Exploration and Practice of Course Homework Metaverse Based on Extended Reality Under Edge Computing

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Abstract. The metaverse originated from science fiction at first, but it gradually came into reality with the continuous power of technology. Aiming at the problems of course work in Chinese universities, such as its function is weakened or suppressed, its form is too abstract, and it lacks elaborate design, this paper proposes a design method of course work meta-universe based on extended reality under edge computing. XR technology is used to realize the interactive immersion of the coursework meta-universe, in order to improve students' learning enthusiasm and ability to solve abstract problems. Based on the international perspective, this paper systematically combs and analyzes the integration architecture, application scenarios and future trends of the meta-universe education application based on Edge computing (MEC). Four key processes are described: teacher-student interaction, data collection, data feedback and comprehensive evaluation. In order to promote the application of the metaverse in the field of education to provide mirror. The validity of the method is illustrated by the data.

Keywords: Extended Reality · Edge Computing · Metaverse · Multi person collaboration

1 Introduction

In recent years, the concept of the metaverse has already set off a great stir in the current science and technology world, which has become one of the biggest points in the century of technological changes.

Jeremy, Virtual Human-Computer Interaction Laboratory, Stanford University Professor Bailenson points out that education is one of the "killer" application scenarios in the metaverse [1]. Professor FrankPiller of RWTH Aachen University is convinced that metaverse teaching is closer to the learning experience of classroom teaching than network teaching [2]. Professor Stylianos Mystakidis of the University of Patras points out

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that the metauniverse will become an important factor in promoting the democratization of education, enabling global learners to participate and learn together on an equal basis [3].

However, the current exploration of the educational application of the Metaverse is still in its infancy, lacking mature theoretical achievements and clear ideas for the construction and application [4].

Moreover, the Metaverse is a virtual digital world, and to be highly synchronized with the real society, the scenes in the real world must be materialized into the virtual world, such as in the form of data [5, 6]. Therefore, the first thing to be solved is the problem of data transmission.

However, the original cloud computing method will lead to many problems such as high delay, high cost, low experience and low data processing capacity in the Metaverse and extended reality interaction, which makes the Metaverse education and extended reality technology unable to be really applied. In addition, deploying XR devices equipped with Mobile Edge Computing (MEC) [7] servers to provide computing services at the edge of the network has also become an emerging approach to Metaverse education.

In view of this, based on the international perspective, this study will systematically sort out and analyze the fusion architecture, application scenarios and future trends of the Metaverse education application based on Edge computing (MEC) [8], in order to provide a mirror for promoting the application of Metaverse in the education field, and propose a distributed security architecture based on master-slave multi chain, breaking through the traditional single chain performance bottleneck. Table 1 below shows the concepts and technologies that are characteristic of the Metaverse.

Table 1. Related concepts and technologies with characteristics of the metaverse.

Time	Name	Technology	Important changes
In 1992	Snow Crash	concept	The concept of "Metaverse" was put forward for the first time
In 2003	Second Life	Internet	The most popular virtual world game in the world
Since 2006	Roblox	Metaverse and VR	It is the first public offering with the concept of metaverse, allowing users to construct 3D and VR, and design their own interactive activities to achieve their own content creation
In 2009	Open Simulator	Multiple clients	The world's first open source multi-client, multi-protocol access 3D virtual world server, it provides a distributed configuration solution for the construction of the metaverse
Since 2018	Ready Player One	Virtual World	Breaking down the boundary between reality and games, bringing the "Metaverse" to the masses

2 Related Work

2.1 Overview and Research Status of Extended Reality (XR)

Extended reality (XR), as the development trend of virtual technology in the future, is actually a general term, which includes VR, MR and AR, namely virtual reality (VR), mixed reality (MR), augmented reality (AR) and everything in between [9]. The following table (Table 2) shows the differences between VR, MR and AR.

However, with the continuous update of technology, the concepts of the three are often confused. XR is now commonly used to refer to this type of highly interactive "Virtual World" created using computers.

Table 2. Comparison Among VR/MR/AR

Comparison Item	Virtual Reality	Mixed Reality	Augmented Reality
Common display devices	VR glasses ,HMD helmet	MR glasses, Holographic projection	Phone,Projector
Common auxiliary interactive equipment	Handle, eye tracker, motion capture equipment	Hand capture	Not necessarily required
Current limitations	Fixed display space layout and positioning equipment are required	The software needs to be installed in the user's mobile phone in advance	The sense of immersion is weak, the motion capture is unstable.
Main advantages at present	Widely used and mature technology	It has broad development prospects, is not limited by space, and has a better user experience	It is not limited by space, portable, low cost and easy to promote

Since Ivan Sutherland, the father of computer graphics, designed the first head mounted AR and VR combined display (HMD: Head Mounted Display) in 1968, it has always been human's dream to recreate a world.

Although the concept of XR was put forward many years ago, it has been limited by computer software and hardware, and XR technology has not been well developed and applied. Nowadays, the development of digital twins, computer graphics, human-computer interaction and other technologies have paved the way for the advent of the virtual world.

XR technology has gradually entered the public's vision and has been applied into various fields. Based on the increasing popularity of Virtual Reality (VR) and Augmented Reality (AR) applications, on March 7th, 2022, Professor Georgios Minopoulos and Professor Konstantinos E. Psannis revealed the necessity of implementing Extended Reality (XR) to users and proposed a simplified Tangible XR system to solve Opportunities and Challenges of Tangible XR Applications for 5G Networks and Beyond.

On February 10th, 2022, Professor BaoTrinh and Professor Gabriel-Miro Muntean proposed a resource management scheme for SDN-MEC supporting XR application, based on deep reinforcement learning.

2.2 Bloom Model

B.J.Bloom, an American educational psychologist, divides educational goals into three fields [10]: cognitive field, emotional field and operational field, which constitute the educational goal system.

In the field of cognitive learning, the teaching objectives are divided into eight levels which include memorization, understanding, application, analysis, synthesis, evaluation, design and innovation from the lowest to the highest.

Although the traditional course homework also adopts a similar model, Bloom model pays more attention to the role and relationship of these eight levels, which is more in line with the blended teaching structure once required by the "Golden class [11]".

Under the background of "Internet + Education", scholars at home and abroad have focused on blended teaching, and the course assignments realized by expanding reality and blended teaching based on Bloom theoretical model will become a new trend of contemporary education development in the future.

3 Metaverse and Edge Computing Fusion Architecture

3.1 Overall Architecture Design

With the advent of the 5G era, the 5G cloud network fusion service gateway for the educational metauniverse is deployed by combining the 5G network, the double gigabit education private network and the 5G base station, which supports routing, bridging, bypass and other modes.

Flexible deployment is made according to the equipment of the metauniverse immersion, making it possible to interact with the multi-user metauniverse network. Compared with the previous network environment, 5G environment can realize real-time XR image transmission, natural image and voice transmission, seamless cross-ground interaction, real-time sharing of big data, and smooth metaverse application transmission.

There are new developments in network slicing technology. This technology can through virtualization technology will calculation, storage and network resources and dedicated hardware decoupling, form a unified resource pool, according to a certain operation rules for different requirements of applications, meet different demand for resources, make the best use of existing hardware resources [12, 13] form a reliable virtual network environment. This environment can serve as the basis for the implementation of an edge computing system architecture. The overall architecture is shown in Fig. 1 below.

However, at this stage, VR/AR/MR There are problems such as high investment cost of computer teaching and lack of unified operation and management mechanism. The development of the meta universe also has problems such as industrial support, difference in ideas, and imperfect governance system of the meta universe.

In the course of multi person collaboration, the meta universe proposed by me decreases the throughput of the network due to the increase of network data volume. There are problems such as insufficient processing capacity of huge data, extended transmission time, and information loss. In order to meet the needs of delay sensitive businesses, and solve the problems of Internet device security authentication, limited

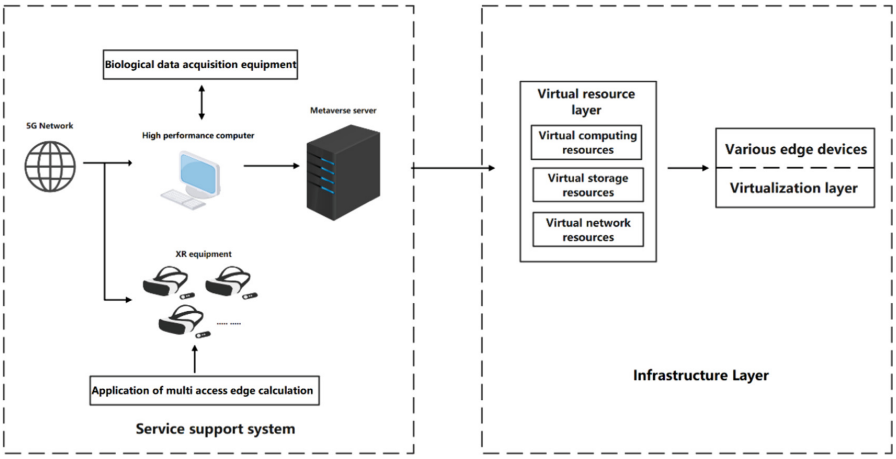

Fig. 1. Overall architecture diagram.

edge server resources, etc., time delay and security are taken as optimization goals, The improved deep reinforcement learning algorithm is used to allocate the resources of the meta universe scene.

To solve the optimization problem of network congestion control, the original edge computing architecture is not suitable for the course assignment universe I designed, and its edge nodes have poor security and high latency.

In order to solve the problems of data security, privacy protection and high latency caused by the original edge computing mode, this paper proposes a distributed secure trusted authentication model based on edge computing. Based on the traditional single chain, a master-slave multi chain structure is designed, and a three-tier architecture is deployed by integrating edge computing; It is predicted that this model is safe and reliable.

Compared with the single chain architecture of traditional deployment mode, the storage overhead is reduced by 50% on average, and the delay will also be significantly reduced. Compared with the existing schemes, the scheme in this paper has greater advantages in throughput.

The ratio of transmission rate to throughput will reach 1:1, which can meet the practical application requirements of large-scale meta universe, with high scalability and high security It makes the network load more balanced and avoids network congestion, providing a basis for design and testing.

3.2 Service Support System

To build an educational metaverse, hardware should be configured in the 5G network coverage environment, the central server of the metaverse should be deployed, and each learner should be equipped with a set of virtual reality equipment.

Second, it should be configured with a high performance computer in the meta-universe environment, the operating system must be Windows10 or above version, the

processor is intelcorei5-4590 with the same performance and above, and the graphics card is NVIDIA GeForce GTX970 with the same performance and above. It should also be configured with gigabit wired network port and 5G router.

Network port, router and computer network cable require six types of cable and above specifications. For users, multiple access devices can be configured, such as smart phones, tablets and other wireless devices to directly access the server, high performance computers can also be used to access the web, or directly with the server for wired streaming connection to access the meta-universe content.

At the same time, the bioelectrical analysis of learners should also be equipped with physiological analysis equipment, mainly including ECG, EEG, skin and other biological collection equipment, which is used to detect the changes of immersion, concentration, flow experience and other conditions of learners when they are immersed in the metaverse environment. In order not to affect the immersion of learners, the bioelectricity collection equipment does not choose professional medical psychological analysis equipment, but simple equipment such as hand bracelet, maker brain wave kit, maker skin electric kit and so on.

3.3 Infrastructure Layer

The infrastructure layer is the lowest layer of the entire network architecture, including the hardware resource layer, virtualization layer and virtual resource layer.

The hardware resource layer consists of a large number of geographically dispersed edge devices of different types and models, which can provide computing, storage, and network resources for the network system.

However, since many edge devices are simple iot sensors, etc., with limited computing, storage and networking capabilities, lightweight virtualization technologies are needed to make full use of them [14]. The virtualization layer uses lightweight virtualization technology to achieve strong isolation of each virtual machine.

The micro operating system oriented to micro service or container runs in the virtual machine, which can simplify a lot of useless functions and realize the transformation of embedded device-level hardware resources into virtual resources [15]. In the virtual resource layer, hardware resources are virtualized into virtual computing, storage, and network resources, facilitating unified management and control.

4 Metaverse Data Analysis

It is difficult to use a consistent standard to judge the collected multi-dimensional user data due to its different dimensions, so entropy method is used for mining and analysis. The entropy method regards the object as a system, according to the probability Pi (I = 1, 2, …, m) to determine the entropy value E of the system, see Eq. (1). The smaller the entropy, the higher the stability.

$$e = \sum_{i=1}^{m} P_i \times lnP_i \tag{1}$$

At the same time, the combination of atomic economy algorithm and Cosine algorithm can calculate the similarity of the learner's behavior, see formula (2) and formula (3). In formula (2), AE is the atomic economic value, MW is the MolecularWeight, and AE is the percentage of the ratio between the molecular mass of educational output MW and the original educational input ΣMW. In Formula (3), (X1, X2) is the first kind of atomic economic value vector AE1, and (Y1, Y2) is the second kind of atomic economic value vector AE2. The cosine of the included Angle represents the similarity of learner behavior data. The closer the value is to 1, the more similar the two kinds of learning behaviors are.

$$AE = \frac{MW}{\Sigma^{MW}} \times 100\% \tag{2}$$

$$\cos\theta = \frac{x_1x_2 + y_1y_2}{\sqrt{x_1^2 + y_1^2} + \sqrt{x_2^2 + y_2^2}} \tag{3}$$

5 Research Design

5.1 Extended Reality Based Metaverse of Course Homework

Taking *Principle of Computer Composition* as an example, the main teaching contents are decomposed based on Bloom model. There are some problems in traditional course homework, such as too abstract concept, repeated and rigid content, single evaluation method and so on. Here, we divide the Bloom model into four layers [16]. The first layer is to remember and understand; Application and analysis of the second layer; The third level is comprehensive evaluation; The fourth layer is design and innovation.

Comprehensive extension reality XR technology characteristics of the interaction of the different aspects of computer constitute principle design method, this article in view of the course content and extension reality (XR) technical characteristics of yuan respectively designed the universe VR, MR different application scenarios and AR, explore the three show effect in course feedback, interaction, and the difference between the usage scenario [17, 18]. The specific frame design is shown in Fig. 2 [18].

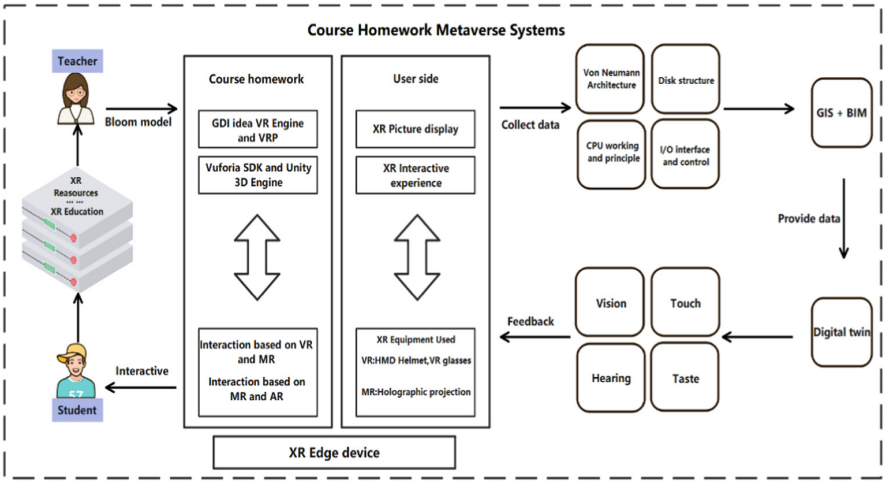

Fig. 2. A metaverse framework for course homework

5.2 Interaction Derived from VR and MR

XR technology as the core to establish teaching practice course assignments Metaverse, "expanding the real leading" hybrid teaching mode, will Bloom model with BOPPS mode structure of the hybrid teaching fusion, in combination with the practical situation of students in the learning process and the content of the course of computer constitute principle, design meet the requirements of the "Gold" gender once course assignments.

Based on BOPPPS teaching mode will "online and offline" organic integration of teaching, the autonomous learning before and after class and class feedback teaching, the combination of class assignments, students through XR platform into yuan universe on autonomous learning before class, by extending the reality (XR) technology design display of abstract concepts, build a model of the course assignments independently. For example, the 3D simulation based on the 3D engine Unity3D shows the abstract concept, and the ideaVR engine and VRP are added to the immersive VR and MR interactive system, so as to break the inherent abstract concept and enable students to immersive learning and achieve the first level of memorization and understanding.

5.3 Scenes Presented in AR and MR

The Metaverse of coursework designed in this paper enables students to master basic knowledge points by extending immersive online learning with realistic technology. Traditional teaching listens to students' expressions and communicates with students in class according to the feedback of offline learning effects and after the teacher's checking and making up for gaps and key breakthroughs. However, XR-based course work is highly interactive and expressive. Its core is supported by digital twin technology, which restores the teaching model one-to-one and collects students' learning data.

With the MR device, students can see the real image through the semi-permeable membrane lens, and the semi-permeable membrane can reflect the projection to superimpose the computer-rendered image onto the real image. MR devices can also draw

images based on realistic scenes and allow users to see three-dimensional images through left-right eye disparity. Students can control the computer through gestures and voice. In the teaching activities of participatory learning, timely and targeted examination of students' learning effects, and guide students to draw inferences by analogy through AR model scenes, etc., to consolidate what they have learned.

The AR technology used starts with the course information and computer model data, and uses the graphics and modeling software to process the data into text, two-dimensional image, three-dimensional model and video. Combined with VuforiaSDK and Unity3D engine, the design and development of online computer hardware model interactive teaching system based on AR technology is realized. After class, homework should be adjusted according to the different learning effects of each student, and online and offline learning content and teaching methods should be adjusted according to the learning results of students to maximize the learning effect. In line with the second layer of application, analysis and the fourth layer of design, innovation.

5.4 Master Slave Multi Chain Design

In order to break through the bottleneck of traditional single chain performance, a master-slave multi chain structure is designed, as shown in Fig. 3 [20].

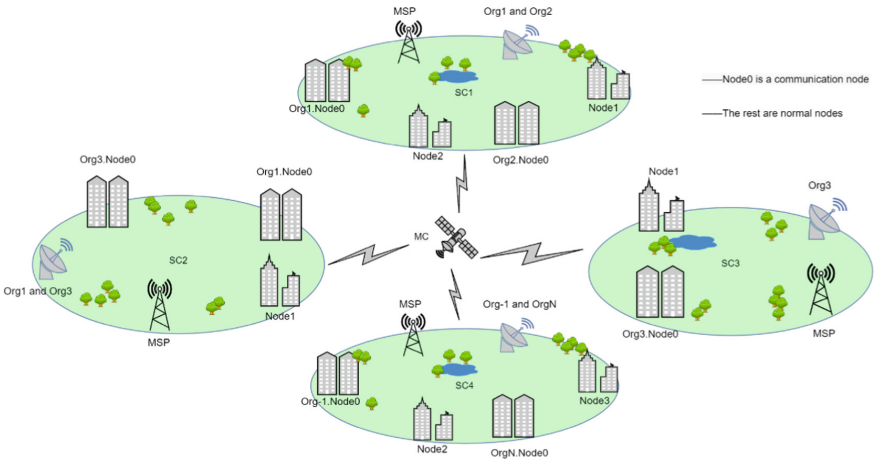

Fig. 3. Master-slave multi-chain structure

The master-slave multi chain structure includes a main chain (MC) and multiple slave chains (SC). As a trusted platform in the domain, the SC manages access operations in the domain, and defines common nodes and communication nodes.

Common nodes are responsible for data storage, communication nodes are the hub of network interaction, and connecting to MC. MC is the bridge of interaction between slave chains, which is used to resolve cross chain requests, Realize trusted identity authentication. MC defines communication nodes and cache nodes [21].

Communication nodes interact with SC networks to achieve interconnection and interworking between chains. Cache nodes cache cross domain data through CouchDB state database. Communication nodes form the index of MC and SC, connecting multiple SCs to form an infinitely expanded master-slave multi chain, It has good flexibility and scalability.

The membership service provider (MSP) is a certificate management server that participates in the maintenance of the local blockchain ledger, and conducts identity audit and certificate issuance for the nodes joining the blockchain.

The advantage of master-slave chain structure lies in its strong scalability. The slave chain can be dynamically expanded, so that the performance of the entire system will not be limited to a certain chain, breaking its scalability bottleneck.

As a trusted authentication platform, the main chain stores the hash time lock of its transactions, maintaining the atomicity of transactions between secondary chains.

5.5 Distributed Security Architecture Based on Master-Slave Multi Chain

Integrated edge computing under master slave multi chain, a three-layer distributed security architecture is designed, as shown in Fig. 4, including the device layer, slave chain network and master chain network, and three-layer bottom-up services.

The device layer provides trusted computing services for the upper layer. After the identity registration process, the edge devices in this layer access the slave chain network to form the "miner" of the slave chain network - the edge node (En).

En stores the data in the SC node after preprocessing, and the SC provides a secure data storage environment and access control within the domain for the devices in the current domain [22]; The communication nodes in SC and MC jointly maintain reliable communication and provide services for cross domain access control. The main chain network supports access across different SC domains.

The three-tier architecture covers the core functions of blockchain and edge computing, and provides distributed security services from different levels of storage, network and computing.

The slave chain and edge nodes in the architecture can be developed according to needs, and it is an unlimited expansion alliance.

(1) The lower layer is the device layer, which has two functional modules: the perception module and the device management module. The device management module has designed a secure access process based on cryptography, and the device can become a legitimate En only after being verified by this process.
(2) The middle layer is a slave link network, which includes two functional modules: data processing and intra domain access control.

    In the data processing module, En preprocesses the data collected by the device layer, packs them into blocks in a unified format, and stores them in the SC ledger; The intra domain access control module is the core function module of the middle layer, which realizes the intra domain access management of the Internet of Things.
(3) The upper layer is the main chain network. As a trusted sharing platform between domains, this layer is the controller for cross domain management of data.

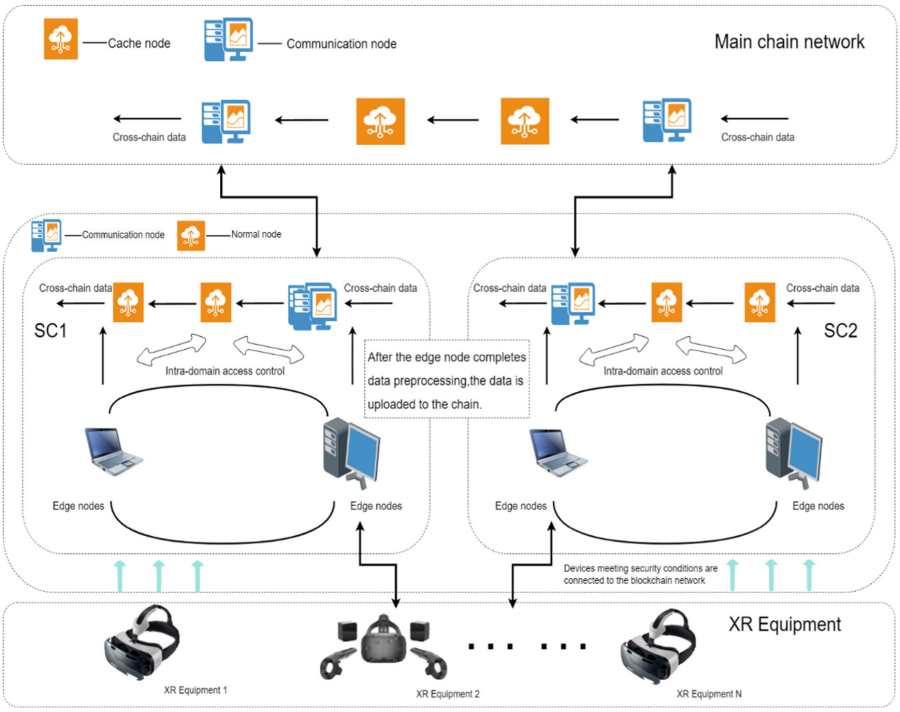

Fig. 4. Distributed Security Architecture

This layer is equipped with a cache module and an inter domain access control module. The inter domain access control module jointly manages cross domain access behavior with SC, and the cache module caches cross domain data and related information.

5.6 Metaverse Comprehensive Evaluation System

The Course homework Metaverse records the course work progress and standards achieved by each learning module. While paying attention to the learning process of students, the process evaluation of students is carried out, the behavior of students in the meta-universe is assessed, and the learning effect of students is evaluated through exams and tests. Course assignments with different difficult exercises and test, in view of teaching difficult point to incorporate knowledge in each layer of computer constitute principle, make learning content modular, convenient students according to their own needs in the yuan universe for selective learning, abstract concept abstract content by XR technology in coursework yuan show in the universe, enhance students' acceptance, deepen knowledge understanding. In teaching design, from the perspective of students, embodies the student-centered teaching idea, and designs meta-universe content in line with students' cognitive laws.

During teaching, students should pay close attention to students' feedback through interactive communication design, adjust teaching content and teaching strategies in

time, and guide students to get timely answers to questions through active and active thinking and creative exploration activities. Teachers summarize and analyze the problems left by students in the meta-universe of course work before class, and explain these problems in simple and profound ways in class. After class, teachers assign homework of different difficulty to facilitate students of different levels to review, consolidate and apply the knowledge points, timely grasp the completion of students' homework, reasonably design the subsequent teaching content and teaching methods, and help each student to maximize the learning effect from the perspective of individualized teaching. In terms of the assessment content, the students' mastery of curriculum knowledge, emotional attitude and comprehensive ability are evaluated. The evaluation index system of the effect of students' learning advanced mathematics course and the teaching process of teachers is established based on the high order, innovation and challenge standards of "gold course".

5.7 Application Scenarios of the Coursework Metaverse

John Smart, the project leader of the American metaverse roadmap, proposed a very pioneering and inclusive metaverse application scenario classification framework [23], which was widely recognized because it reflected the consistency of cognition, body and environment, and had rich cognitive embodied thoughts and educational implications [24]. Contemporary embodied cognitive theory reexamines the relationship between body, cognition and the world, and proposes that "body is the core of cognitive process" and "cognition is generated in the interaction between body and environment" [25].

The accompanying embodied learning encourages and supports learners' embodied interaction and perceptual experience, aiming to realize the close coupling and dynamic evolution of learners, learning environment, learning resources and other elements. Embodied cognition theory provides a new perspective for understanding the educational application scenarios of the metaverse.

The learning process in the metaverse is embodied in the practice of the learner's body, that is, the interaction and interweaving between the body and the learning environment. Thus, the practice in the metaverse can be understood as Dewey's "learning by doing" [26].

6 Practical Challenges for Metaverse Educational Applications

Compared with foreign countries, Chinese researchers keep up with the frontiers of international metaverse research and have made preliminary achievements, but the depth of research and the breadth of practice need to be improved. At present, the metaverse has been widely concerned by the society, and the majority of educators have fully realized that the metaverse has important value in promoting education intelligence, realizing education scale and individuation. However, the current industrial layout of the metaverse has not yet been formed and is still in the initial exploration stage.

Since 2022, the governments of Wuxi, Beijing, Shanghai, Xiamen and many other places have stepped up the layout of the metaverse industry and issued intensive policies

related to the development of the metaverse. However, few policies and technology enterprises have laid out the application of the metaverse education. How to fully implement the metacosmic educational application and how to form a scalable mature application mode is still a big problem in our educational circles.

Therefore, it is suggested that top-level design and scientific layout should be carried out at the national level, and development suggestions and construction guidelines for the application of metaverse education should be issued. To organize universities and scientific research institutions to set up specialized metaverse education and research institutions to carry out prospective research and solve difficult problems in the application of metaverse education; Combined with the strategic needs of the digital transformation of education, some typical and valuable metaverse education application models and cases are extracted and summarized, and first tried in the smart education demonstration zone to lead the educational innovation and application of the Metaverse.

7 Future Trends in Metaverse Educational Applications

The Metaverse is a new direction of online education [27], which is helpful to meet the growing lifelong learning needs of human beings and adapt to the needs of learners in school, family and society, and is of great significance for the construction of a learning society in which "everyone can learn, everywhere can learn, and can learn all the time".

With the development of Web3.0, XR, artificial intelligence, 5G and other technologies, the integration of virtual world and physical world will accelerate, and the metauniverse education application and market scale may show the following development trends [28]. Forecast of development trend is shown in Fig. 5 below.

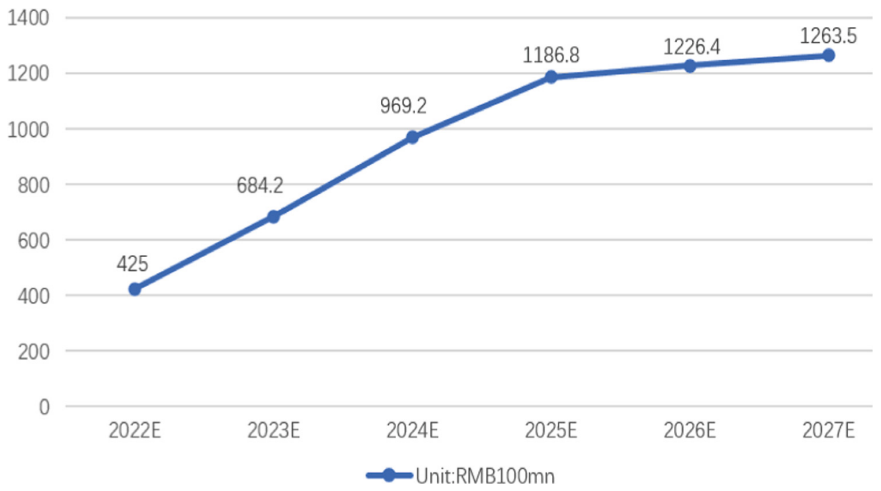

Fig. 5. Forecast of development trend

At present, VR/AR/MR has some problems, such as high investment cost and lack of unified operation and management mechanism. The development of the metaverse

also has some problems, such as industrial support, concept differences, and imperfect governance system of the metaverse [29].

Looking into the future, in the era of 5G and 6G, the arrival of XR technology and the rise of the metauniverse will subvert the teaching method of computer teaching, reduce and reduce the cost of user terminals, unify the content of teaching resources, and greatly improve the quality of talent training.

The super-high-speed network experience will bring a qualitative and quantitative leap to computer teaching.

Especially with the popularity of 5G communication technology, the reduction of data delay and the increase of bandwidth, as well as the research and development of high-performance graphics processors, XR technology hardware can enter the mass production stage like smart phones, into thousands of households; With the support of new technology and metaverse, computer science will usher in a new era [30].

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References

1. Nover, S.: The Metaverse Will mostly be for Work [EB/OL] (2021). https://qz.com/2083099/the-metaverse-will-mostly-be-for-work/. Accessed 17 Apr 2022
2. Almirall, E.: Teaching in the Metaverse Is much Closer to Being in the Classroom than in an Online Session [EB/OL] (2022). https://dobetter.esade.edu/en/technology-virtual-reality-education. Accessed 21 Apr 2022. Author, F.: Article title. Journal 2(5), 99–110 (2016)
3. Mystakidis, S.: Metaverse. Encyclopedia **2**(1), 486–497 (2022)
4. Liu, D., Cao, Z., He, Y., Ji, X., Hou, M., Jiang, H.: Exploiting concurrency for opportunistic forwarding in duty-cycled IoT networks. ACM Trans. Sens. Netw. 15(3), 31:1–31:33 (2019)
5. Digital Intelligent Human: a fundamental unit in the meta-universe, and a new manifestation of service intelligence, [EB/OL] (2022–03–19). https://www.shangyexinzhi.com/article/4684994.html. Accessed 14 June 2022
6. Zhao, X., Lu, Q.W.: Governance of the metaverse: a vision for agile governance in the future data intelligence world. J. Libr. Sci. China **48**(1), 52–61 (2022)
7. Hu, Z., Zeng, F., Xiao, Z., Fu, B., Jiang, H., Chen, H.: Computation efficiency maximization and QoE-provisioning in UAV-enabled MEC communication systems. IEEE Trans. Netw. Sci. Eng. **8**(2), 1630–1645 (2021)
8. Kimkylin. What is edge computing and what is the difference between it and cloud Calculation. https://m.elecfans.com/article/1684192.html
9. Lee, M.J, Georgieva, M.,Alexander, B., et al.: The State of XR and Immersive Learning Outlook Report (2020). https://immersivelrn.org/ilrn2020/

10. Bloom, B.S., Englehart, M.D., et al.: Taxonomy of Educational Objectives: the Classification of Educational Goals,Handbook 1. Cognitive domain. Longmans Green, NY (1956)
11. Wu, Y.: Building China's 'golden course.' China Univ. Teach. **12**, 4–9 (2018)
12. Samdanis, K., Wright, S., Banchs, A., et al.: 5G network slicing: part 1-concepts, principles, and architectures. IEEE Commun. Mag. **55**(5), 70–71 (2017)
13. Ordonez-Lucena, J., Ameigeiras, P., Lopez, D., et al.: Network slicing for 5G with SDN/NFV: concepts, architectures, and challenges. IEEE Commun. Mag. **55**(5), 80–87 (2017)
14. Jiang, H., Dai, X., Xiao, Z., Iyengar, A.: Joint task offloading and resource allocation for energy-constrained mobile edge computing. IEEE Trans. Mob. Comput. **1**(3), 733–747 (2022). https://doi.org/10.1109/TMC.2022.3150432
15. Tiburski, R.T., Moratelli, C.R., Johann, S.F., et al.: A lightweight virtualization model to enable edge computing in deeply embedded systems. Softw. Pract. Experience **51**(9), 1964–1981 (2021)
16. Samsung. The Next Hyper--Connected Experience for All. https://chinaflashmarket.com/Uploads/Report/20200714145321809946.pdf
17. Myrden, A., Chau, T.: Effects of user mental state on EEG-BCI performance. Front. Hum. Neurosci. **9**, 308 (2015). https://doi.org/10.3389/fnhum.2015.00308
18. Rashkov, G., Bobe, A., Fastovets, D., Komarova, M.: Natural image reconstruction from brain waves: a novel visual BCI system with native feedback. bioRxiv (2019)
19. El Meouche, R., Rezong, M., Hijazi, I.: Integrating and managing BIM in GIS, software review. ISPRS-Int. Arch. Photogrammetry Remote Sens. Spat. Inf. Sci. **1**(2), 31–34 (2013)
20. Minmin, H., Lingyun, Y., Xue, P.: Secure and trusted authentication model under edge computing and multi-block chain [J/OL]. Mod. Distance Educ. Res. (2022)
21. Jiang, H., Xiao, Z., Li, Z., Xu, J., Zeng, F., Wang, D.: An energy-efficient framework for internet of things underlaying heterogeneous small cell networks. IEEE Trans. Mob. Comput. **21**(1), 31–43 (2022)
22. Su, W., Liu, D., Zhang, T., Jiang, H.: Towards device independent eavesdropping on telephone conversations with built-in accelerometer. Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. **5**(4), 177:1–177:29 (2021)
23. Smart, J., Cascio, J., Paffendorf, J.: A Metaverse Roadmap: Pathways to the 3D Web [EB/OL] (2007). http://www.metaverseroadmap.org/MetaverseRoadmapOverview.pdf. Accessed 22 Apr 2022
24. Kye, B., Han, N., Kim, E., et al.: Educational applications of metaverse: possibilities and limitations. J. Educ. Eval. Health Prof. **18**, 1–13 (2021)
25. Chen, X., Wang, G.: The research process, theoretical development and technological turn of international embodied learning. Mod. Distance Educ. Res. **31**(6), 78–88,111 (2019)
26. Yarchi, M., Baden, C., Kligler-Vilenchik, N.: Political polarization on the digital sphere: a cross-platform, over-time analysis of interactional, positional, and affective polarization on social media. Polit. Commun. **1**, 1–42 (2020)
27. Liu, G., Wang, X., Gao, N.: Metaverse exploration based on extended reality under edge computing. Res. Mod. Distance Educ **33**(6), 12–22 (2021)
28. China Commerce Industry Research Institute. Forecast and analysis of China's metaverse market size and future development trend in (2022). http://wap.seccw.com/Document/detail/id/12637.html
29. Xu, Z.: Introduction and enlightenment of computer programming courses in American colleges and universities. Comput. Edu. **12**, 169–172 (2019)
30. Zhao, Q., et al.: A brief survey on virtual reality technology. Sci. Technol. Rev. **34**(14), 71–75 (2016)