Open another door to education—Applications, challenges and perspectives of the educational metaverse

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ABSTRACT

The metaverse is a new form of the future of the Internet that integrates many new technologies, and its combination with the education sector has great potential. The article firstly points out that metaverse is a concept that is constantly developing and evolving, while the educational metaverse has three core features: interactivity, immersion and multiplicity, and introduces the six underlying supporting technologies and application scenarios of the educational metaverse. The article then presents the current development of the educational metaverse represented by the VR/AR learning environment, starting with case studies from the fields of subject education, informal learning and vocational training. Finally, the article analyses the problems and challenges faced by the educational metaverse and makes suggestions for the initial development of the educational metaverse in terms of mechanism, technology and teaching. The educational meta-universe opens another door to the study of the complexity of educational systems and the laws of educational occurrence and development, while the study of its applications, challenges and perspectives gives direction and impetus to the development of the educational meta-universe.

Keywords: metaverse; educational metaverse; VR; AR; learning environment

In his book Snow Crash, American science fiction author Stephenson[1] first introduced the concept of the metaverse and described it as a virtual urban environment parallel to real life. With Facebook changing its name to Meta, the meta-universe quickly exploded in front of the public and became the most popular buzzword of the year. At present, Microsoft, Tencent, Byte Jump and other technology giants are all laying out metaverse, and 2021 is therefore regarded as the “Year of Metaverse”. In recent years, emerging education technologies such as virtual reality and augmented reality have led the new direction of future education. The metaverse, which integrates technologies such as virtual reality, artificial intelligence and blockchain, provides a virtual learning environment for learners and will potentially bring about new changes in education and teaching. In this context, the feasibility of metaverse applications in education has become a hot topic of interest for researchers, and the potential of educational metaverse deserves to be explored and analyzed in depth.

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1. Definition and characteristics of the metaverse

The word “metaverse” is made up of the prefix “meta” (meaning “beyond”) and the stem “verse” (derived from “universe”). At present, there is no authoritative and unified definition of metaverse, and it is still a concept that is constantly developing and evolving. For example, the Metaverse Development Research Report 2020-2021 gives the following definition: “metaverse is a new type of Internet application and social form that integrates reality and reality by integrating multiple new technologies, which provides an immersive experience based on extended display technology, generates a mirror image of the real world based on digital twin technology, and builds an economic system based on blockchain technology, which closely integrates the virtual world and real world closely integrated in economic system, social system and identity system, and allows each user to produce content and edit the world”[^2]; Wikipedia explains a metaverse as “an online 3D virtual environment that is used to describe a future persistent and decentralized environment”; and Zhu[^3] sees a metaverse as a future Internet-based 3D virtual space that is connected-aware and shared through a virtual augmented physical reality that is convergent and physically persistent. In addition, there are different descriptions of what a metaverse is and how it is characterized by industry. For example, Baszucki[^4], CEO of Roblox, suggests that the “metaverse” has eight basic characteristics: Identity, Friend, Immersive, Low Friction, Variety, Anywhere, Economy and Civility, while Radoff[^5], founder of Beamable, suggests that the “metaverse” is built on seven levels: Experience, Discovery, Creator Economy, Spatial Computing, Decentralization, Human-Computer Interaction Economy, and Infrastructure.

It can be foreseen that the metaverse will bring two dimensions of expansion to human existence: first, the dimension of survival, i.e., the metaverse provides an integrated environment that is both independent of and integrated with the real world; The second is the expansion of the human sensory dimension. In the metaverse users will experience the multiple senses of the virtual world and the real world, and the virtual world will not only be visual, but an integrated sensory experience of virtual vision, real vision, hearing and touch[^2].

2. Features, technical support and application scenarios of the educational metaverse

2.1. Educational metaverse and its characteristics

Education is characterized by openness, irreducibility, non-linearity and non-equilibrium. It is a complex system and it is not easy to gain a deep understanding of its developmental laws. In the past, people usually studied education systems in two ways: theoretical studies and experiments. The emergence of the meta-universe has the potential to bring a third way for human beings to understand the complexity of education systems and the developmental laws of education. For the sake of argument, this study refers to the application of metaverse in education as the “educational metaverse”. The “educational metaverse” is a new concept and does not yet have many of the characteristics described by the technology industry, but there are at least three core characteristics that should be present if the educational metaverse is to be developed:

Emphasize social interaction—Interactivity

Deploying a metaverse begins with a focus on its social interactivity[^6]. Teachers, students, learning resources and learning environments are the four basic elements of an educational scenario[^7], while virtual learning environments in an educational metaverse are not fixed and can be modelled and modified by some or all of the users who inhabit them, thus facilitating interaction between students and learning resources and learning environments. In addition, the educational metaverse allows students or teachers to build relationships through agents, with each avatar used to communicate the student’s or teacher’s role in the world. Students can also so-
cialize and build social relationships within the educational metaverse. This anytime, anywhere immersive social interaction creates an almost realistic social context for student-student and teacher-student interactions, which not only expands the learning space, but also provides more opportunities for learning, socializing and forming a sense of community. The interactive nature of the educational metaverse opens another door to different stages, disciplines, levels and fields of education, injecting new inspiration into these varied forms of educational activity.

Real world simulation—Immersion

The educational metaverse presents an environment very similar to the real world and is able to provide the user with a realistic real-world environment by simulating the laws of physics. As a result, some of the familiar behaviors (e.g., bodies not being able to pass through walls, objects falling due to gravity, etc.) can be reflected in a three-dimensional virtual environment, which greatly enhances the realism and immersion of the virtual world\[6\]. However, to facilitate user exploration in the educational metaverse, there are some exceptions, such as the ability for users to levitate or instantly teleport to any place in the educational metaverse. The highly realistic and immersive nature of the educational metaverse will further enhance the user’s sense of presence, immediacy and make immersive learning possible\[8\].

Free, open, flexible rules—Diversity

The educational metaverse does not have pre-set rules like commercial games, it does not impose any set rules or goals. All inhabitants of the educational metaverse (i.e., the users, not the developers of the platform) are responsible for defining the rules and conditions of their own ideal environment, which allows users to do almost anything they want in the educational metaverse, such as organizing concerts, organizing games\[9\], and offering university lectures\[10\]. In addition, because educational metaverse uses distributed cloud computing technology to host multiple servers in different parts of the world, educational metaverse allows users to scale up or down their learning environment as required. The educational metaverse also provides support for access control, allowing authorized users to define restrictions and rules on individual lands, which makes it possible to introduce private space in a shared environment, so that both Massive Open Online Courses (MOOC) and Small Private Online Course (SPOC) can be delivered through 3D immersion. This flexible rule allows users in the educational metaverse to move, create and communicate freely, and this results in an infinite and diverse range of educational activities.

2.2. The underlying supporting technologies and application scenarios of the educational metaverse

Although the concept of educational metaverse is still in its infancy and its representative, the 3D virtual/augmented reality learning environment, is not yet available\[11,12\], its characteristics are in line with traditional theoretical perspectives such as Behaviorism, Situated Cognition, Embodied Cognition, Constructivism, and Flow\[13,14\].

There are many descriptions of the underlying supporting technologies of the meta-universe in the current industry, which can be broadly grouped into six categories: network and computing technologies, Internet of Things technologies, blockchain technologies, interactive technologies, video game technologies, and artificial intelligence technologies \[15\]. In the education meta-universe, these six underlying supporting technologies and their application scenarios are shown in Figure 1.

1) Network and computing technologies, 5G campus network, edge computing, multi-terminal collaborative cloud computing can be used as network and computing infrastructure for the education meta-universe, providing a solid hardware environment foundation for future students and teachers to enjoy high-bandwidth, low-latency, multi-connected ubiquitous learning scenarios; 2) Internet of Things (IoT) technology, the miniaturization of chips and the dramatic increase in computing power have facilitated the rapid spread of IoT tech-
Figure 1. Underlying supporting technologies and application scenarios for the educational metaverse.

Technologies, providing a transmission channel for the educational metaverse to sense signals from and access to the physical world. This connected learning environment for everything will surely inspire students to create new worlds with their hands and provide strong support for future safe campuses, creator education and multimodal smart classrooms; 3) blockchain technology, with its decentralized, distributed, traceability, high trust and other technical features, ensures the integrity and security of data information generated in the process of education management and teaching, and can provide a guarantee of knowledge sharing and authentication based on rules and algorithms operating in the future education meta-universe for the authentication of learning outcomes, construction of credit banks, digital resource management and distribution, ecological construction of open education resources, and self-organized operation of digital campus communities, etc.; 4) Interactive technologies, 3D virtual reality/augmented reality learning environments supported by human-computer interaction technologies such as computer graphics, computer vision, gesture recognition, gesture recognition and even brain-computer interfaces, bring unlimited imagination to the educational metaverse, so that students' learning is no longer limited to the visual and auditory channels, as the multi-channel fusion of VR/AR technologies allows students' learning activities in the educational metaverse to bring together integrated sensory experiences such as vision, hearing, touch, smell and taste; 5) video game technology, gamified learning and delightful learning derived from video game technology make learning more interesting for students in the educational metaverse. Together with multimodal data and brain science techniques, gamified learning provides more immersion while making the learning process more scientific and rational for students; 6) artificial intelligence technology, personalized recommendation, teaching behavior data mining, knowledge mapping and multimodal emotional computing in the educational metaverse. Thanks to the rapid development of current artificial intelligence technology, intelligent tutors, intelligent assessment and multimodal emotional computing will be more widely developed and applied in the education meta-universe. These underlying supporting technologies and application scenarios provide a solid, powerful foundation for
the development and implementation of the educational metaverse, and paint a highly imaginative blueprint for the future of education.

However, at this stage, the education sector attaches great importance to intelligent learning and interactive environments and tools. Artificial Intelligence (AI) technologies, represented by machine learning and natural language processing, and interactive technologies, represented by Virtual Reality (VR) and Augmented Reality (AR), have received the most attention. From people’s intuition, the educational metaverse is an extension of real life, based on VR/AR technology that maps the real world into a virtual learning environment with a certain level of intelligence. Therefore, the focus of this study is on building an intelligent VR/AR learning environment.

3. Application cases of the educational metaverse

The 3D scenes in the educational metaverse have already existed in the field of education, in the form of 3D virtual learning environments represented by VR technology and virtual-reality learning environments represented by AR technology, but the current level has not yet reached the gorgeous blueprint depicted by the metaverse. In this regard, this study argues that cases from the fields of subject education, informal learning and vocational training can be used to understand the current state of development of the educational metaverse.

3.1. Academic education

Math, physics, chemistry, biology—Virtual lab

Currently, many educational researchers and developers have used VR/AR technology and have done many physics, chemistry and biology experiments using VR/AR glasses and tablets, such as three-dimensional geometry\(^{[16]}\), electromagnetic phenomena\(^{[17]}\), astronomical knowledge\(^{[18]}\), chemical elements\(^{[19,20]}\), and chemical reactions\(^{[21]}\), and have confirmed that VR/AR technology can bring a better learning experience to students\(^{[22–24]}\). The educational metaverse of the future may not require identification charts and bulky equipment such as helmets and glasses. Students can come to their ‘virtual labs’ with lightweight equipment and immerse themselves in a more realistic and immersive learning experience by observing, operating and interacting with experimental equipment in real time.

Language, English, History, Geography—Immersive contextual experience

Most subjects like Chinese, English, History and Geography allow students to learn about language and culture, historical situations or human landscapes of different places through pictures and videos, which in some cases are not yet possible to provide students with 100% restored realistic virtual situations due to the limitations of technology. The educational metaverse creates near-real social, practical and cultural contexts for students to observe and experience the human, historical and geographical environments of different times and places in a way that allows learning to take place naturally in near-real contexts. The “VR/AR + Education” Lab of Beijing Normal University and the Primary School of Tsinghua University conducted a series of AR-based language learning activities\(^{[25]}\), using AR applications to create an augmented reality learning environment in which fourth grade students observed and interacted with the sun and the earth in English class, while learning English conversation, as shown in Figure 2.

3.2. Informal learning

Virtual learning community

The emergence of the new coronary pneumonia epidemic and the development of Internet technology have made the establishment of virtual learning communities a hot concern\(^{[27]}\). A complete virtual learning community mostly has basic elements such as history, identity, interdependence, diversity, autonomy, participation, social etiquette, reflection, and learning\(^{[27]}\). Numerous studies have shown that a collaborative web-based learning environment leads to a stronger sense of community
and engagement among community members, can promote interaction among members\textsuperscript{[28,29]} and facilitate members’ understanding of knowledge\textsuperscript{[30]}. In recent years, there have been many cases where this has been attempted, the more typical ones being:

1) Sloodle, which features a virtual community, integrates the Moodle learning management system with the Second Life game, it is convenient for users to participate in community interaction at any time, as shown in Figure 3. Both developers and users of Sloodle can participate in community building and social interaction within the community, creating a sense of community; any user can participate in regular meetings and discussions held on Sloodle Island, etc.\textsuperscript{[31]}. The learning platform can be called a prototype for the combination of a metaverse and a virtual learning community.

2) Hodoo Labs. Hodoo Labs is an English learning-focused learning community that transposes more than 300 characters and some 4,300 scenarios into virtual reality scenarios of conversational English, where users travel freely through five continents and more than 30 imaginary villages in order to improve their English skills in the process, as illustrated in Figure 4.

3) Virbela is the first virtual world platform built specifically to address the challenges of remote collaboration, as shown in Figure 5. The platform allows users to create their own identity and hold meetings, events, participate in courses, etc., in an immersive 3D world. In Virbela’s virtual
campus, teachers can present documents, show videos, browse the web or redecorate learning spaces, and students can explore the campus’ learning areas, meeting rooms or participate in activities that create a sense of community and culture through online course learning.

Figure 5. International conference at Virbela.

When the New Crown Pneumonia outbreak occurred in 2020, Davenport University in the USA used Virbela to create a bespoke virtual campus, “Davenport Global”. This virtual campus maintains the classroom culture and hands-on experience of a physical campus, such as interactive auditoriums, presentation screens, private tutorial rooms and free space for socialising and learning, giving students a sense of belonging as if they were on a real campus.

4) In 2021, Stanford University offered a course called ‘Virtual People’, which was taught entirely in a VR environment[32]. As shown in Figure 6, students can take classes remotely from anywhere with a VR headset. Classroom scenarios include virtual museums, life-like scenarios, sparsely populated corners of the planet (e.g., volcanic craters, underwater reefs), etc. According to Bailenson, the course’s lead professor, “Our course is the meta-universe, and this class is a standard example of how to build one. Our goal is to construct enduring spaces and scenarios filled with avatars and use them to achieve (pedagogical) goals”[33].

Museum education/science and technology museum education

In recent years, VR/AR technology has become very common for the display of museums, science and technology museums or some places of interest[34,35]. VR/AR technology can help present some objects that cannot be easily or realistically displayed, enrich the content and form of the exhibition, and bring visitors a more comprehensive tour experience. The educational metaverse can enrich the educational format of museums, science and technology museums even more, enabling students to cross time and space and creating near-real museum, science and technology museum situations for students, so that learning occurs naturally in the relevant contexts.

(a)

(b)

Figure 6. Stanford University’s first metaverse course “Virtual People”: (a) Real-world students attending classes via VR equipment; (b) Course discussion scenarios in the virtual world.

Vocational training

At present, VR/AR technology plays a pivotal role in the field of vocational education. Some experiments and training that are difficult or dangerous to carry out due to objective constraints can be realized through VR/AR technology in the educational metaverse. On 29 May 2021, the 29th Online Congress of the Asian Society of Cardiovascular and Thoracic Surgery was held, at which Seoul National University Hospital in Korea used VR/AR technology to share surgeries in real time, an initial attempt to apply the educational metaverse in the field of medical education. In addition, in areas such as architecture, industry and manufacturing,
Omniverse, an open platform developed by US company NVIDIA, helps creators, designers, researchers and engineers connect key design tools, assets and projects so that project teams can collaborate on the same 3D model anywhere, anytime, to collaborate and discuss in a shared virtual space, improving communication and productivity.

4. Challenges and prospects of the educational metaverse

Based on the above analysis, it is foreseeable that the educational metaverse has huge potential and the application prospect is optimistic. In fact, before the concept of educational metaverse became popular, China’s government gave strong support to the application of its underlying core support technologies such as AI, VR and AR in the field of education, and a series of documents were issued to promote the application of virtual reality technology in basic education, higher education, vocational education and other fields and in high-risk experimental courses such as physics and chemistry. In addition, many schools have also started to establish virtual reality teaching laboratories in recent years, which indicates that virtual reality education applications have moved from “concept” to “grounding”. However, as the future picture described by the educational metaverse is too advanced, the existing relevant technologies are not yet mature, and the design of the underlying core supporting technologies for education applications is relatively simple, the reliability and universality of the existing research findings have their limitations, and the educational metaverse still has a long way to go from theory to implementation.

4.1. Issues and challenges

Lack of top-level design and evaluation mechanism

At present, there is no systematic planning for the application of metaverse in education in China, and there is a lack of clear development goals and market mechanisms. The documents issued by the state in recent years are only programmatic policies to support the application of VR/AR education, but lack a systematic collation of the adaptation of the content of teaching materials to VR/AR teaching methods in various subjects and school levels, and no unified plan has been formed, for example, there is no top-level design plan for information networks, platform systems and digital resources in the context of the education meta-universe. In addition, the relevant theoretical research and practice are mostly scattered, and there is a lack of corresponding curriculum standards and evaluation mechanisms. There is still a need for in-depth research on what kind of courses are suitable for innovative teaching, what kind of effect they can achieve, and whether they meet the training needs of society and the state.

The technology is not mature enough and the application threshold is high

Although China has made great progress in the development and application of the underlying support technologies for the educational metaverse, there are still many technical difficulties to be broken through, such as 5G networks not being popular enough, artificial intelligence not being smart enough, virtual reality not being immersive enough, augmented reality not being realistic enough, and human-machine interaction not being natural enough. In addition, special hardware devices such as helmets, glasses and grips are not portable enough, and their operation is complicated, while the contradictions between the functional design of software and the threshold of practical application are prominent. Overall, the shortcomings and optimization problems of the underlying technology of the educational metaverse make the threshold for its application high, and there is still a long way to go to achieve its diffusion and popularity.

Lack of in-depth inquiry into teaching applications

At present, VR/AR teaching applications in campus classrooms are mainly science-based experiences, many of which remain at the demonstration and simple interaction stage, with insufficient in-depth exploration of course content. The application of the educational meta-universe in the class-
room requires much more than that, and therefore there is a need to continue to strengthen the deeper construction of the curriculum knowledge system. In addition, the current design of relevant teaching products is mainly technology-oriented, favoring the design and development of software, while lacking systematic pedagogical theoretical support. In the new learning environment of the educational metaverse, producers of teaching applications need to consider how to combine embodied cognition theory and immersion theory to innovate the design of teaching content and introduce learning resources and teaching applications that are suitable for a multimodal learning environment.

**Be wary of capital speculation and kidnapping**

The concept of “meta-universe” is hot, and it is not known whether there is capital hype behind it, to which the People’s Daily, the Economic Daily, the Securities Times and other mainstream media have also called for calm\(^{[39,40]}\). In the educational metaverse, every second of a user’s time is creative labor, while the means of production are firmly clutched in the hands of the platform, and millions of ordinary users are the proletariat of the digital age, with the blurring of the boundary between amusement creation and labor obscuring the exploitative nature of capital. In addition, the current education meta-universe platforms are fragmented, without a unified standard, and are easily monopolized and kidnapped by capital and the power of a few technically powerful companies.

**Ethical risks**

Existing research on VR/AR learning environments has focused on exploring the effects of classroom teaching and learning in terms of teaching effectiveness, motivation and attitudes to learning, and has mostly explored positive effects, while lacking research on negative effects and ethical issues, so the case for risk assessment in the educational metaverse has yet to be added. In the extremely open world of the educational metaverse, how students can properly develop ethical values needs to be explored and considered: 1) from the perspective of privacy, how to protect individual private data and how to reasonably collect and store student data in the metaverse world manipulated by capital needs to be further discussed; 2) from the perspective of values, it is a challenging issue to establish correct values and worldviews in the context of a border-breaking and decentralized metaverse, where students are exposed to different cultural outputs and false opinions. In addition, educational metaverse has a strong risk of “addiction” due to embodied interaction, immersive experiences and the “compensatory effect” on reality, and this issue needs to be taken seriously.

**4.2. Outlook and recommendations**

At present, research on the application of metaverse in education is still in its infancy at home and abroad, and most of the relevant research results are empirical hypotheses and designs. If the research results of existing technologies are combined with specific educational teaching practices in China, the feasibility of applying metaverse in the field of education is explored in depth, and the risks and problems of the current educational metaverse are practically solved, then it will be possible to successfully establish a systematic theoretical system and application model of educational metaverse. From this perspective, the healthy development of the educational metaverse will potentially bring about new educational and pedagogical changes, breed new teaching methods and approaches, and become an opportunity to liberate the productivity and creativity of the education industry. Based on this, this study makes recommendations for the initial development of the educational metaverse in the following three areas:

**Define the objectives and layout of the programme**

The education administration should strengthen top-level design and strategically clarify the development goals and concrete plans for the application of metaverse-related technologies to education and teaching. Firstly, it should clarify what core qualities and competencies are to be developed in students through the educational metaverse, how to
design the curriculum content, what kind of teachers are needed and how to encourage teachers to participate in it; Secondly, experience can be gained for universal implementation through pilot schools on a trial basis; Finally, attention should be paid to collecting the needs of front-line teachers and students from different sections and subjects, fully exploring the diversity of needs and their corresponding markets, and actively and steadily promoting the application of the education meta-universe.

**Focus on multi-channel natural interaction**

The metaverse scenes give a great visual impact, thanks to the rapid development of computer graphics and computer vision technology. However, in an ideal educational metaverse learning environment, teachers and students should be able to see realistic virtual scenes and their teaching behaviors should interact very naturally. Therefore, in addition to the full development of visual experience technologies, the educational metaverse cannot ignore the development of natural interaction technologies in the teaching and learning environment. It should mobilize multiple sensory channels such as visual, auditory, gestural, gesture, haptic and even electroencephalography, focusing on the fusion of multi-channel natural interactive information to create a realistic and immersive educational metaverse environment that provides a multi-channel natural interactive experience. The multi-channel information generated in this process can facilitate the collection of learning process data and educational big data research based on multimodal data, thus helping to understand the complexity of the education system and the laws of education occurrence and development.

**Focus on teaching content design**

In the process of applying the educational metaverse, it is important not to put the cart before the horse and put the technology at the center, but to make it clear that teaching design and teaching activities are the top priority, so attention should be paid to the design of the corresponding teaching activities. In terms of the selection of teaching content, cases from real teaching environments should not be forcibly copied wholesale into the educational metaverse environment; At the same time, it is important to recognize that the virtual is a complement to, not a substitute for, reality, so the educational metaverse should follow the principle of ‘realism not imagination’, and we should prioritize the development of teaching and learning examples that are either not possible or costly to implement in real spaces. In the classroom, due to space constraints or safety concerns, we should use lightweight devices such as tablets and semi-immersive AR goggles for AR teaching and learning activities, rather than full immersive, heavyweight devices such as head-mounted VR goggles. In addition, teaching and learning activities in the educational metaverse should also take into account the problems of inefficient teaching and learning and disorderly classroom conditions brought about by new equipment and environments.

**Conflict of interest**

The authors declare no conflict of interest.

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