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Research Article

A Review Of The Application Of The Metaverse In Education

Yufei Liu[1*], Jiahui Huang[2], Salmiza Saleh[3]

[1]School of Intelligent Engineering, Shaoguan University, Shaoguan 512005, China
[2]School of Biology and Agriculture, Shaoguan University, Shaoguan 512005, China
[3]School of Educational Studies, Universiti Sains Malaysia, Penang 11800, Malaysia

***Corresponding Author:** Yufei Liu
*Email: sgliuyufei89_usm@student.usm.my

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ABSTRACT

The metaverse concept has garnered significant attention in recent years, particularly its potential educational applications. The metaverse, a virtual digital world bridging the gap between reality and the digital realm, offers immersive experiences and individual interactions. This paper reviews the evolution of metaverse technology, tracing its roots and development. It explores the diverse scenarios where the metaverse can revolutionize education, offering innovative solutions for personalized and secure learning environments. The metaverse presents myriad opportunities for enhancing educational experiences, from virtual classrooms to interactive simulations. The paper delves into various aspects of metaverse integration in education, including content creation, student engagement, and assessment methods. Additionally, it provides recommendations for the further advancement of the educational metaverse, emphasizing the importance of collaboration, accessibility, and ethical considerations. Overall, this paper underscores the transformative potential of the metaverse in education and offers insights for its continued development and implementation.

Keyword: Metaverse; Metaverse Education; Educational technology; Virtual teaching

1. Introduction

In recent years, the metaverse has emerged as a highly discussed concept (Lim et al., 2023). The metaverse is a virtual digital world that integrates the real world with the digital realm through technology, enabling immersive experiences and individual interaction (Zhai et al., 2023). The metaverse development holds tremendous potential across various fields, particularly in education. The Educational Metaverse (Edumetaverse) represents a digitized, intelligent paradigm for learning, merging the physical and virtual worlds to create a more personalized, autonomous, and secure learning environment (Han et al., 2023).

The Edu-metaverse not only revolutionizes the traditional educational environment and teaching methods but also profoundly impacts the achievement of educational objectives(Al-Ghaili et al., 2022). It stands as the future vision for the digital transformation of education. The inception of the Edu-metaverse is rooted in internet-based virtual simulations, utilizing computers to construct multidisciplinary, highly interactive virtual scenarios for teaching. Thriving within the virtual reality environment, the Edu-metaverse allows students to enter immersive, interactive learning scenarios using devices such as head-mounted displays and digital gloves, facilitating knowledge acquisition and skill enhancement (Cheng et al., 2022).

The Edu-metaverse connects real-world teaching settings and the virtual realm, constructing an intelligent learning environment(Rane et al., 2023). Leveraging technologies such as artificial intelligence, big data, cloud computing, blockchain, and information security, the Edu-metaverse provides schools with more personalized, efficient, and comprehensive learning support and services (M. Wang et al., 2022). This article explores the potential of the Edu-metaverse for use in education, highlights its role in reshaping educational landscapes and methodologies to enable more dynamic and effective learning experiences, and discusses the risks faced.

2. The History of the Development of the Metaverse Technology

During the conceptualization phase in 1992, the metaverse concept emerged with the dual notions of inclusivity and infinite expansion(Radanliev et al., 2023). In the literary work "Snow Crash," the virtual parallel world where users interact through digitized avatars is termed the metaverse, a foundational reference point frequently cited by scholars. Published in 1992, the science fiction novel "Snow Crash" by Neal Stephenson depicts the metaverse as a realm where users, equipped with headphones and goggles, can enter a virtual space parallel to the real world by connecting to a terminal in the form of a virtual avatar (Zakarneh et al., 2024).

Furthermore, the existing metaverse has seen the culmination of key technologies through cumulative advancements. From the inception of the first commercial VR device in 1984 to Meta's Oculus, and from blockchain, initially considered fundamental to the metaverse, to the emergence of phenomena like Bitcoin, Ethereum, and NFTs, all substantiate this progression (Vidal-Tomás, 2023). In 2003, the United States-based Linden Lab launched the first virtual game, "Second Life," which exhibited nascent metaverse elements by a less stringent standard (Dwivedi et al., 2022). Players could simulate various real-world activities within the game, including socializing, learning, working, shopping, and traveling.

Concept Popularization Phase (2011-2019): The introduction and promotion of the metaverse concept through media such as "Sword Art Online," "Ready Player One," virtual music festivals, and other mediums. On March 29, 2018, the movie "Ready Player One" was released, showcasing people experiencing a completely virtual world through VR devices(Kuş, 2021). This visual representation provided a more concrete understanding of the metaverse. On February 3, 2019, the metaverse concept transitioned from visual works to gaming as electronic music artist Marshmello hosted a virtual concert in the game platform "Fortnite," offering people a broader understanding of practical metaverse applications (Sami et al., 2023).

Technological Breakthrough Phase (2020-2023): Key events such as Facebook's acquisition of Oculus, the IPO of Roblox, the rise of blockchain-based platforms like Decentraland, and Meta's announcements garnered global attention for the metaverse. In 2021, Microsoft declared its efforts to build an "enterprise metaverse." At the end of July, Facebook founder Mark Zuckerberg boldly declared "all in on the metaverse," strategically positioning Oculus in the VR domain and launching Facebook Horizon as a VR social platform(Dolata and Schwabe, 2023). The aim is to transform Facebook into a metaverse company within approximately five years. On December 21, 2022, at the China Unicom Partner Conference Smart Life Forum, China Unicom unveiled its metaverse strategy and established the Metaverse Innovation Industry Alliance. In 2022, Siemens and Nvidia collaborated on the industrial metaverse, building upon Nvidia's Omniverse collaborative engineering environment and Siemens' comprehensive platform for digital twins in aerospace, healthcare, manufacturing, automotive, and energy industries (Tang, 2022).

The current concept of the metaverse is more like a rebirth of this classic notion, manifesting under new technologies such as virtual reality, augmented reality, blockchain, cloud computing, 5G, and digital twins. The metaverse leverages augmented reality technology for immersive experiences creates real-world reflections using digital twin technology, and establishes an economic system through blockchain technology (Kuru, 2023).

The metaverse represents the latest stage in visual immersion technology, fundamentally an online digital space parallel to the real world, with its core constructed by virtual reality technology (Wu et al., 2023). Based on the development and widespread application of such technology, the evolution of metaverse visual immersion technology can be divided into four stages:

In the first stage, desktop virtual reality predominates. An exemplary case is the launch of Second Life by Linden Lab in the United States, a shared 3D virtual space allowing users to explore, interact with others, build objects, and exchange virtual goods(Berger, 2008). This laid the foundation for the shared virtual world concept, experiencing continuous growth with over 70 million registered Second Life accounts (Kaplan & Haenlein 2009). During this phase, users could only observe the virtual world through computer screens, limited by interaction devices and technologies like stereoscopic vision and 3D modeling, resulting in a relatively low level of immersion. Second Life has found wide applications in online offices and remote socializing, particularly during the COVID-19 pandemic, with a monthly average of over 12 million visitors (Vartiainen, 2021).

The second stage is primarily characterized by immersive virtual reality. Leveraging immersive technology and human-computer interaction, immersive virtual reality has evolved from flat, passive, and unidirectional experiences to three-dimensional, active, and interactive breakthrough (Wang et al. 2024). Microsoft's HoloLens, introduced in 2016, marked the debut of mixed reality (AR and VR). HoloLens allows people to create holographic images before them, placing them in the real world for manipulation using augmented reality(Bach et al., 2018). In recent years, VR terminal devices represented by Sony, Oculus, and HTC have rapidly advanced, enabling users to translate sensory stimuli (visual, auditory, tactile) generated in the virtual world into real-world experiences through VR devices and motion-sensing equipment, overcoming traditional physical constraints and significantly enhancing immersion(Bekele et al., 2018).

The third stage is dominated by augmented reality and digital twins. With the deep integration of nextgeneration information technologies such as 5G, cloud computing, artificial intelligence, and VR, a more mature metaverse technology system is gradually taking shape. The high speed, low latency, and massive device connectivity features of 5G connect users or multiple virtual worlds distributed geographically, allowing

each user to simultaneously join the same virtual world and collectively experience virtual encounters(Yang, 2023). Based on VR/AR/MR, augmented reality technology transforms from real space to virtual space and then to a fusion of virtual and real spaces(Njoku et al., 2023). Digital twin technology represents a deeper development in virtual reality applications, linking physical object space with virtual object space, seamlessly merging and connecting the real and virtual worlds(Venugopal et al., 2023). Big data, cloud computing, and artificial intelligence provide powerful computational foundations and intelligent support for the metaverse, aiding its higher-quality development (Mo and Mo, 2023).

The fourth stage marks the early emergence of the metaverse. Utilizing brain-computer interfaces breaks down the barriers between reality and virtuality, allowing users to freely control various parts of their virtual bodies with their thoughts interacting with the virtual world at will. Simultaneously, the bidirectional transmission function of brain-computer interfaces can convey feedback from various senses to users through brain signals, achieving sensory experiences identical to the real world and realizing the integration of humans with the virtual world (Semertzidis et al., 2023). Blockchain technology is the key technology for the metaverse's ascension, as it establishes economic links between real and virtual spaces and unifies virtual and real values(Dhillon & tinman, 2024). The metaverse will achieve the fusion of humans and the virtual world and the integration of the real and virtual worlds.

3. The Application Scenarios of Metaverse in Education

Applying the metaverse in the field of education can span across all stages of student learning. In France, the European Institute of Administration utilizes metaverse virtual reality to enhance educators' teaching processes and manage students' learning. In Spain, the metaverse has been employed in exhibitions and visits to science museums(Contreras et al., 2022). Additionally, case-based interactive conferences have become more effective through virtual reality. For instance, in Singapore, students operate a juice bar within a virtual space through virtual reality experiences(Qiu et al., 2023a). Metaverse technology is also considered valuable in language teaching, allowing participants to interact in a virtual world(Park et al., 2023).

Virtual Labs and Environments. The metaverse can create realistic virtual laboratories and environments using virtual reality technology, providing students with practical experiences (Chatwattana et al., 2023). Students can conduct chemistry, physics, and biology experiments in virtual labs, simulating real-world operations and experimental processes(Lin et al., 2022). Moreover, the metaverse can also create scenes in history, geography, and art, allowing students to immerse themselves in historical events, geographical landscapes, or artistic works(Wang et al., 2023). The AI Lab at Inha University in South Korea has proposed a metaverse for Boeing 737 aircraft maintenance training and education. This metaverse provides instructional guides, 3D models, 3D simulators, and aircraft maintenance knowledge (Siyaev & Jo, 2021). The assembly of aircraft components is recreated in the digital space, significantly reducing training costs. With the help of the metaverse, students can carefully inspect various historical and architectural sites. For example, Gaafar explored the potential of the metaverse in architectural education by allowing learners and teachers to analyze heritage sites through virtual and interactive 3D models. Gaafar concluded that interactive models of cultural heritage, examined in a fully immersive experience, enable learners to observe details (Kurniawan et al., 2023). The Industrial Engineering Department at the University of Jyväskylä in Finland has focused on the digital factory domain (Qiu et al., 2023b). They teach lean management to students through a virtual reality game based on the 5S method, which originates from five Japanese concepts starting with the letter "S" and is used to establish workplaces conducive to visual control and lean production (Muotka et al., 2023). This virtual world platform aligns with Toyota's production system proposed in courses like digital business, operations management, creating production and assembly systems, and designing production processes (Krajčovič et al., 2021). In January 2022, the virtual campus of the Communication University of China officially debuted on
Baidu's XiRang platform becoming China's first "virtual university" open to the public on a metaverse platform. Users can access Baidu's XiRang platform through virtual reality, mobile devices, or personal computers, simulating a real campus experience (Wang, 2022). The "Virtual Experiment Teaching Service System" established by the China National Institute of Education Technology can provide primary and secondary school students with platforms for virtual labs for physics, chemistry, biology, and science. Using VR headsets (such as HTC, PICO) and control handles, students can immerse themselves in virtual space, using and operating various experimental equipment, engaging in real-time interaction, and observing various experimental phenomena (Song et al., 2023).

Personalized Learning and Tutoring. The metaverse, powered by artificial intelligence technology, can provide personalized learning content and tutoring based on students' learning needs and interests. Students can interact with the metaverse through virtual characters or AI assistants, receiving tailored learning guidance and feedback. The metaverse can automatically adjust learning content and difficulty according to students' learning data and performance, helping them better grasp knowledge (Kumar et al., 2023). Dallas Hybrid Prep, a school in Texas, utilizes the STEMuli metaverse platform for online education, being one of the first schools in the United States to implement a metaverse platform. STEMuli is a 3D engine-based gaming platform that creates 3D learning environments for STEM (science, technology, engineering, and mathematics) and language courses for K-12 students (Vaughn, 2022). Students access the STEMuli metaverse platform using their laptops or tablets. In this virtual world, they can see the avatars of all their classmates, and the metaverse,

based in Dallas, showcases different parts of the U.S. Aviation Center and the Dallas skyline (Castro & Edwards, 2021). While waiting for classes, students can drive cars worldwide or play games. When the teacher begins the class on their platform, students are immediately transported into the virtual classroom for instruction.
Students use the 3D gaming environment to learn and earn game tokens, allowing them to interact and collaborate with classmates, completing learning tasks and gamified assignments. Additionally, virtual learning companions guide students along personalized paths from any starting point to any learning goal(Zhao et al., 2022). Teachers can engage in personalized teaching based on student's interests, learning foundations, and styles, utilizing new tools within the metaverse to share learning data and assignments and evaluate and reward students. The metaverse system's analytics engine provides real-time student course learning data, offering timely feedback. Cross-Cultural Communication and Collaboration, the metaverse, utilizing virtual and augmented reality technologies, can break down geographical and cultural barriers, providing students with opportunities to communicate and collaborate with classmates worldwide(Peredo Alarcon, 2023). Students can simultaneously learn, discuss, and solve problems in a virtual environment, fostering cross-cultural exchange and understanding(Wu et al., 2024). This cross-cultural collaborative learning experience contributes to developing students' global awareness and cross-cultural communication skills. A PricewaterhouseCoopers (PwC) study indicates that students' learning speed in VR courses is four times faster than in traditional classroom environments(Boland, 2023). The immersive experience of gamification, engaging practices, 3D elements, and entertaining activities in the virtual world allows learners to stay ahead. Metaverse learners are less likely to be distracted as they can better comprehend topics through 3D simulations that fully engage their visual attention (Hopp et al., 2020). In August 2021, Professor Cai Wei's team at The Chinese University of Hong Kong, Shenzhen, established the first campus metaverse model, CUHKSZ Metaverse, using the consortium blockchain FISCO-BCOS as the underlying blockchain architecture (Xu et al., 2023). This virtual communication platform was created for students to introduce the school to new students and parents through a three-dimensional campus model and interactive puzzle-solving entertainment (Duan & Cai, 2023).
Resource Sharing and Creation, the metaverse can establish a decentralized education marketplace, allowing students and teachers to share and trade learning resources. The metaverse allows Students to access various educational resources, such as instructional videos and e-books (Rahman et al., 2023). Additionally, students can create and share their learning achievements and works within the metaverse. This will inspire creativity and self-directed learning abilities, enriching the diversity and accessibility of educational resources. Roblox and Zepeto serve as VR metaverses that provide a new social space for people unable to go out due to Covid-19(Lee, 2022). These platforms enable users to meet and socialize virtually. During school closures and the inability to attend classes in person due to Covid-19 lockdowns, the popularity of "classroom maps" and other 3D maps within Zepeto increased. Students did not go to actual classrooms but visited Zepeto classrooms, where they could meet and interact with friends.In July 2022, the International Business School of Shanghai International Studies University created a virtual and augmented reality combined digital graduation ceremony scene for graduates(Qiu et al. 2023c). This allowed teachers, students, and parents to engage in speeches, cap-throwing, and group photos in an immersive virtual space, providing a more intuitive experience of this important life ceremony.
Remote Education and Blended Learning, the metaverse can use virtual reality and augmented reality technologies to enable remote education and training. Students and teachers can engage in remote teaching and interaction through the metaverse, regardless of their physical location. This flexibility allows students to arrange their learning schedules based on their time and location, and teachers can expand their teaching reach and impact. Using metaverse technology, universities can establish a metaverse hub, allowing students, teachers, and other school staff to interact and communicate flexibly through video calls or meetings as if they were physically together (Moolenaar & Sleegers, 2015). A UK company has developed metaverse tools for maritime training using Oculus Quest 2, primarily for training the "International Regulations for Preventing Collisions at Sea" and effective Bridge Resource Management (BRM) (Raymer et al., 2023). Trainees can undergo localized training without needing centralized training in facilities worth millions of dollars. Davenport University in the United States has used Virbela to create a customized virtual campus called "Davenport Global"(Gallon & Lorenzo, 2023). This virtual campus maintains the physical campus's classroom culture and practical experience, featuring interactive auditoriums, demonstration screens, private tutoring rooms, and social and learning spaces, providing students with a sense of belonging like a real campus (Cai et al., 2022). The Hong Kong University of Science and Technology has established the world's first physicaldigital twin campus in the metaverse, bringing emerging technologies such as the metaverse and Web3 to the public eye and showcasing how these cutting-edge technologies can be applied to traditional education (Y. Wang et al., 2022). VictoryXR, based in Iowa, has begun building virtual classrooms for various schools and universities. Morehouse campus is an early adopter of this technology, allowing students and professors to interact virtually, engaging in classrooms, labs, and corridors like face-to-face interactions(Majewska and Vereen, 2023). Mukund et al. designed a course in the metaverse based on an online interactive digital game.
It is developed around a text-based chat interface game that introduces students to the global refugee crisis. The course utilizes pause points in the game and embedded explicit activities such as discussions, reflections, and podcasts, highlighting key points that require acknowledging one's own and immigrant perspectives. The

course also enables teachers to facilitate classroom discussions, creating a blended learning model (Mukund et al., 2022).

4. The Application Aspects of Metaverse in Education

(1) Educational Metaverse Supporting Virtual Teaching and Experiments

The Metaverse provides students with an almost realistic physical environment and social, practical, and cultural contexts, allowing them to transcend the limitations of time and space (Hwang et al.,2023a). They can immerse themselves in observing and experiencing scientific, humanistic, historical, and geographical environments from different times and locations, enabling learning in near-real situations. Any specific historical period can be recreated in the Metaverse in history courses, allowing students to understand it. For example, students can witness the French Revolution as if it were happening live. Students in geography and astronomy majors can explore different layers of the solar system or Earth through the Metaverse's augmented reality experiences. The Metaverse promotes laboratory activities in science courses, enabling students to conduct experiments in virtual settings(Suzuki et al., 2020). For instance, they can dissect virtual cockroaches to study insect anatomy or experiment with Newton's concepts of weight, mass, and gravity. In art courses, students can analyze works of famous artists in the Metaverse, drawing inspiration to create their digital art pieces. In literature studies, the Metaverse allows the recreation of novels or stories, enabling students to enter and witness unfolding scenes, aiding their understanding and connection with characters (Baía et al., 2022).

Currently, the Metaverse has been applied in the teaching practices of various courses, with many educators and developers utilizing VR/AR technologies, intelligent wearable devices, and other Metaverse teaching tools across different disciplines(Prakash et al., 2023). Applying the Metaverse in virtual experimental learning breaks the constraints of the physical world, such as space, funding, site limitations, equipment, or potential risks. Virtual laboratories can be virtually reconstructed in the Metaverse, and 3D representations of experimental equipment can be projected into the virtual world for various virtual experiments (LópezBelmonte et al., 2023).

Metaverse research by scholars from many countries worldwide mainly investigates college students' cognition and experience of the virtual universe and explores the metaverse platform in higher education (Pradana & Elisa, 2023; Rojas et al.,2023). Ren, Longfei, and others found that university students using Metaverse technology in basketball courses tended to unconsciously develop automatic actions and habits, potentially significantly increasing the utilization rate of Metaverse technology and promoting the long-term development of interactive virtual reality teaching(Yang et al., 2022).

In their study using Metaverse MRI technology, cabero-Almenara, Barroso-Osuna, Martinez-Roigd, and others taught the "Mathematics Foundation of Architecture" course to 44 first-year architectural students. They discovered that Metaverse teaching positively influenced students' mastery of the course's technical aspects and the architectural mathematics teaching process. Additionally, their research suggested encouraging MRI-based Metaverse teaching methods in university classrooms(Cabero-Almenara et al., 2021). In Altıok's (2020) study, the impact of Metaverse mobile augmented reality support on the mathematics performance of elementary school students was investigated, along with their perceptions of the combined educational process. The study involved 23 third-grade students, and the results indicated improved success rates in creative and symmetry concepts. The research found positive effects of Metaverse mobile AR, such as embodying abstract concepts, making courses more engaging, and facilitating learning (Altiok, 2020). In 2021, Stanford University offered the world's first Metaverse course, "Virtual People," in global higher education history (Hutson et al., 2023). In this course, learners from different locations could break spatial limitations by simply wearing VR headsets and appearing in the same 3D virtual classroom. "Virtual People" is the firstever Metaverse course fully supported by VR technology, offered by Jeremy Bailenson, the founder of Stanford University's Virtual Human Interaction Lab, in 2021. 263 students have used VR headsets to participate in the 20-week summer and fall semester course, accumulating over 3500 hours of total learning time (Chen et al., 2023). According to Professor Bailenson, the "Virtual People" course is an exemplar of Metaverse application in educational teaching, covering hardware, software, and content and achieving predetermined teaching objectives through the joint participation of teachers and students (Vieira & Medeiros, 2023).

New Taipei City's Longpu Elementary School recently successfully introduced the UNIVERSE by ViewSonic education Metaverse platform. Teachers share teaching content and conduct group activities in this 3D virtual classroom, while students easily access the Metaverse classroom using tablet computers (Caglar, 2023). Teacher Shih Hsinyuan from Longpu Elementary School expressed satisfaction after completing the course with 30 students in Metaverse mode, stating that students entered the virtual classroom smoothly and the operation was very smooth (Nguyen & Ngo, 2024). Compared to traditional 2D online teaching tools, students were excited and looking forward to classes on the new platform, significantly increasing their focus during classes. This provided significant affirmation and encouragement for on-site teachers and team members. This study conducted a one-month Korean language oral course for approximately 23 Korean beginners in Gather-town, utilizing the Metaverse platform developed to date. Korean language education demonstrated the highest utilization rate on the platform. Results indicated that over 90% of learners expressed satisfaction with the interest, interaction, and usefulness of oral exercises in the classroom(Hwang et al., 2023b). Additionally, Tsinghua University's Material Science and Engineering Virtual Simulation

Experimental Teaching Center established specialized foundational experiments, including metallographic preparation, construction, and usage of metallographic microscopes, observation of Fe-Fe_3C phase diagrams and microstructures, material hardness testing, and heat treatment(Li, 2018). Through these threedimensional virtual experiments, the study effectively addressed practical challenges in materials science experimental teaching, such as limited experimental apparatus, insufficient teaching staff, high consumption of materials, extensive financial investments, and elevated risks associated with certain experiments. This approach significantly alleviated the workload for teachers, enhanced students' learning and understanding of theoretical knowledge in material science courses, and laid the groundwork for improving students' practical abilities, comprehensive analytical skills, and innovative awareness.

(2) Educational Metaverse supports vocational education

Metaverse education plays a crucial role in the field of vocational education, addressing experiments or training that are challenging due to objective constraints or high levels of risk through the implementation of VR/AR technology in educational metaverse environments(X. Li, 2022). Lee et al. proposed using metaversebased technology in an online education system within a classroom setting. Researchers developed a virtual reality (VR) simulation for aircraft maintenance(Kye et al., 2021). The method outperformed video-based training in both knowledge acquisition and retention test scores. This technology provides a sense of spatial presence, demonstrating better usability than video-based training methods. Embry-Riddle Aeronautical University, a prominent aerospace education institution in the United States, utilizes the metaverse to enhance its competitiveness. Focused on aviation accident and safety investigation, the university is transitioning to a metaverse university through its Virtual Crash Lab. The Virtual Crash Lab allows students worldwide to assume the role of investigators in virtual accident scenes, experiencing firsthand visuals and sounds. Students can witness aircraft accidents in the cockpit, listen to dialogues between pilots and air traffic control, evaluate emergency response measures, conduct on-site investigations, and interview witnesses. They can also take photographs or measurements, modify them, and submit their investigation records to professors (Rickel,2023). Asia Pacific University of Technology & Innovation in Malaysia has established Malaysia's first virtual metaverse university town. Equipped with virtual reality (VR) glasses, students enter the virtual metaverse university town for various educational activities in virtual buildings. Ongoing educational practices have shown that metaverse education technology significantly boosts student enthusiasm for learning while enhancing instructors' teaching efficiency. Upon completing metaverse-based courses, students can obtain vocational education certificates(Hanafi et al., 2023). The National Vocational Education Virtual Simulation Demonstration Training Room in China has been established, encompassing 28 virtual simulation teaching experiment centers for different professional groups(Zhuang, 2023). These training rooms support various forms of training, including multi-user collaboration and head-mounted virtual reality. Each room is equipped with VR desktop all-in-one machines, VR glasses, and multimedia smart teaching devices, accommodating up to 10,000 students simultaneously for internship training.

(3) The Promotion of Special Education by the Educational Metaverse

The introduction of special education aims to ensure that every child, regardless of their special needs, can receive education and necessary support in a mainstream school environment(Molina Roldán et al., 2021). Children with special needs primarily refer to those with disabilities, and the scope extends to include children who have been abandoned, abused, or suffer from mental illnesses. However, integrating students with special needs seamlessly into regular classrooms poses a challenge for most educators. Given the unique characteristics of virtual spaces, the virtual environment can serve as an ideal zone where children with special needs can learn alongside their peers without barriers.

Utilizing the educational metaverse to drive the integration of vocational and special education facilitates rehabilitating and enhancing vocational skills for individuals with disabilities(Yenduri et al., 2023). This enables disabled students to acquire valuable skills, laying the foundation for future employment and entrepreneurship. The educational metaverse offers several advantages in special education(Alam & Mohanty, 2022). Firstly, the social spaces within the metaverse facilitate these benefits through simulated face-to-face interactions in a socially virtual reality, allowing individuals to interact freely without obstacles in the physical world. Secondly, the metaverse may enhance the range and quality of educational pathways available to disabled users. Immersive technologies mean higher education can be delivered in engaging ways without the need for physical attendance. The metaverse can provide job opportunities that might be challenging for individuals with disabilities or older age to secure in the physical world. Thirdly, the metaverse can present new employment opportunities for special education students who may face challenges in securing certain jobs in the physical world due to their disabilities or age but can find relevant employment positions in the virtual environment of the metaverse.

In 2022, DesignInspire collaborated with Mirum to create a metaverse exhibition space, showcasing artworks created by artists from disadvantaged backgrounds and children with special education needs (Tiffany & Munhoe, 2024). This initiative aimed to explore infinite possibilities, promote understanding, and foster inclusivity among individuals. DesignInspire's metaverse seeks to showcase the talents of individuals with different abilities to the public, exploring more possibilities within communities and promoting mutual understanding and inclusion. Research by Syamsul Bakhri, M. Ali Sofyan, and others has shown that current

special schools or special education programs focus on developing students' soft skills and character (Bakhri & Sofyan, 2022). Suppose the development of metaverse technology expands the accessibility of course content for students with special needs. In that case, the implementation of special education will be realized, as each student enjoys equal conditions and environments in the online space.

(4) The Educational Metaverse in Support of Medical Education

The metaverse utilizes augmented reality (AR), virtual reality (VR), mixed reality (MR), 3D graphics, and other technologies to construct a virtual space for medical education. Within this virtual space, medical content is presented in three-dimensional graphics(Bansal et al., 2022). Operators can use AR/VR/MR devices to observe details and angles not visible in physical samples or models. Additionally, integrating big data models allows for the simulation of various directions and possibilities in medical research and development, providing broader perspectives and optimal solutions for medical research, clinical medicine, and medical education.

On May 29, 2021, during the 29th Online Academic Conference of the Asian Society for Cardiovascular and Thoracic Surgery, Seoul National University Hospital shared real-time surgical procedures using VR/AR technology, marking an initial attempt at applying the educational metaverse in the field of medical education (Koo, 2021). Beijing Mengke Technology Co., Ltd. used VR technology to redesign a biology class on "Gene Expression." Unlike traditional classrooms that rely on textbook diagrams, microscopes, animations, and videos, students, when wearing headsets, were immersed in coursing blood, observing red and white blood cells in motion. They could follow blood circulation to various parts of the human body, entering tissues from blood vessels. By rotating the headset, students could explore microscopic substances such as ribosomes, mitochondria, centrioles, and cell nuclei (Jamshidi et al., 2023). Guangzhou Huarui Interactive VR Medical Simulation Experience System aids in cultivating medical talents by transforming medical education into a lively classroom that combines theory with practical operations, breaking the mold of traditional teaching methods(Pottle, 2019). The VR medical simulation experience system integrates existing medical equipment with VR hardware, allowing participants to quickly grasp knowledge in the medical field and transform dull theoretical knowledge into vivid teaching and practical scenarios. The solution involves sensory behavior and interactivity, creating an indistinguishable sense of reality and making it easier to train medical professionals. In a dental education study, Locurcio proposed an innovative approach using a virtual environment that mimics an operating room setting and focuses on educating students about different surgical stages(Chen, 2022). Utilizing different scenarios in dental training helps students acquire knowledge rapidly. Koo and colleagues presented a study describing a metaverse training course in South Korea (Koo, 2021). Medical students at Case Western Reserve University wore HoloLens glasses to observe organs and systems in the body, with mixed reality environments replacing traditional anatomy labs filled with cadavers (Pierre et al., 2016). The metaverse also aids medical education by allowing educators to simulate surgical scenarios and corresponding solutions using patient information registered in hospital databases, significantly improving practical skills in medical students. Renowned medical institution Case Western Reserve University showcased its integration of Microsoft's MR tools with educational software platforms at the 2022 Miami Immersive Global Summit(Inceoglu & Ciloglugil, 2022). Peking University School of Nursing fully integrates metaverse technology with traditional medical practice teaching, transforming and constructing virtual simulation training room environments, establishing immersive XR training rooms, deeply advancing practical teaching reform, continuously optimizing practical teaching content, accelerating improvements in practical teaching methods, and steadily enhancing the quality of practical teaching (Jamshidi et al., 2023).

5. Suggestions for the Development of Metaverse in Education

Education authorities should strengthen top-level planning for the deep application of the educational metaverse. On the one hand, government departments should clearly define the development goals and specific regulations for applying metaverse-related technologies in educational instruction from a strategic perspective. On the other hand, they should focus on developing metaverse-related technologies and infrastructure. Firstly, attention should be given to the development trends of metaverse-related technologies and their potential applications in education. Secondly, focusing on the pathways and standards of technological development ensures that the technology can contribute effectively to education. Thirdly, attention to the construction of related technologies and infrastructure in education is crucial. Lastly, considerations should be made regarding the opportunities or challenges the technology and its application may bring to schools, teachers, or students.

In the educational metaverse, suggested future development goals for schools can include the following aspects:

Personalized Learning: One of the future development goals for schools is to achieve personalized learning. Through the technology and platforms of the educational metaverse, schools can customize learning plans and provide resources based on each student's learning needs, interests, and abilities. Students can autonomously choose learning content in a virtual environment, learning at their own pace and in their preferred manner, thereby maximizing their potential and achieving learning outcomes.

Global Connectivity and Cross-Cultural Exchange: The educational metaverse can break geographical and cultural limitations, facilitating global student connectivity and cross-cultural exchanges.

Immersive Learning Experience: The educational metaverse can offer immersive learning experiences through virtual reality, augmented reality, and mixed reality technologies, allowing students to participate in learning as if they were physically present. Future development goals for schools involve creating realistic and highly interactive virtual teaching scenarios, enabling students to engage in virtual experiments, historical reconstructions, field trips, etc., enhancing participation and effectiveness in learning.
Interdisciplinary Integration: The educational metaverse can promote the integration and crossover of different disciplines. Future development goals for schools may include designing interdisciplinary learning projects and activities, allowing students to synthesize various knowledge and skills to solve real-world problems. Through interdisciplinary integration, students can cultivate systems thinking, innovative thinking, and comprehensive literacy.
Career Readiness and Skill Development: The educational metaverse can provide a learning environment that closely simulates real-world work scenarios, assisting students in gaining career readiness and skill development. Development goals include collaborating with industries and businesses to design virtual training projects and occupational simulations, enabling students to practice the skills and abilities required in actual workplaces within a virtual environment.
On the enterprise side, development activities should include constructing technological platforms and infrastructure, designing and optimizing virtual environments, and developing educational applications and tools. The development of metaverse development tools can facilitate the creation of educational environments. Enterprises can offer comprehensive solutions to schools, aiding in the planning and designing of educational metaverse construction. These solutions may involve the construction of virtual classrooms and laboratories, the establishment of virtual learning platforms, and the design and development of teaching scenarios. Enterprises can provide customized solutions based on the needs and goals of schools, assisting them in achieving educational objectives such as personalized learning, interdisciplinary integration, and immersive learning.

6. Risk Prevention in the Education Metaverse

Any technological development and implementation come with corresponding risks. However, the emergence of risks does not equate to denying a particular technology. Instead, it should involve actively anticipating potential risks and proposing strategies to address them. The educational metaverse is no exception. The low latency and high immersion characteristics of the educational metaverse environment benefit teachers' scenario-based training and students' immersive knowledge acquisition. The application of the metaverse in education is becoming an inevitable trend. Therefore, while embracing the educational metaverse, exploring various risks it may pose and providing reasonable mitigation strategies is essential.
In the era of the educational metaverse, the protection of personal privacy faces greater challenges due to its inherent characteristics. The convenience of intelligent technology largely depends on open data sharing, exposing potential security risks. Technologies like NFTs, which provide ultra-integral records of information, currently struggle to protect users' personal information strictly. Leakage of sensitive and private personal information could significantly impact individuals' lives. Educational platforms possess vast amounts of user information, and with the increasing popularity and realism of virtual reality applications, it could pose a greater privacy threat. Additionally, modern communication technologies may escalate privacy infringements and data leaks to more severe doxxing and cyberbullying scenarios. In the context of the educational metaverse, privacy issues extend to underage groups, making the scope of harm from campus bullying more extensive and potentially affecting the healthy development of minors, leaving indelible scars on their life paths.
Regarding intellectual property protection, standardized digital copyright protection is a crucial prerequisite for conducting educational research in the metaverse. Effective protection of creators' rights is essential for delivering high-quality education and resources. In the era of the digital economy, the application of blockchain technology in the digital publishing industry is an evident trend. This technology has shown its effectiveness in areas such as digital signatures, reinforcing the value chain of digital copyrights, and constructing judicial protection systems related to content ecosystems. However, as blockchain is in its early development stages, it inevitably brings technical risks in industrial applications, including security vulnerabilities, high energy consumption, and low transaction efficiency. Technical risks include risks of forgetting or losing private keys, computational attacks, and information attacks based on quantum computing capabilities, among others. Security incidents continue to occur worldwide.
In terms of teaching data security risks, in the backdrop of the metaverse, data security issues become more pronounced, with all interactions becoming fully digitized, presenting risks in data acquisition, application, and storage. In the educational metaverse, teaching activities are based on various data, and data security directly affects the quality and fairness of education. Simultaneously, the current trend in technology companies leans towards using biometrics, including iris and fingerprint information, for secure verification. Since collected data is more profound, any leakage of such information could result in irreversible losses. Criminals using intelligent technology to simulate identities for criminal activities may become simpler and more dangerous. The metaverse is currently in the early exploration stage, lacking specific laws, regulations, and industry policies for the industry's development. Uncertainties exist regarding the impact of changing regulatory policies on industry development.

Addiction risk is a significant concern in the educational metaverse. The immersive experiences created by the metaverse can lead adolescents in critical cognitive development periods to develop psychological dependencies. Moreover, suppose the rules of the virtual world, behavior norms of virtual avatars, and values conflict with the real world. In that case, it can cause unstable interpersonal relationships, exacerbate social phobia, and lead to social isolation, disrupting real-world social order. Beyond its impact on adolescents, the metaverse can induce "technology addiction," where individuals become engrossed in the sensory impact created by digital intelligent technologies, immersing themselves in the dazzling virtual world. This immersion may result in a neglect of the stark reality, nurturing a value system that favors the virtual over the real. This shift may lead to a sense of unfamiliarity and rejection of real-life responsibilities, potentially causing problems such as self-identity disorders and obstacles in real-world interpersonal interactions.
Ethical risks are also a concern in the educational metaverse. The metaverse is constructed using technologies such as digital twins, digital surrogates, NFTs, and immersive interactions. Due to technological limitations, metaverse applications may not always have a positive impact, potentially triggering ethical issues.

7. Conclusion

This study reflects the current technological developments in the educational metaverse and its applications in education and explores future trends and development directions of the educational metaverse. It aims to chart the optimal path for the future development of the educational metaverse. The educational metaverse represents a significant innovation in the field of educational technology, poised to transform the form and content of education, promoting its balance and scientification and providing robust support for sustainable social development. It is hoped that this research will serve as a valuable reference and inspiration for educators, educational policymakers, and educational technology companies, facilitating the accelerated construction and development of the educational metaverse.

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