THE METAVERSE AS AN EDUCATIONAL ENVIRONMENT: FROM VIRTUAL WORLDS TO PERSONALIZED AI TUTORS

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Abstract. *Rapid advances in digital technology are transforming higher education. The Metaverse, combining virtual, augmented, mixed, and extended reality technologies, blockchain, digital twins, and non-fungible tokens, offers an exciting, personalised, and interactive learning experience, making it a powerful tool in modern higher education. In this paper, the authors set out to analyse scientific sources that highlight the use of the Metaverse in combination with AI technologies to improve higher education. To achieve this goal, scientific papers were selected from three international scientometric databases (Scopus, Web of Science, ERIC), a search strategy was developed based on key search queries and inclusion and exclusion criteria, and a bibliometric analysis and narrative review of the selected scientific papers was conducted. Using bibliometric analysis in VOSviewer, network visualisation was performed to analyse and display the co-occurrence of keywords in the selected scientific publications. A narrative review of the papers selected according to the established criteria was used to identify ways to combine the Metaverse with AI technologies to enhance higher education; the main directions include the creation of user-friendly and useful environments and their expansion to virtual university campuses, the implementation of AI capabilities for security in the Metaverse, creating personalised user experiences based on their behaviour and preferences, facilitating real-time communication, generating content for the Metaverse, combining the physical and digital worlds, and implementing AI tutoring.*

Keywords: *AI tutor, artificial intelligence, higher education, Metaverse.*

INTRODUCTION

Currently, in the context of the digital transformation of education, there is growing interest in innovative learning environments, particularly virtual technologies such as the Metaverse. After all, first the COVID-19 pandemic and then global challenges stimulated the search for alternative ways of educational interaction and student engagement in learning through new technologies with which they were born.

Early implementations of the Metaverse concept appeared in virtual worlds and games such as Active Worlds (1995), The Palace (1995) and Second Life (2023), and many modern platforms, such as Roblox (2006), VRChat (2014), Fortnite (2017), Decentraland (2020), continue this development. In 2021, Microsoft released Microsoft Mesh, a mixed reality platform designed for team collaboration (Roach, 2021). That same year, Facebook announced its rebranding as Meta and began research efforts aimed at developing the Metaverse (Meta, 2021).

The Metaverse refers to experiences in which the outside world is perceived by the users (human or non-human) as being a universe that is built upon digital technologies as a different universe ("Virtual Reality"), a digital extension of our current universe ("Augmented Reality"), a digital counterpart of our current universe ("Digital Twin"), Mixed Reality (MR), blockchain, eXtended Reality (XR), Artificial Intelligence (AI) and different forms of non-fungible token (NFT) (IEEE SA, 2024). In more general and less technical terms, the concept of the Metaverse is defined as the top-level hierarchy of persistent virtual spaces that may also interpolate in real life, so that social, commercial, and personal experiences emerge through Web 3.0 technologies (Hackl et al., 2022). In the interesting philosophical and social context, this concept is interpreted as the culmination of the Internet and the limitless possibilities of augmented and virtual reality technologies; not as a separate technology, but as a limitless and uncontrollable space; as a movement towards a digital lifestyle that we are gradually implementing year after year, app after app; as a metaphorical digital ecosystem that is growing and becoming more real every day and becoming more important to people with every technology that makes digital life more attractive than its physical counterpart (Terry et al., 2022). In our previous study (Osadchyi & Osadcha, 2025), we defined the Metaverse as an immersive three-dimensional virtual world (a network of interconnected virtual worlds) for user interaction via the Internet to integrate the physical world with digital objects, based on blockchain technologies, augmented user interfaces and AI.

While the Metaverse was initially associated with the gaming industry and entertainment, with the development of cloud services and EdTech platforms, it is now entering the educational sphere. This is because the Metaverse has the potential to be an environment where

users can not only consume content, play games, and entertain themselves, but also actively interact, create, and learn. Virtual campuses, professional activity simulations, avatar mentors, and more are emerging. Since traditional education faces challenges with student motivation, personalisation of the learning experience, accessibility of educational content, and a lack of practical orientation of learning, the use of the Metaverse can solve these problems by creating an immersive experience, modelling real professional situations, and adapting to the learning style of each student or group of students with similar characteristics.

The discussion about the Metaverse in education has taken a back seat for some time following the spread of generative artificial intelligence (AI). Still, the technology is not dead, and its development may now be closely linked to its direct competitor, AI (Nolan, 2025).

Therefore, there is a need to rethink the Metaverse and the role of AI in its development and the emergence of new education opportunities. Therefore, the ***purpose of this study*** is to analyse scientific sources that highlight the use of the Metaverse in combination with AI technologies to improve higher education.

LITERATURE REVIEW

Although scientific articles on the application of individual virtual worlds in education appeared in 2008 (Leenes, 2008), and as early as 2009, scientists were considering the concept of learning spaces supported by the metaverse (MeLS) (Marmaridis & Griffith, 2009), in the 2020s, certain articles appeared on the application of the Metaverse itself in education (Alvaro-Farfan et al., 2020), in its modern understanding. However, scientists still use the concept of "virtual world" (Díaz et al., 2020) in their articles and they use the term "Metaverse" less frequently.

In 2021, scientific papers that already offer bibliometric (Damar, 2021) and content (Gökçe Narin, 2021) analysis of scientific papers on the Metaverse appeared. This indicates that the experience of implementing the Metaverse in education has become widespread and that there is a sufficient number of articles on this topic. 2022 is characterised by a sharp increase in articles on the Metaverse in education. In particular, a search query (TITLE-ABS-KEY (metaverse AND education)) in Scopus returns information on 195 articles, compared to 6 articles in 2020 and 7 articles in 2021 (Fig. 1).

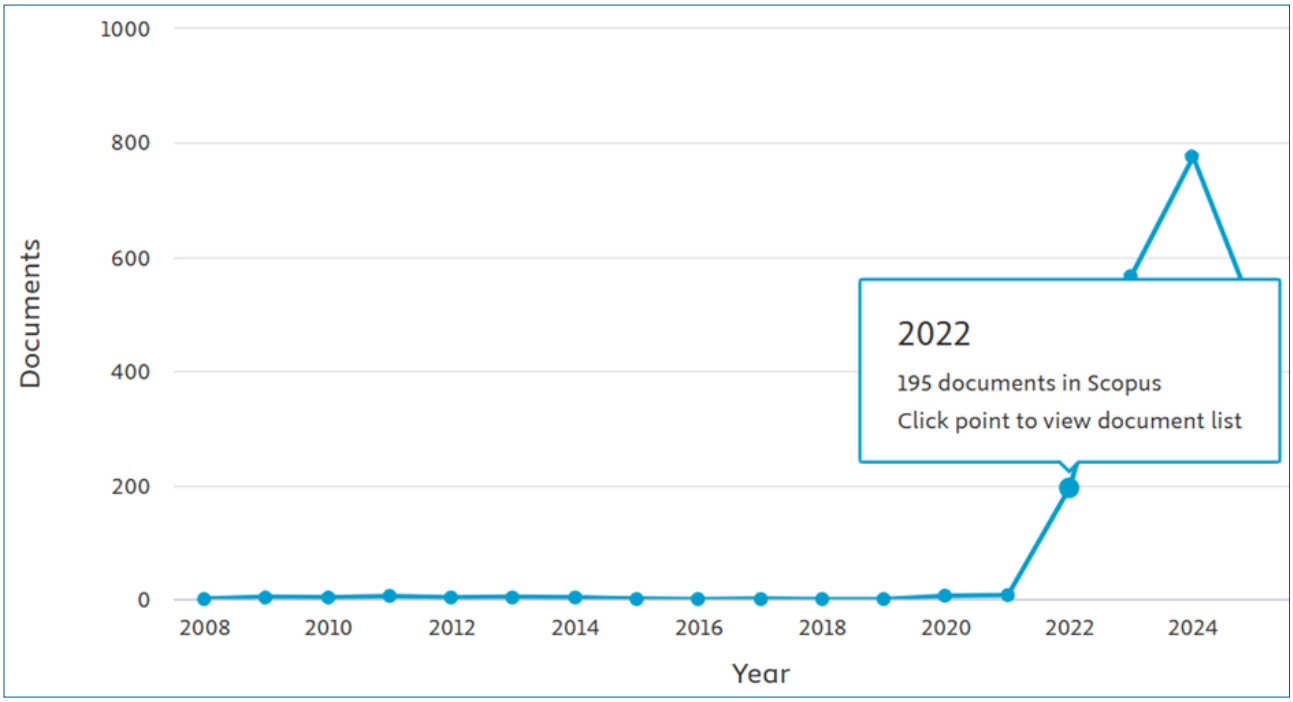

Figure 1. Sharp increase in the number of articles in Scopus in 2022

Source: Created by the authors based on a search query (TITLE-ABS-KEY (metaverse AND education)) in Scopus.

In the article "The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics" authors (Zhang et al., 2022) highlight the concept Metaverse, including its origin, definitions, and shared features; propose a detailed framework of the Metaverse in education, along with in-depth discussions of its features; describe four potential applications of the metaverse in education with reasons and cases: blended learning, language learning, competence-based education, and inclusive education.

Among the 567 articles published in 2023, the most cited paper is the work by Koohang et al. (2023), which offers insights into several important industries (marketing, tourism, manufacturing, operations management, etc.), including education, that are likely to be affected by the introduction and use of the Metaverse.

According to Scopus data for 2024, among 776 scientific publications, the article by Onu, Pradhan, and Mbohwa (2024) stands out. Based on semi-structured in-depth interviews, the authors confirmed that students, teachers, and program administrators perceive Metaverse-based education as an innovative and effective approach to delivering learning experiences. Sysoiev rightly believes that the integration of augmented reality (AR) technologies and AI contributes to the development of emotional intelligence within adaptive learning (Sysoiev, 2024).

Currently, one of the most cited studies in Scopus for 2025 is the article by Calderón-Fajardo et al. (2024), which investigates the acceptance of Metaverse technology. The development and application of these technologies in education to improve user experience, learning, emotional connections, and motivation were explored by Anwar et al. (2025).

These publications cover various aspects of Metaverse implementation in education: experience in using virtual spaces, the concept and structure of Metaverse, integration effects, students' perception of Metaverse technology, and user experience analysis. Metaverse is developing and being implemented in education.

METHODOLOGY

The methodology consisted of conducting a bibliometric analysis and narrative review (Sukhera, 2022) of scientific publications selected from the authoritative international databases (Scopus, Web of Science Core Collection, and ERIC).

The study was conducted in several stages:

1. Choosing data sources.

To ensure academic reliability and representativeness, three international scientometric databases were selected: Scopus, Web of Science, and ERIC (Education Resources Information Center).

2. Formulation of a search strategy.

Key search queries were formulated, including combinations of the terms "Metaverse," "Virtual worlds," "Artificial Intelligence," and "Higher Education".

The search was conducted according to the following criteria: 1) English-language publications (scientific articles, reviews, conference proceedings, book chapters, books); 2) publications from 2022 (the year of mass adoption of generative AI) to 2025; 3) full-text scientific publications with open access; 4) publications in subject areas such as computer science, social sciences, psychology, pedagogy and multidisciplinary publications; 5) publications containing empirical or theoretical information on the application of the Metaverse and AI in higher education.

Analyses that concerned only one of the components (only Metaverse or only AI) without any connection to higher education and duplicates were excluded.

3. Conducting bibliometric analysis.

VOSviewer software (version 1.6.20) was used for bibliometric analysis to create a network visualisation that enabled the analysis and display of keyword co-occurrence in the selected scientific publications based on bibliographic data.

Table 1.

Search queries and number of sources found in Scopus, Web of Science, and ERIC as of October 2025

№	Search query	Database	Number of sources found
1	"Metaverse" OR "Virtual worlds" AND "Artificial Intelligence" AND "Higher Education"	Scopus	16
2		Web of Science	897
3		ERIC	6

Source: Created by the authors based on Search queries and number of sources found in Scopus, Web of Science, and ERIC as of October 2025.

4. A narrative review of selected articles.

After that, the articles were analysed and summarised to identify ways to combine the Metaverse with AI technologies to improve higher education.

MAIN RESULTS

Results of bibliometric analysis

In the study, VOSviewer was used to visualize the relationships between keywords (Fig. 2) and identify thematic clusters in selected scientific studies related to the metaverse.

It is evident that the central node of the network is the "metaverse", confirming its role as the main object of study. Coloured clusters reflect thematic areas that often coexist in scientific publications. Each cluster is a microecosystem of concepts that form a specific research paradigm.

The central term "metaverse", which dominates the field under study, branches out into concepts such as "virtual reality", "augmented reality", "extended reality", "mixed reality",

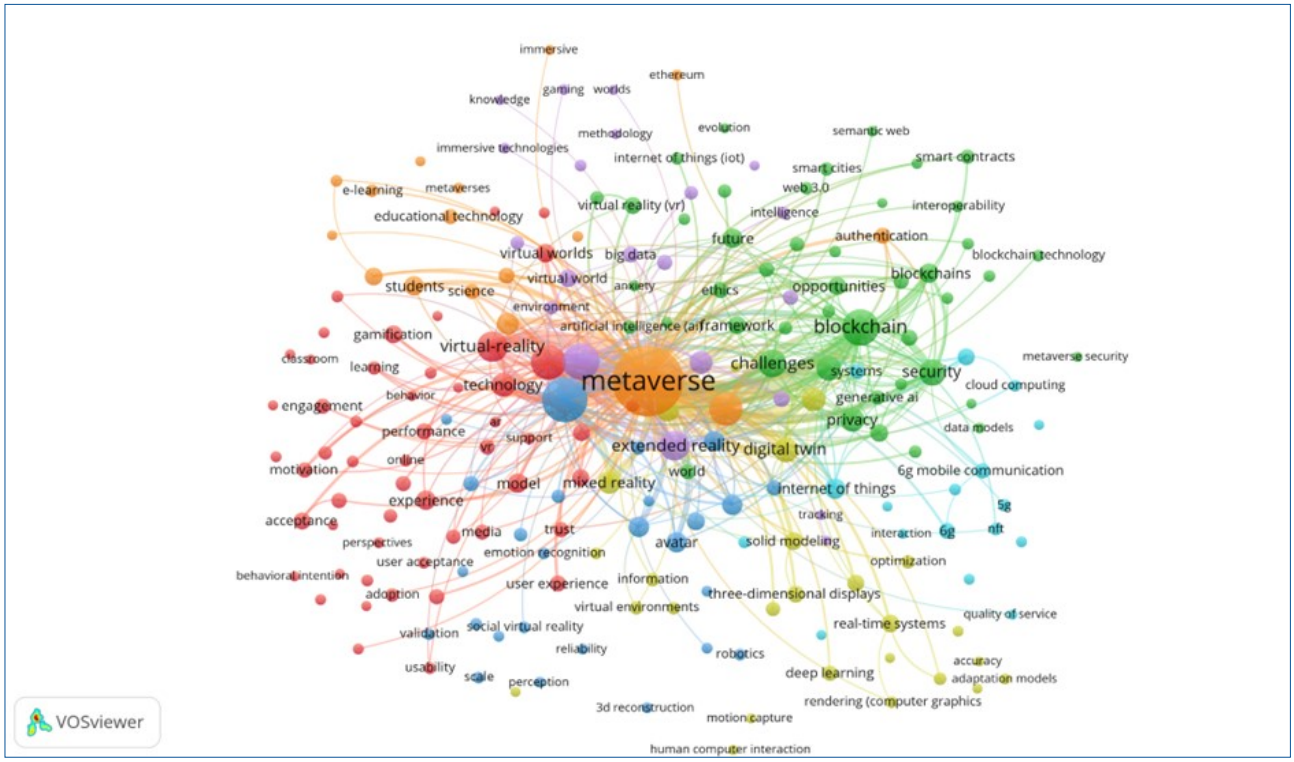

Figure 2. Network visualisation in VOSviewer

Source: Created by the authors based on visualization of the relationships between keywords using VOSviewer.

and "digital twin", forming the technological core of the domain. The concepts of "education" and "artificial intelligence" represent key pedagogical terms that combine technological and educational aspects. The map shows a high density of connections between terms, indicating intense scientific discussion of the Metaverse and AI in the context of education. The presence of seven clusters indicates the multifaceted nature of the topic, including technological, pedagogical, and ethical aspects.

As a result of bibliometric analysis and data cleansing of words not relevant to the study (e.g., tourism, bibliometrics, surveys, etc.), the number of included elements was 206 keywords, which were divided into 7 clusters, each marked with a separate colour (Fig. 2), (Table 2). A filter was applied to the analysis based on the number of repetitions (≥5), allowing us to focus on relevant terms.

Table 2.

Typology of clusters of terms by subject area

Colour	Cluster number	Examples items	Thematic direction
Red	1	Acceptance, adoption, attitudes, behaviour, classroom, collaboration, distance education, education, engagement, environments, experience, gamification, higher-education, immersive technology, impact, metaverse applications, motivation, VR, AR, XR	Understanding, acceptance, and experience of using the Metaverse in higher education
Green	2	Artificial intelligence (ai), blockchain, cybersecurity, data models, data privacy, ethics, internet of things (iot), large language models, nfts, security	Artificial intelligence, ethics, and the technological architecture of the Metaverse
Blue	3	Applications, avatar, communication, computer vision, embodiment, emotion recognition, emotions, identification, immersive learning, perception, prediction, reliability, social virtual reality, sustainable development	Psychological and cognitive interaction and intellectual modelling in virtual environments
Yellow	4	Adaptation models, computational modelling, digital twin, digitalization, human-computer interaction, human-computer interaction, motion capture, real-time systems, rendering, solid modelling, three-dimensional displays	Digital modelling, simulation, and visualization in virtual environments
Purple	5	Industrial metaverse, industry 4.0, industry 5.0, intelligence, knowledge, methodology, simulation, virtual world	Industrial Metaverse and industrial simulations in virtual worlds

Continuation of Table 2.

Colour	Cluster number	Examples items	Thematic direction
Light blue	6	5g, 5g mobile communication, 6g, 6g mobile communication, cloud computing, edge computing, interaction, protocol, systems, wireless networks	Network infrastructure and computing technologies for interactive digital environments
Orange	7	Distance learning, e-learning, educational innovation, educational technology, electronic learning, higher education, immersive, metaverse, science, students, technologies	Educational innovations and digital learning in the Metaverse

Source: Created by the authors based on bibliometric analysis and data cleansing of words not relevant to the study.

Based on the analysis performed using VOSviewer, it is possible to identify the most frequently mentioned concepts and those with the highest number of connections. The top 10 are presented in Table 3.

Table 3.

Most frequently used terms

Term	Frequency of mentions	Number of connections
metaverse	593	2,493
virtual reality	198	956
augmented reality	116	731
blockchain	118	714
education	101	628
artificial intelligence	94	587
virtual-reality	77	498
extended reality	72	451
challenges	61	435
security	54	410

Source: Created by the authors based on the analysis of the most frequently mentioned concepts using VOSviewer.

So, as mentioned above, the concept of metaverse dominates, with the highest frequency of mentions (593) and the largest number of links (2,493). Terms related to virtual technologies (virtual reality, augmented reality, extended reality) and digital innovations (blockchain, artificial intelligence) also attract considerable attention. The educational context (education) and security issues (security) also have a noticeable presence, albeit less pronounced. Overall, based on the data obtained, we can conclude that there is a focus on inte-

grating the latest technologies (Metaverse, AI) into the digital environment, with an emphasis on challenges, security, and the potential for transformation.

A narrative review of selected articles

For a narrative review of the topic, we selected articles whose content was relevant to the research objective again. This review allowed us to describe what is known about ways to use the Metaverse in combination with AI technologies to improve higher education. Scientists emphasise the need for further research and the effective use of technologies such as artificial intelligence, blockchain, and the metaverse in education and management processes, as advances in this field could lead to significant transformations in education and management (Ugur et al., 2024).

This is emphasised, in particular, in a study by Abdelmagid et al. (2025), which highlights the potential of immersive virtual learning environments and AI-driven content creation tools for enhancing digital literacy and fostering sustainability-oriented innovation.

Several studies emphasise the effectiveness of integrating the latest technologies to improve education, in particular considering the combination of Learning Management Systems (LMS), Artificial Intelligence (AI), and Virtual Reality (VR) (Roa González et al., 2025); AI, machine learning (ML), augmented reality (AR), big data, blockchain, cloud computing, Internet of Things (IoT), Metaverse, robotics and VR (Ahmad et al., 2024); blockchain, Non-Fungible Tokens (NFTs), Large Language Models (LLMs) and metaverse environment (Islayem et al., 2025); advanced sensor systems (LiDAR, radar, cameras), AI models for data interpretation, fast data fusion algorithms, and edge computing with 5G networks (Hatami et al., 2024); metaverse, AI, digital currencies, blockchain (Yang et al., 2022); the Metaverse, AI, blockchain, robotics, AR, VR, and MR (Uddin et al., 2024).

Marinescu and Iordache (2023) note that convergence of technologies such as VR, AR, blockchain, AI, and 5G Networks makes it possible to create the creation of complex virtual worlds, enhances user interactions, enables dynamic environments, facilitates seamless integration across platforms, and ensures scalability and persistence, while also introducing significant privacy, security, ethical, and legal challenges.

This combination of technologies also contributes to the creation of new learning systems, such as: intelligent tutoring systems (ITSs), which offer behavioural, cognitive, and social personalization, have a virtual presence, and can effectively be used as tutors or peer learners, can be created (Lampropoulos, 2025); an avant-garde metaverse-based learning platform AIIS (Artificial Intelligence, Innovation, and Society), that tailored for undergraduate students in computer engineering, medical, and nursing fields, and excels in its capacity to captivate learners and cultivate an electrifying learning atmosphere (Pyae et al., 2023); Explainable Educational Metaverse, which is a reference architecture for a learner-centred educational metaverse with an intelligent tutoring framework (Yun et al., 2024).

The expansion of such environments leads to the creation of virtual university campuses, in which on-demand VR lectures are conducted in virtual lecture halls, automated evaluations of student learning and training using machine learning are provided (Nagao, 2023). So, Metaverse brings a new era in educational settings, providing a wide range of services, such as VR-and XR-based skill training and AI-driven individualised learning experiences (Sakka et al., 2024). As noted by Yadav et al., “the future promises even more sophisticated learning environments, with emotionally intelligent AI tutors, real-time translation, and multilingual communication tools” (Yadav et al., 2025).

Some studies show that combining Metaverse technology and AI helps motivate students to learn. In particular, Molina-Barron et al. (2024) emphasise that the Metaverse and activities with AI “contribute to maintaining motivation and maximize the interest of students,

likewise, it encourages collaborative activities since an ideal context is created for the development of learning".

Several scientific papers explore the combination of Metaverse technology and AI in the field of cybersecurity (Otoum et al., 2024), offering approaches and solutions to enhance security in the virtual environment. In particular, Nkoro et al. (2025) offer the AI-powered Network Intrusion Detection Systems (NIDSs) at the network layer to detect and respond to threats in real-time. Aloudat et al. (2025) discovered some advanced solutions adopting AI, blockchain and privacy enhancing technologies (PETs) for securing the metaverse and enhancing its privacy. Park et al. (2022) propose the AI-Enabled grouping algorithm that focuses on securing various bridgehead strategies to secure topics for security and safety within the metaverse. Sharma et al. (2025) introduce DAI-TIRS, a holistic security framework designed to proactively secure the metaverse. DAI-TIRS is the integration of machine learning-based anomaly detection, dynamic honeypots, and predictive threat modelling that detect, classify, and mitigate AI-driven threats in real-time. Not only security issues, but also privacy issues in the Metaverse are being addressed through the use of AI (Gardner et al., 2025).

Scientists (Soliman et al., 2024) emphasise that combining the Metaverse, as a VR space, with AI creates new possibilities for immersive experiences that were previously impossible. Also, one potential benefit of using AI in the Metaverse is the ability to create personalised experiences for individual users, based on their behaviour and preferences.

With the emergence and widespread adoption of generative AI (GenAI), its capabilities are also being leveraged in the Metaverse. Tabassum et al. (2025) emphasise that GenAI is indispensable in powering the metaverse's dynamic and immersive experiences, enabling the autonomous generation of diverse digital content. LLMs, as a component of GenAI, play a critical role by facilitating real-time communication, multilingual translation, and personalised interactions, enhancing user engagement in shared virtual spaces. However, the combination of GenAI and Metaverse raises unique ethical and legal issues as bias in AI-generated content, misinformation, and data privacy concerns, related to the deployment of GenAI and LLMs. Therefore, it is necessary to develop individual ethical and legal frameworks for the responsible management of the convergence of these technologies, ensuring fair and sustainable growth in the Metaverse. GenAI can also be used to generate content for the Metaverse, including scene content generation and personalised content (Wang et al., 2023).

Studies investigating the convergence of physical and digital environments have revealed promising and insightful results. In particular, users' physical inputs may be used to train AI systems to provide client users with highly customised offerings. This technology offers an appropriate answer in the sphere of education and training by using its process (Rahman et al., 2023). This has led to significant achievements in physical education, allowing the creation of a virtual and realistic football training process (Li et al., 2022).

The culmination of AI and Metaverse integration is the emergence of 'non-player characters' (NPC) 'non-player characters' (NPC) tutor and peers. Agrati (2023) distinguishes the following roles in the Metaverse, established by AI:

- NPC tutor or advisor – "wise" or "expert" support, that offers advice to the user, especially involved in professional contexts and linked to the resolution of complex problems;
- NPC tutee/student – simulation of a student-teacher relationship, mainly involved in pre-service teacher training;
- NPC peer – peer-to-peer support between learners-users that fosters interaction and discussion underpinning socio-constructivist learning processes.

El Hajji et al. (2025) note the positive experience of using non-gaming characters based on LLM, emphasising that the integration of LLM and Metaverse plays an important role in providing a personalised learning experience, ensuring that the system is tailored to the individual needs of students.

According to Chu et al., the introduction of an AI-powered virtual tutor in the Metaverse improves learning outcomes in higher education by introducing features that support a personalised and engaging learning experience (Chu et al., 2025). Hemminki-Reijonen et al. (2025) share the same opinion regarding GAI-powered pedagogical characters in an intellectual virtual environment, noting that these characters addressed 9 out of 12 identified needs of educators, highlighting their potential to enhance higher education learning experiences.

Svoboda and Knihová underscore the critical role of AI and metaverse technologies in enhancing learning experiences, paving the way for more engaging, personalised, and effective educational outcomes, and also demonstrate that metaverse and AI boost student engagement and knowledge retention (Svoboda & Knihová, 2025). Villegas-Ch et al. note improvements in learning with the help of VR, AR, and AI (Villegas-Ch et al., 2024).

Fadhel et al. (2024) conclude that the contribution of artificial intelligence to the Metaverse can be outlined as follows:

- facilitating a heightened level of immersion by generating captivating and lifelike virtual environments;
- enabling the progression of complex NPCs with lifelike behaviours and decision-making capabilities;
- examining user preferences and behaviours to produce personalised content customised to individual interests;
- facilitating seamless and genuine social interactions among users through AI-powered chatbots and virtual assistants;
- ensuring the efficient distribution of computational power, storage, and network resources, and enhancing overall performance and scalability;
- analysing large volumes of data in real-time proficiently, enabling the capability to adjust to virtual environments based on user interactions, feedback, and changes in the environment;
- having impact on the preservation of safety protocols and the observance of ethical standards.

CONCLUSIONS

The analysis of scientific sources covering the use of Metaverse in combination with AI technologies to improve higher education was carried out in four stages, including: selection of data sources in three international scientometric databases (Scopus, Web of Science, ERIC); the formation of a search strategy based on a key search query combining the terms “Metaverse”, “Virtual worlds”, “Artificial Intelligence”, and “Higher Education” as inclusion and exclusion criteria; conducting a bibliometric analysis using VOSviewer software to analyse and visualize the co-occurrence of keywords in selected scientific works and a narrative review of selected articles.

Based on a narrative review, the following ways to integrate the Metaverse and AI to improve higher education have been identified:

1) combining the Metaverse and AI with other technologies (LMS, blockchain, ML, big data, cloud computing, IoT, robotics, NFTs, LLMs, digital currencies, blockchain, AI, blockchain, robotics) to create user-friendly and useful environments, complex virtual worlds, intelligent tutoring systems, avant-garde metaverse-based learning platforms, explainable educational metaverses;

2) expanding virtual environments to virtual university campuses that use machine learning for educational analytics;

3) leveraging AI capabilities to protect, enhance security, resilience, and data privacy in the Metaverse;

4) the ability to create personalized experiences for individual users based on their behaviour and preferences;

5) facilitating real-time communication, multilingual translation, and personalized interaction to increase user engagement in shared virtual spaces;

6) generating content for the Metaverse, including scene content generation and personalized content;

7) combining the physical and digital worlds, using physical data to improve the learning process;

8) implementing 'non-player characters' in the Metaverse (virtual tutors, peers) to support a personalized and engaging learning experience.

Further research could focus on exploring the possibilities of integrating the Metaverse with existing educational ecosystems, such as LMS, e-portfolios, accreditation systems, etc.

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