the learning process but also establishes a new pedagogical paradigm centred on interaction, personalisation and research-based learning. The comparative analysis made it possible to trace how each technology performs its own function while simultaneously enhancing the effect of the other. VR creates conditions for immersive learning, fostering students' emotional engagement, the

development of spatial thinking and a sense of presence in the learning scenario (Loucif et al., 2019; Kryshtanovych et al., 2021). In contrast, AI provides the intellectual support for this process: analysing student activity data, predicting learning outcomes, and adapting educational content to students' preparedness and pace of learning. This combination allows VR and AI to be viewed as a system of interconnected technological components, where one creates an environment for action and the other an environment for thinking. This supports the notion of a new type of learning environment – an interactive digital ecosystem – in which the learning process is not linear but dynamic, with continuous feedback between the user and the technological system. Such an approach promotes a shift from passive knowledge acquisition to active exploration, experimentation and independent discovery of new knowledge. The comparison results also demonstrated that VR and AI perform a compensatory function with respect to the limitations of traditional education. Virtual reality enables the reproduction of learning conditions that are physically inaccessible (for example, laboratory experiments or complex technical or clinical processes), while artificial intelligence ensures accurate analysis of outcomes and personalised support for students (Akylbekova et al., 2025; Shaikh, 2026). In this way, digital technologies do not merely supplement the educational environment but transform the very logic of learning, making it adaptive, continuous and responsive to the changing needs of users.

The comparison also indicated that integrating VR and AI supports the development of future-oriented competencies, including creativity, critical thinking, communicative flexibility, the ability to work with large datasets, and decision-making based on analytics. This outcome is particularly relevant for universities seeking to modernise the educational process in line with the demands of the digital economy. As a result, the learning environment is transformed into a "laboratory of the future", where the student is not merely a consumer of information but an active creator of knowledge and a participant in intellectual interaction with digital agents. The application of the comparative method enabled the identification of common patterns in the implementation of VR and AI in higher education. In particular, it was determined that the effectiveness of these processes depends on a balance between technical infrastructure and pedagogical appropriateness, the level of digital literacy among lecturers, and the institution's readiness for innovative change. It was also established that successful examples of VR and AI integration are always founded on interdisciplinary collaboration, combining pedagogical, engineering and cognitive approaches. Thus, the synthesis of the comparative results provided the basis for justifying the development of a generalised conceptual model of an interactive learning environment, in which VR and AI are considered not as separate innovations but as components of a unified system of educational interaction. This formed the foundation for subsequent conceptual modelling, aimed at integrating both technologies into a coherent pedagogical framework that combines the cognitive, technological and communicative dimensions of learning. Thus, the results of the comparative analysis

not only confirmed the complementary nature of VR and AI but also established a direction for future research towards the development of intelligent, digitally managed educational ecosystems.

2.2 Results of the content analysis on the role of virtual reality and artificial intelligence

Content analysis enables the identification of key trends in understanding the role of virtual reality and artificial intelligence in the transformation of educational systems. Three thematic domains were highlighted during the analysis: pedagogical, technological, and managerial-strategic, which together provided a comprehensive view of the concept of an interactive learning environment.

In AI and education: guidance for policy-makers (Fengchun et al., 2021) and Reimagining Education in the Age of AI (Tabor, 2025), the central focus was on rethinking the roles of lecturers and students in the context of digitalisation. Emphasis was placed on the shift from a transmissive model of teaching to an interactive, project-based approach, in which VR facilitates immersion in learning activities, while AI supports individual learning pathways through adaptive algorithms. OECD (2023) and the World Bank (2025) reports stressed that intelligent technologies create conditions for the development of students' cognitive autonomy and enhance motivation for independent learning. In these frameworks, VR is viewed as a tool for constructing simulated learning scenarios that bring the educational process closer to real professional contexts. The pedagogical dimension also encompassed the development of emotional intelligence and social skills, which, according to the World Economic Forum (2018) Shaping the Future of Education, Gender and Work, remain fundamental in digital learning environments. Most sources emphasised that the combination of VR and AI supports the development of future-oriented competencies, including creativity, communication, critical thinking and self-reflection.

The content of documents such as the European Education Area (2026) Digital Education Action Plan 2021-2027, Artificial Intelligence and the Futures of Learning (United Nations Educational, Scientific and Cultural Organization, 2024), and Education in the digital age: Healthy and happy children (Burns and Gottschalk, 2020) indicated that effective implementation of VR and AI is only possible with the establishment of an integrated digital infrastructure. VR technologies in higher education are described as an interactive educational interface that combines learning resources, communication channels, and feedback tools. AI performs an analytical and predictive function: it collects and analyzes learning data, assesses the level of understanding, and provides personalized prompts and recommendations. The report "Digital Competence Framework for Educators" (Joint Research Centre: EU Research Hub, 2026) emphasizes the need to train teachers to work with intelligent platforms. Technological readiness was determined not only by the availability of technical resources but also by the level of digital literacy among educators—their ability to use VR and AI to create an inclusive and ethically responsible learning environment (Arkabaev et al., 2025; Kapoor et al., 2025). Publications by Times Higher Education (2026) and the British Council (2026) emphasized the practical aspects of implementing projects using VR and

AI in the educational process. It was found that the implementation of these technologies enables the creation of interactive simulation labs that model complex processes in a safe environment, as well as intelligent mentoring systems that support students in completing practical tasks.

The documents emphasized that the implementation of VR and AI in higher education requires a systematic approach to management. The 2026 GEM Report: "Countdown to 2030: Access and Equity" (United Nations Educational, Scientific and Cultural Organization, 2026) recommended that policies on digital transformation take into account issues of data ethics, privacy protection, and academic integrity. Particular emphasis was placed on institutional readiness for the integration of VR and AI. As noted in the Digital Education Action Plan for 2021–2027 (European Education Area, 2026), an important aspect is the creation of interdisciplinary teams that combine expertise in pedagogy, IT, psychology, and educational administration. Research by the World Bank, United Nations Educational, Scientific and Cultural Organization (UNESCO) and Coursera (2025) indicated that universities integrating VR and AI into their curricula exhibit higher programme flexibility, active international collaboration, and the development of open learning platforms. The results allowed for the structuring of the identified thematic directions into three clusters, reflecting the comprehensive logic of developing an interactive learning environment (Table 2).

Table (2). Structure of content analysis results on the implementation of VR and AI in higher education

Cluster	Thematic characteristics	Key focus areas
Pedagogical	Transformation of the lecturer's role, personalised learning, interactivity and development of cognitive autonomy	Shift to a student-centred model; development of future-oriented competencies; immersion through VR
Technological	Development of digital infrastructure, integration of VR and AI into learning platforms, educator training	VR as an educational interface, AI as an analytical tool; fostering digital literacy among lecturers
Managerial-strategic	Policy development, ethical standards, institutional readiness, international collaboration	Systematic management of innovations, academic integrity, interdisciplinary cooperation

Source: compiled by the author based on World Economic Forum (2018), Burns and Gottschalk (2020), Fengchun et al. (2021), Organisation for Economic Co-operation and Development (2023), Artificial intelligence revolution in higher education: What you need to know (2025), Tabor (2025), Coursera (2025), United Nations Educational, Scientific and Cultural Organization (2024; 2026), European Education Area (2026), British Council (2026), The Joint Research Centre: EU Science Hub (2026), Times Higher Education (2026).

The analytical conclusion from the content analysis indicates that contemporary international educational policy views VR and AI not as isolated technological innovations but as strategic drivers of systemic higher education modernisation. Analysis of regulatory, programme and analytical documents demonstrates that these technologies are gradually becoming fundamental components in the construction of interactive educational ecosystems that integrate pedagogical, technological and

managerial dimensions of university development. The pedagogical cluster of documents highlights a rethinking of the lecturer's role and a shift towards a student-centred approach to learning. UNESCO recommendations show a consistent trend towards implementing learning formats focused on research activity, creativity and cognitive autonomy. In these sources, VR is presented as a tool for immersive learning experiences, creating a sense of presence, stimulating student interest and motivation, and enhancing knowledge acquisition through interactive engagement. AI, in turn, is defined as a tool for providing personalised support and analytical guidance within the educational process. This integration allowed the identification of the primary pedagogical focus: the development of future-oriented competencies, including critical thinking, interdisciplinarity and digital reflection. The technological cluster of materials highlighted the leading directions in the digitalisation of higher education. In these documents, VR is described as a new educational interface, enabling the creation of interactive laboratories, simulation environments, and learning spaces with elements of augmented reality. AI is presented as an analytical mechanism capable of processing large volumes of educational data, generating adaptive learning trajectories, and predicting outcomes. The content analysis indicated that the effectiveness of implementing VR and AI directly depends on the digital literacy of educators and the availability of appropriate infrastructure. For this reason, international strategies emphasise the need to prepare teaching staff to operate effectively within interactive digital environments.

The managerial-strategic cluster revealed a trend towards institutionalising the digital transformation of education. The documents highlight the need for ethical standards for AI use, academic integrity, data-risk management and national frameworks for digital education policy. The importance of international cooperation and interdisciplinary exchange in the development of VR/AI projects for universities is also stressed. These sources demonstrate that sustainable implementation of VR and AI is possible only under systematic innovation management, where digital solutions are integrated into the educational strategy at the level of institutional culture. Comparing the results across the three clusters allowed for the formation of a comprehensive understanding of the trends shaping higher education in the digital age. VR and AI emerge as interconnected tools of pedagogical innovation, combining elements of visual interaction, adaptability, and cognitive analytics. Educational strategies increasingly define the interactive learning environment not merely as a collection of technological solutions, but as a dynamic educational ecosystem in which technologies are subordinated to pedagogical objectives (Hamam and Loucif, 2009; Artyukhov et al., 2025). A clear trend was identified towards establishing global quality standards for digital education, emphasising transparency, ethical practice, and the effective use of artificial intelligence in learning. Consequently, the content analysis provided methodological guidance for the further conceptual modelling of an interactive university learning environment. Based on the analysed documents, VR is defined as a medium for simulated interaction that ensures immersive learning, while AI functions as an analytical and predictive mechanism, providing intellectual support for

educational processes. Together, these components form the foundation for a coherent model of digital education aimed at fostering adaptability, creativity, and critical thinking among students. Thus, the content analysis not only highlighted the key directions of universities' digital transformation but also provided a structural basis for the theoretical modelling and verification of the proposed educational concept.

Building on the generalised theoretical principles and the results of analytical methods, a consolidated model of an interactive university learning environment was developed, in which virtual reality and artificial intelligence function as complementary components of a unified digital ecosystem. To visually represent the interconnections between the main blocks of the model, it is useful to refer to the generalised diagram of its structure (Figure 1).

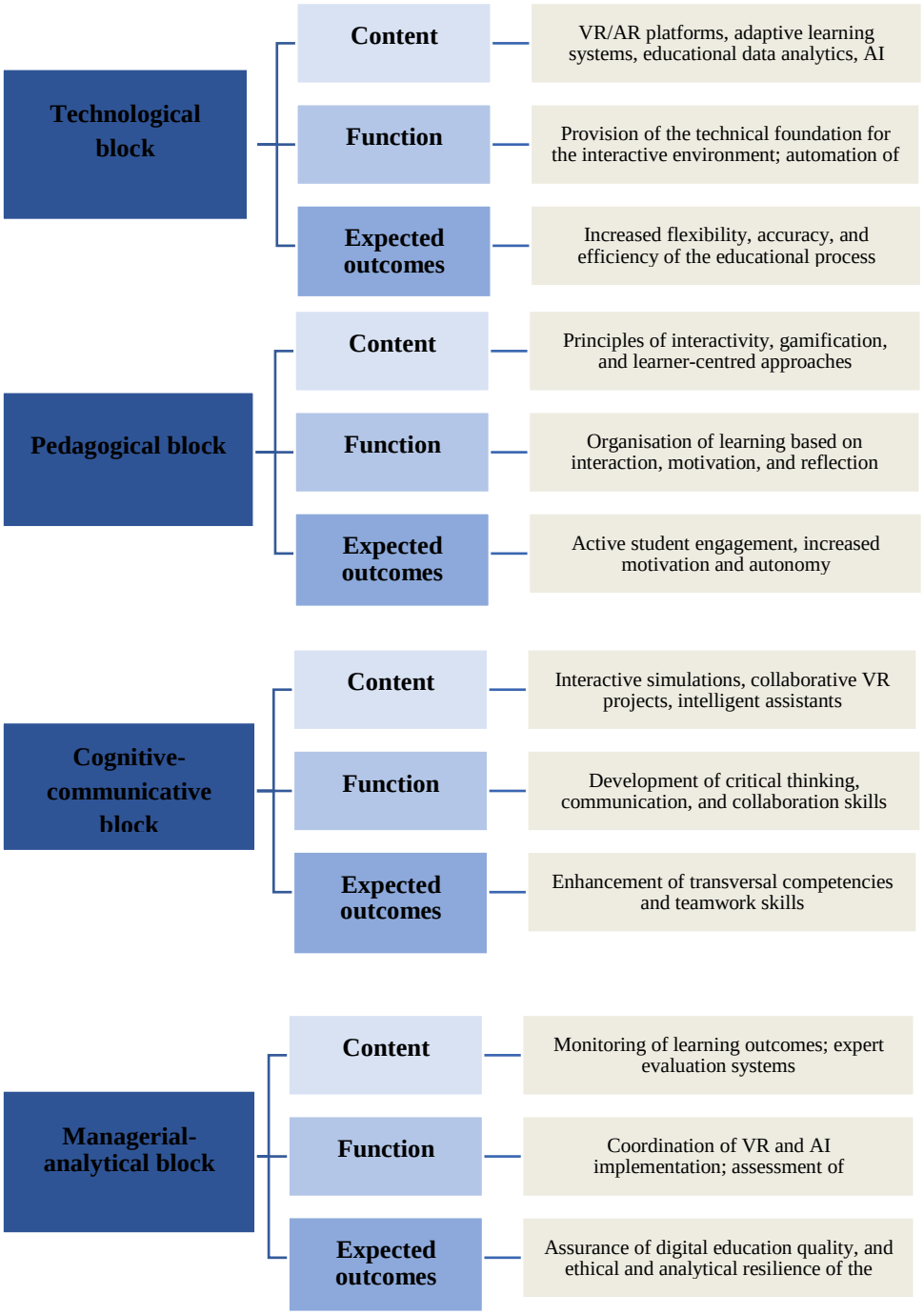


Figure (1). Conceptual model of an interactive university learning environment with integrated VR and AI

Source: compiled by the authors.

The conceptual model of the interactive university learning environment, as presented in Figure 1, demonstrates a holistic view of the process of integrating VR and AI into the modern educational system. The generalised structure allows for the tracing of interconnections among the four blocks – technological, pedagogical, cognitive-communicative and managerial-analytical. Its construction provides not only a systematic organisation of theoretical work but also establishes a logical foundation

for the practical implementation of digital transformation in university education. The inclusion of the technological block made it possible to identify the key role of VR and AI as tools that form the infrastructural foundation of an interactive learning environment. The technological component enabled the flexible adaptation of learning scenarios, the creation of virtual laboratories, the simulation of professional situations, and the personalisation of educational content. This provided a basis for individualising the learning experience, allowing each student to follow an optimal developmental trajectory according to their own abilities and needs. The pedagogical block provided a conceptual framework for structuring the educational process around interaction, gamification, and the development of student autonomy. Its presence within the model confirmed that, even in a digitalised context, the central principle remains the humanisation of education, where technology does not replace the teacher but enhances the impact of pedagogical interaction. Through this block, VR and AI are positioned not as ends in themselves, but as didactic tools capable of improving knowledge acquisition and student motivation.

The inclusion of the cognitive-communicative block in the model clarified how interactive technologies contribute to the development of critical thinking, collaboration, communicative competence, and digital reflection. This component emphasised that the effectiveness of learning in a digital environment is determined not only by the amount of information acquired, but also by the depth of understanding, the ability to work in teams, to justify one's position, and to reflect on one's own learning experience. In this way, the model confirmed that the development of cognitive and communicative skills constitutes a central outcome of integrating VR and AI into the educational process. The addition of the managerial-analytical block provided the model with systemic coherence and practical completeness. This block functioned as a regulator, coordinating the other components, monitoring learning outcomes, evaluating the effectiveness of technology implementation, and ensuring compliance with ethical standards. The inclusion of a managerial dimension demonstrated that digital education cannot operate without continuous quality control, risk assessment, and forecasting the implications of technological decisions.

Synthesising the data across the four interrelated blocks revealed the systemic logic underlying the construction of an interactive learning environment. The model showed that the effectiveness of integrating VR and AI into higher education depends on alignment between technological capabilities, pedagogical principles, cognitive outcomes, and managerial support. This integration enabled a shift from the fragmented use of digital tools to a holistic approach, where each element has a clearly defined function within the structure of the learning process. The developed model not only consolidated the results of previous research stages but also established a theoretical foundation for subsequent experimental testing and the development of practical methodologies. Its significance lies in providing a conceptual framework for understanding the mechanisms of integrating innovative technologies into university education, taking into account pedagogical, cognitive, and managerial aspects. Consequently,

VR and AI can be considered not as isolated tools but as components of a unified digital ecosystem aimed at fostering a new quality of the learning experience. Thus, the generalised conceptual model provided a methodological foundation for further research, including the expert verification of its components and the identification of practical conditions for its effective implementation in the learning process. It reflected the logic of a systemic approach, where the university learning environment is regarded as an open, dynamic, and self-regulating system, capable of continuous development and adaptation in the context of digital transformation.

2.3 Expert evaluation of the model and scenario modelling

To consolidate the results of the second and third stages of expert verification, a statistical analysis of the assessments was conducted across three criteria: necessity, feasibility, and innovative potential. The analysis considered the frequency distribution of scores on a five-point scale, as well as the calculation of mean and median values for each criterion. This enabled the determination of the degree of consensus among experts before and after the repeated evaluation (Table 3).

Table (3). Distribution of expert evaluations of the interactive learning environment model (Delphi procedure)

Criterion	Mean value (Stage II)	Median value (Stage II)	Mean value (Stage III)	Median value (Stage III)
Necessity	4.6	5	4.8	5
Feasibility	4.2	4	4.4	4
Innovative potential	4.7	5	4.8	5

Source: compiled by the authors.

The results of the expert verification indicated a high level of consensus and confirmed the stability of expert judgments regarding the structure and content of the university's interactive learning environment model. In the second round, most experts gave high ratings for necessity: 42% awarded 4 points, 48% awarded 5 points, while only 8% rated this parameter as 3 points. The mean score was 4.6 and the median 5, demonstrating widespread recognition of the model's conceptual significance. For the criterion of feasibility, a slightly greater variation of opinions was observed: 55% of experts rated it 4 points, 22% gave 5 points, and 18% assigned 3 points. A small proportion (5%) rated this indicator at 2 points, reflecting differences in assessments of the technical and resource capabilities for implementing such solutions at various universities. The average rating was 4.2, and the median was 4, indicating a high level of feasibility; however, the need to refine the management and analytical component was acknowledged. The highest ratings were given to innovative potential, where 53% of experts gave 5 points, 37% gave 4 points, and only 10% gave 3 points. The average rating of 4.7 and the median of 5

clearly indicated that the model was perceived as innovative and relevant to current trends in the digitalization of education.

After the third evaluation stage, the ratings converged toward a greater consensus. Regarding necessity, the percentage of top ratings (5 points) rose from 48% to 56%, and the average score increased to 4.8. Regarding feasibility, the percentage of 3-point ratings decreased from 18% to 9%, while the percentage of 4- and 5-point ratings rose to 86%, and the average score increased from 4.2 to 4.4. Regarding innovation potential, the share of 5-point ratings rose from 53% to 61%, and the average rating increased from 4.7 to 4.8. Calculation of median values demonstrated the stability of group ratings. For all criteria, median ratings remained in the range of 4 to 5, indicating a high level of consensus. The interquartile range for all three criteria did not exceed 1. The percentage of experts who assigned ratings in the 4–5 range ranged from 90% in the second round to 96% in the third. This indicates that all criteria met the consensus criteria (median ≥4, interquartile range ≤1, and at least 70% of ratings in the range of 4 to 5).

A comparison of the results obtained in the second and third stages showed a gradual increase in the level of agreement and a decrease in discrepancies in the perception of the model. Some experts who had expressed doubts about the practical feasibility of implementing certain elements changed their assessment to broad support after reviewing the collective results. This trend demonstrates the effectiveness of the Delphi procedure in achieving group consensus without direct discussion and confirms the relevance and balance of the proposed model. Overall analysis of the score distribution indicated that the expert community unanimously recognised the model's high necessity, practical feasibility, and innovative potential. The quantitative data confirmed the stability of the group's decision and the existence of consensus, providing a foundation for the model's further use as a conceptual basis for designing interactive university educational environments integrating VR and AI technologies.

To identify possible trajectories for implementing VR and AI technologies in university educational processes and to forecast potential directions for the development of interactive learning environments, scenario modelling was applied (Table 4).

Table (4). Scenarios for the implementation of VR and AI in university educational processes

Scenario	Description	Goals and objectives	Expected outcomes	Potential risks/limitations
Innovation-adaptive	Focused on the gradual introduction of VR and AI according to the needs of students and educators, with a flexible combination of	Provision of personalised learning; increased student motivation and engagement; development of digital competence among educators	Formation of an interactive learning environment with adaptive courses; improved quality of the educational experience; increased student participation in	High demands on educators' digital skills; need for systemic administrative support; uneven access to technology

	pedagogical and technological tools		blended learning formats	
Technology-optimisation	Based on using VR and AI as tools to enhance the efficiency of managing educational processes and to automate educational analytics	Optimisation of administrative processes; improved assessment accuracy; creation of systems for analytical decision support	Effective monitoring of educational outcomes; reduced workload for educators; development of the university's digital infrastructure	Risk of reduced pedagogical interaction; focus on technology over content; potential ethical issues regarding data use
Transformation-forecasting	Envisions a systemic rethinking of the university's educational model, with VR and AI at the core of a new digital pedagogy	Integration of VR and AI at all stages of learning; creation of autonomous, adaptive educational environments; development of students' research and analytical competencies	Transition to a flexible, predictive education system; enhanced analytical component of learning; increased university competitiveness	High implementation costs; need for regulatory adaptation; risks of technological dependency

Source: compiled by the authors.

The analytical synthesis of the scenario modelling results revealed that the implementation of VR and AI technologies in university educational processes can follow three strategic trajectories, reflecting varying levels of readiness of educational systems for digital transformation. A comparison of the characteristics of each scenario demonstrated a gradual progression from incremental forms of digitalisation to a systemic transformation of the pedagogical model, in which the interactive educational environment functions not merely as a tool, but as an autonomous space for learning and research. The innovation-adaptive scenario showed the greatest alignment with the realistic conditions of contemporary universities. Its main advantage lies in the possibility of gradual implementation of VR and AI without placing excessive strain on institutional resources, thereby preserving the pedagogical autonomy of educators while simultaneously enhancing the level of personalised learning. Analysis of this scenario indicated that flexible adaptation of technologies to the needs of participants in the educational process ensures the highest level of acceptance of innovations within the academic environment. The technology-optimisation scenario proved effective from the perspective of a managerial approach to digital technology implementation. Its application allows for improved efficiency in educational analytics, reduced time spent on administrative processes, and automated monitoring of learning outcomes. However, the modelling results also indicated that focusing predominantly on technological

aspects may lead to a reduction in pedagogical interaction and a diminished role for creativity in the learning process. Consequently, this scenario is appropriate as a transitional stage towards deeper digital integration, but it cannot be considered a final model for development.

The transformation-forecasting scenario represented an ambitious and resource-intensive trajectory of development. Its implementation required a complete rethinking of the educational paradigm, within which VR and AI form the foundation of an interactive university ecosystem. Within this scenario, the learning process acquired characteristics of adaptability, self-directed learning, and analytical self-regulation, reflecting global trends in the shift from traditional education to systems of intelligent learning. At the same time, the analysis highlighted risks related to regulatory and ethical issues surrounding AI, the need for stable funding, and the development of a new type of academic personnel. Comparative evaluation of the three scenarios indicated that the innovation-adaptive scenario appears to be the most balanced and practically achievable option for contemporary universities within the conditions considered in this study. It can serve as a foundational model for the gradual digital modernisation of higher education, combining flexibility, pedagogical appropriateness, and technological innovation. This approach creates conditions for the integration of VR and AI as complementary components of the learning ecosystem. The results of the scenario modelling confirmed that effective digital transformation is possible only through a comprehensive approach, where technological solutions are aligned with pedagogical and cognitive objectives, and innovations are supported by an appropriate managerial and ethical framework. Consequently, the constructed scenarios not only described potential directions for the development of interactive educational environments but also outlined the strategic logic for transitioning from local implementation of VR and AI to systemic renewal of the university's educational model.

3 DISCUSSION

The study allowed the identification of key patterns in the implementation of virtual reality and artificial intelligence technologies within university curricula. It was established that the integration of VR and AI created conditions for an adaptive and individualised learning environment, in which students could gain interactive experiences, while lecturers were provided with tools for the analytical support of learning. The results of the comparative analysis demonstrated that the pedagogical components of the model enabled personalised learning, the development of cognitive autonomy, and interactivity in the educational process. Meanwhile, the technological elements ensured the integration of VR and AI into learning platforms, and the cognitive-communicative components created opportunities for adaptive feedback and research activities. The application of the Delphi procedure confirmed the necessity, feasibility, and innovative potential of all model components. The mean scores for necessity were 4.6 in the second round and 4.8 in the third; for feasibility, 4.2 and 4.4, respectively; and for innovative potential, 4.7 and 4.8. Median scores were 5 for necessity and innovative potential, and 4 for feasibility,

indicating a high level of consensus among experts. The results showed that VR provided spatial, visual, and sensory capabilities, immersing students in learning scenarios, while AI facilitated automated assessment, anticipated educational needs, and optimised learning trajectories. The three scenarios for developing interactive educational environments — innovation-adaptive, technology-optimisation, and transformation-forecasting — outlined potential strategies for implementation, reflecting varying levels of university readiness and diverse student learning needs. The results of the first aspect of the study confirmed the effectiveness of a personalised approach to learning and the integration of VR and AI into the educational process. Dimitriadou and Lanitis (2023) found that the use of AI in "smart" classrooms enhanced the efficiency of educational processes, which aligned with the high scores obtained for necessity and innovative potential. Mustafa and Chaudhary (2023) reported that the combination of VR and AI created an interactive learning environment, supporting conclusions regarding improved student engagement with learning materials. Lampropoulos (2025) demonstrated that integrating AI with VR and AR increased the productivity of educational environments and fostered the development of adaptive learning methods, corresponding with the findings for the cognitive-communicative component of the model.

The second aspect of the study addressed the technological readiness of universities and the practical feasibility of integrating VR and AI. Constantinescu et al. (2024) found that mixed reality and AI enhanced access to educational resources and enabled the creation of innovative learning applications, consistent with the feasibility scores obtained in the third round of the Delphi procedure. Hwang and Chien (2022) confirmed that the implementation of AI-based metaverses required a robust technological infrastructure and the preparation of teaching staff, which was reflected in the analysis of the technological component of the model. Luan et al. (2020) highlighted that the use of big data and AI in education improved the prediction of students' learning needs, which corresponded with the high scores for innovative potential. The third aspect of the study focused on the pedagogical effectiveness and cognitive-communicative outcomes of integrating VR and AI. According to Shakina and Podzygun (2025), the use of AI in educational processes has contributed to improving students' analytical skills and their interaction with instructors, which aligns with the high indicators of necessity for the model's components. The use of VR in combination with the optimization of the educational process has led to better acquisition of practical knowledge in the field of physical education, which aligns with the results regarding the VR component in the model, as confirmed by Wang et al. (2024). In line with findings regarding the development of the cognitive-communicative component, Qian (2022) demonstrated that VR and AI enabled the integration of creative practices into digital learning. Attention was also paid to the use of VR and AI to support inclusive education. According to studies by Al Balushi et al. (2024) and Caiza et al. (2025), AI-based VR and AR provided learning opportunities for students with diverse needs in line with expert recommendations regarding the model's innovative potential. Cui (2023) found that AR in music education enhances students' creativity, thereby confirming the effectiveness of the pedagogical components of the interactive environment.

The results of the content analysis revealed key trends in VR and AI. The findings of AlGerafi et al. (2023) demonstrated that VR and AR increase student engagement in learning. This supports the conclusions regarding the pedagogical component of the model. The results of scenario modeling were consistent

with the study by Soliman et al. (2024), who demonstrated that AI-based metaverses facilitate personalized learning and the prediction of educational needs. Gandedkar et al. (2021) confirmed that students' professional skills improved through the use of VR and AR, which aligns with the high feasibility scores obtained in the third round of the Delphi procedure. The study also found that the use of VR and AI contributed to increased productivity in the learning process and improved communication between students and instructors. Buchea-Manea-Tonish et al. (2022) concluded that AI combined with VR enhances the quality of the educational environment and learning outcomes in higher education institutions. This aligns with the assessment of innovative potential. It has been established that the use of intelligent digital technologies enhances the effectiveness of learning environments (Mkhonglo et al., 2023), thereby confirming the validity of scenario modeling. De Oliveira et al. (2023) demonstrated that VR, augmented by AI, enables adaptive learning and helps predict student success, which aligns with the assessment of innovative potential.

Chaka (2023) identified the social risks of digital transformation in higher education, including unequal access to technology and growing dependence on commercial digital platforms. This frames current findings, showing that the combination of VR and AI requires institutional safeguards in addition to technical and pedagogical implementation. The results indicate that the integration of VR and AI into university teaching has, overall, led to the creation of a comprehensive, adaptive, and innovative learning environment. A Delphi method assessment confirmed high scores for necessity, feasibility, and innovative potential for all components of the model. Scenario modeling identified realistic trajectories for the development of interactive learning environments. The findings were consistent with most studies, but Chaka's (2023) conclusions regarding digital inequality and dependence on commercial platforms refine these findings and underscore the need for precautionary measures when implementing VR and AI. The results demonstrated the potential to improve the quality of education, develop the skills of future professionals, and optimize educational processes while taking into account students' individual needs

4 CONCLUSIONS

The study identified and systematised the organisational and technological prerequisites for integrating virtual reality and artificial intelligence into university curricula. Content analysis of strategic documents at both international and national levels indicated that the digital transformation of education was recognised as a key direction in university development; however, the comprehensive integration of VR and AI into the learning process remained only partially addressed. These documents emphasised the need to develop an intellectually and cognitively enriched educational environment, yet specific tools for its implementation through VR technologies and AI algorithms were insufficiently defined. Accordingly, the study addressed this gap by developing a generalised model of an interactive educational environment. The constructed model illustrated the interconnections between pedagogical, cognitive-communicative, technological, and managerial-analytical components, ensuring a systematic approach to the use of VR and AI. Expert verification confirmed a high level of consensus across three criteria. For necessity, the mean score increased from 4.6 to 4.8, while the median remained consistently high at 5,

confirming the significance of all structural elements in achieving educational objectives. For feasibility, scores rose from 4.2 to 4.4, indicating the practical implementability of the model within a university setting without resource constraints. The highest results were observed for innovative potential, with the mean increasing from 4.7 to 4.8 and the median remaining at 5, reflecting expert agreement on the model's high level of novelty. Achieving group consensus, with 90% of experts assigning scores of 4-5 in the second round and 96% in the third round, confirmed the validity of the developed structure and its potential applicability in higher education practice.

The scenarios developed for the implementation of VR and AI modeled three possible trajectories for the development of interactive educational environments. The "innovative-adaptive" scenario was characterized by a gradual increase in the use of VR and AI at the level of individual disciplines, with an emphasis on pedagogical adaptation. The "technological optimization" scenario envisaged the use of intelligent systems for the administration and analysis of educational data. The "transformational forecasting" scenario described the possibility of transitioning to a fully digital learning ecosystem, where VR and AI serve as interdependent drivers of the intellectualization of the educational process.

The main recommendations arising from the study were the need to create a regulatory and methodological framework to govern standards for the use of VR and AI in higher education; the development of a system to enhance teachers' digital competencies; the provision of robust technical infrastructure at universities; encouraging interdisciplinary collaboration among educators, engineers, psychologists, and instructional designers.

The limitations of the study were: the expert sample consisted of only 12 individuals, which limits the representativeness of the results obtained; the assessment was based on a conceptual model and without full-scale implementation, so the practical effectiveness of the proposed solutions requires further empirical testing.

Future work should focus on empirically testing the proposed model in real university settings, comparing the effectiveness of VR and AI in various fields of education, developing algorithms to assess the quality of human interaction with intelligent learning systems, and investigating ethical issues related to the use of artificial intelligence in the educational process.

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