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Research Article

Building a Smart Education Ecosystem from a Metaverse Perspective

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Metaverse is the future of the Internet and integrates a variety of information technologies. It leads future education trends and brings profound changes to education. On the basis of analysis of the development trend of smart education and the connotation and action mechanism of edu-metaverse in the view of metaverse, this paper structures the smart education ecosystem, builds the scenario and modular smart learning space of three education scenarios of resource collaborative interaction, virtuality-reality integration experience, and ubiquitous spatial inquiry by using the six core technologies, and forms the new education mode of virtuality-reality symbiosis, trans-spatial fusion, and collaborative inquiry. Then, it verifies the application effect by AHP. Finally, it creates the smart education ecosystem of "four ecology integration"—resource ecology, interaction ecology, space ecology, and collaboration ecology, which accelerates the organic integration of metaverse and smart education and provides theoretical basis and reference for the new application of future education.

1. Introduction

The term "metaverse" was coined by Neal Stephenson in his 1992 science fiction novel "Snow Crash." In 2021, the "Roblox" game platform was launched, which was a landmark event and garnered widespread attention. The word "metaverse" is increasingly popular nowadays, and this year 2021 is known as the year zero of the metaverse [1]. Metaverse emerges with the development of information technologies such as 5 G, AI, VR, AR, and digital twins. Both national and local governments have incorporated this concept into the 14th Five-Year Development Plan, focusing on digital empowerment, integrating new scenarios, and creating a new ecosystem of content, resources, technology, and services. As the metaverse era unfolds, new opportunities open up for new infrastructure of Chinese education, cultivation of advanced thinking among students, and future educational development. At present, "metaverse" has not yet been uniformly defined. There are four main theories: embodied Internet, social ecology, virtual space and time, and virtuality-reality combination. Thus, this study believes that metaverse is a virtual space parallel to the real world and IS supported by AI, big data, HCI, and other communication technologies, which can meet people's experiential, immersive, sharing and creative needs and can be widely applied in various fields.

The concept of educational ecology integrates pedagogy and ecology. It is an interdisciplinary subject that emerged in the mid-1970s [2–5]. It mainly studies the laws and mechanisms of how education interacts with its surrounding environment, opening up a new field in education studies. From both macro and micro perspectives, educational ecology borrows the principles and methods from ecology to study the process, law, and ecological balance of the interaction between education and information, people, and the environment so as to leverage educational resources to improve students' cognitive ability and improve the level and function of the entire ecosystem, allowing it to enter a virtuous cycle.

Educational ecology has three basic characteristics: overall association, coevolution, and dynamic balance [6]. The smart education ecosystem is also built on the above basic theories. The concept of smart education originated in

2008 when IBM first proposed the concept "Smarter Planet" in *A Smarter Planet: The Next Leadership Agenda* [7]. The concept later spread to various fields and inspired new ideas, leading to the emergence of smart education. The core of smart education is to enable the perception, interconnection and intelligence of everything through the use of information technology. With the development of intelligent technology, especially 5 G technology, China has issued a package of policies to reform its education model and accelerate the development of smart education [8]. To sum up, smart education ecosystem is a "symbiotic, dynamic, balanced, and sustainable" system that integrates the effects, interconnection, and educational elements. It organically connects educational subjects (teachers and students) with educational concept, teaching design, teaching resources, teaching evaluation, and other factors using information technologies, aiming to realize intelligent and ecological education.

With the emergence of the metaverse, information technologies and artificial intelligence have stimulated innovation in education, transformed traditional pedagogical concepts and methods, and formed the basis for smart education. Smart education, driven by the metaverse, has become one of the most heated topics in the current educational research. Leveraging information technologies such as digital twins, 5 G, and artificial intelligence in the metaverse, smart education integrates variables in the education ecosystem such as teachers, learners, resources, and teaching environment and explores the intrinsic nature of each element. It helps to create diversified education scenarios, form a new system of unified and coordinated smart education ecosystem, systematize theoretical research results, and provide new ideas for deeply integrating education and metaverse. By applying the metaverse technology in education, a full-process closed-loop structure can be developed. With no boundaries between online and offline settings, a "multidimensional" teaching approach can be delivered, which effectively overcomes shortcomings of traditional education, creates an intelligent and interactive learning environment, and realizes intelligence-driven and customized education. This new pattern is of great significance for improving educational quality and efficiency, delivering tailor-made education, transforming education modes, and providing new impetus for the development of teaching and learning.

Based on an analysis of the development trend of smart education and the mechanism of education metaverse, this study creates a smart education ecosystem. Using six core technologies, we develop three scenarios, namely, resource orchestration and interaction scenario, virtual-reality combination scenario, and ubiquitous space inquiry scenario and build three scenario-based modular smart learning spaces so as to form a new education mode featured by virtuality-reality symbiosis, trans-spatial fusion, and collaborative inquiry. Then, the application value of the mode is verified using the analytic hierarchy process (AHP). Finally, a smart education ecosystem that integrates four ecologies, namely, resource ecology, interaction ecology, space ecology, and collaboration ecology, are established.

2. Current Research Status

Metaverse-related research started early in developed countries, and many results have been achieved. A number of countries, including the United States, Germany, and India, have developed relatively mature metaverse-related information technology. Based on a review of literature over the past decade, we found that at the technical level, the study of smart education mostly focused on specific technical methods and applications of the smart education platform; the most relevant theoretical aspect was the definition of metaverse. Jonathan Glick, senior editor of the New York Times, believes that the development of metaverse involves two stages. The primary stage is manifested by the desire of participants to live in a completely virtual space. They believe virtuality is somewhat "better" than the real world. The higher stage is the technical ecosystem that ultimately realizes the connection between facts and fictions [9–11]. Metaverse has been used in education in the US, where the University of California, Berkeley held an online graduation ceremony on its Minecraft digital campus. The South Korean Ministry of Education launched a metaverse-based creative science classroom program. In smart education research, Oshima discussed how robots can assist in teaching as intelligent mentors [12]. Professor Rensing proposed a query-based recommendation system of text learning resources and a knowledge recommendation system that automatically generates knowledge bases. Jennifer et al. developed an intelligent writing system based on learners' writing ability [13]. Chae presented IEEE 802.11 ax Optimal Design for XR (Extended Reality) in Education and Training [14]. We reviewed research on the application of metaverse-based smart education in China from well-known databases such as CNKI, Wanfang Data, and Baidu Xueshu, and found as follows: (1) *The Number of Studies*. Taking CNKI as an example, using keywords such as "metaverse," "education ecosystem," and "smart education," 335 relevant papers were published in the past decade. Most scholars began studying metaverse in 2021 and smart education ecosystem in 2013, with research results increasing year by year. (2) *Research Content*. In terms of metaverse education, previous research mainly explained the development trend of metaverse smart education. *Invitation to Metaverse: A Discussion on the Need of a New Space for Future Education* described the potential of the metaverse for educational development in the virtual world [15]. *Metaverse and Education: A New State of Educational Development in the Future* believed that the edu-metaverse will lead to a future education form that combines the edu-metaverse with the physical world as the core of the interstellar civilization [16]. In *Open Another Door of Education—the Application, Challenges and Prospects of Edu-metaverse*, the authors presented the problems and challenges facing the metaverse and propose solutions for the early development of edu-metaverse from mechanism, technology, and teaching [17]. In terms of smart education and ecosystem theory and application, past studies mainly discussed the applications of "Internet +" in smart education, which uses information technologies to influence and transform the education ecosystem. *AI + Education—Smart Education Ecosystem Boosts the Realization of Educational Equity* proposed to enhance the availability of educational resources through information-based methods and realize educational equity through smart learning [18–21]. *Research on the Construction of Ecological Path of Online Education in Universities under 5 G* proposes to develop online education with the support of 5 G and improve the ecosystem of online education in universities with 5 G [22].

Various research results suggest that in the era of metaverse, information technologies have developed rapidly and become more diverse, and the smart education ecosystem is humanistic, intelligent, interactive, immersive, and collaborative. The future research direction is to develop a new smart education ecology using metaverse technology.

3. Smart Education Trends in the View of Metaverse

As information technologies develop, smart education emerged and has transformed traditional education profoundly. The use of digital multimedia and other mobile methods leads to diverse learning forms, allowing students to customize their learning pattern. Technologies create a learner-centered educational ecology, digitalize education, and facilitate the cultivation of intelligent talents. Smart education can be seen as a new form of education amid informatization, an advanced development stage of digital education, and a ubiquitous educational information ecosystem.

With the emergence of metaverse technology, smart education presents new trends and views while driving digital transformation and intelligent upgrading. The *Metaverse Development Report* pointed out that the metaverse integrates virtual Internet application and real social forms generated by a variety of new technologies. It provides immersive experience using extended display technology, generates mirrors of the real world using the digital twin technology, and builds an economic system using the blockchain technology. It closely integrates the virtual and real worlds in terms of the economic system, social system, and identification system and allows users to produce content and edit the world [23, 24].

3.1. Simulating the Real Teaching Scenario. With information technologies, it breaks down the boundaries of space and time in the physical world, expands the traditional learning space, and creates a virtual learning space that simulates the real settings. It gives teachers and students digital identities, allowing them to communicate synchronously in both the physical and virtual worlds. Students and teachers interact and influence each other and develop together, making up for the shortcomings of physical teaching and demonstrating a better teaching pattern.

3.2. Creating Immersive Teaching Experience. In a metaverse-based learning scenario, teachers can adopt highly effective teaching methods and directly and intuitively display videos and images related to the teaching content. Reality and virtuality are seamlessly connected so that students can customize learning services and enjoy real-life learning experiences. Through auxiliary equipment, a three-dimensional interactive presentation method can be employed to produce diversified and comprehensive sensational experience such as vision, hearing and touch, realize multimodal learning and to create a sense of "being there." Rich and 3D teaching experiences stimulate students' curiosity, enhance the teaching effect and quality, and improve learning efficiency.

3.3. Facilitating Students' Cooperation and Personalized Learning. Flexible teaching activities can be carried out by teachers. In the metaverse, teachers customize learning scenarios to cater to the needs of students. Teachers and students interact in the metaverse in real time, and students are allowed to collaborate on learning in different places. Thorough inquiry and discussion, sharing of information and resources in real time, as well as in-depth communication, students can better absorb and internalize knowledge. Teachers can also modify and introduce new learning resources for learning activities to create personalized learning space and enhance students' thinking abilities and literacy level.

3.4. Promoting Interdisciplinary Studies. Smart education transcends the single medium and linear teaching process of traditional teaching, addresses the limits of the original talent training system, breaks down the correlation between curriculum systems, facilitates STEM education as well as interdisciplinary teaching and innovation, and gives students greater freedom to engage in various forms of teaching.

Therefore, in the era of metaverse, smart education is characterized by virtuality-reality integration, collaborative interaction, and resource coconstruction. Compared with traditional education, it breaks down the boundaries of time and space, enhances students' cognition and scenario-based experience, and creates a collaborative, interactive, and dynamic education ecology.

4. Construction of the Metaverse-Based Smart Education Ecosystem

4.1. Ecosystem Architecture. The architecture of the smart education ecosystem is designed on the basis of metaverse-empowered education and ecological principles. Following the definition of smart education ecosystem, the metaverse technology is used to build internal and external ecosystems and to coordinate the internal structure, interaction, and mutual adaptability with the surrounding environment. The ecosystem fully considers the needs of teachers, students, administrators, and other users. It incorporates smart education into the whole process of education and integrates the elements of the smart education system and other elements, reconstructing the relationship between the elements, including the smart education environment and

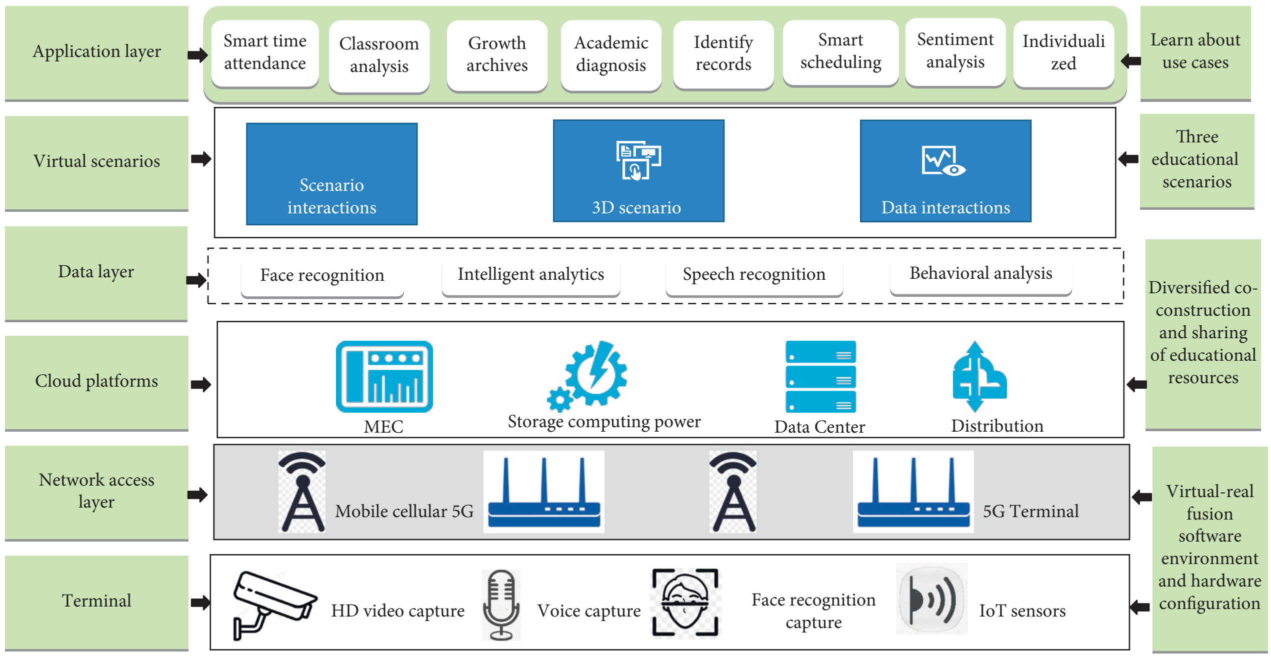

Figure 1: Architecture of the smart education ecosystem in view of metaverse.

technologies. It transforms the traditional educational environment into a ubiquitous one and adopts real teaching resources, flexible teaching modes, and intelligent teaching methods. The students' learning methods are personalized, and the learning content is targeted.

The design idea is supported by six core technologies including virtual reality and artificial intelligence, including the five elements of smart education, teachers, students, environment, technology, and resources. The foundation is the hierarchical principle of information management system architecture. First, the infrastructure layer (IaaS) is constructed. By using virtualization, cloud computing, and cloud storage technologies, an immersive environment is formed to realize cross-level, cross-platform docking, data sharing, and system integration so as to integrate systematic resources and platforms and develop and apply education scenarios. Specifically, the ecosystem has four layers: physical layer (terminal devices), network layer (cloud platforms), data layer, and application layer. The layers are interconnected and developed progressively. Eventually, a logical connection is formed between the underlying environment, resources of the smart education ecosystem, and the high-level scenarios and applications. A sustainable, complete, and balanced system architecture is then created to promote the virtuous circle and for the development of the smart education ecosystem [25–30]. (See Figure 1).

4.1.1. Environment. The metaverse-based smart education environment includes both software and hardware. By setting up hardware and software equipment in the terminal, an environment for implementing metaverse education with an organic brain-computer interface is created. After building the 5G campus network using network and computing technologies, the network infrastructure for multiterminal collaborative cloud computing is built. By accessing the metaverse channel via the Internet of Things, face recognition, high-definition video, and voice acquisition are enabled, effectively linking the physical world with virtual scenarios. Blockchain technology is applied to ensure the security and integrity of data generated in the teaching process, providing guarantee for knowledge sharing and certification. Interactive technology is used to create a wireless learning space in the metaverse and establish a 3D human-computer interaction learning environment based on computer graphics and multimodal recognition. AI technology is leveraged to analyze teaching and learning behaviors as well as data mining, knowledge mapping, multimodal computing, and intelligent analysis. With video game technology and virtual scenarios, students are immersed in the edu-metaverse. Teachers adopt game-based and task-driven teaching methods to optimize interactions, creating a man-machine coordinated classroom. Finally, growth files of students are kept to ensure tailor-made education.

4.1.2. Resources. Resources include learning resources and interactive resources. As part of metaverse education, cloud platforms are used to collect and store digital resources and also process and manage the resources that link virtuality and reality, thus narrowing the digital resource gap and building an open ecosystem of education resources. In addition, students and teachers can freely enter the edu-metaverse to edit or create content. Through collaborative creation and updating, comprehensive, rich, and personalized educational resources can be gathered. At the same time, sharing and allocation of the resources will be promoted to reduce information asymmetry and foster a community of resources available to teachers and students.

4.1.3. Scenarios. According to the interactive, immersive,-collaborative, and diverse characteristics of smart education in the view of metaverse, we establish interactions and realize seamless switch between scenarios using XR, digital twin, and other technologies. We create three education scenarios, namely, resource collaborative interaction, virtuality-reality integration experience, and ubiquitous spatial inquiry scenarios, to replace traditional teaching settings. Scenario-based teaching and immersive experience can enrich learning activities. Through shaping diverse scenarios and generating student portraits, various learning needs of students can be satisfied. Convenient learning and barrier-free communication then lead to smart teaching evaluation and classroom analysis, promoting students' all-round development and enhancing education quality.

4.1.4. Applications. The metaverse-based smart education ecosystem has wide applications. The first one is the education of specific subjects. With the help of intuitive and interactive VR 3D scenarios, students can learn various subjects such as language, humanities, history, and geography and access-recommended personalized resources. The second is virtual learning community. The community can serve as the second classroom where students carry out rich extracurricular activities, such as visiting virtual museums and laboratories and conducting social survey in virtual communities. The last application is interdisciplinary education and vocational training. A highly simulated practical environment not limited by time and space can be created to cultivate students' hands-on abilities and skills, strengthen occupational skills, break down education barriers, and support the recognition and transformation of learning outcomes. A lifelong education system can be established, and more learning opportunities are created for vocational training.

4.2. Scenarios of Metaverse-Based Smart Education Ecosystem. According to the trend analysis and architecture design of metaverse-based smart education ecosystem, we build three education scenarios of resource collaborative interaction, virtuality-reality integration experience, and ubiquitous spatial inquiry [31–33]. The process is as follows.

4.2.1. Resource Collaborative Interaction Scenario. In the resource collaborative interaction scenario, learning theory is used to design the interaction between course teaching resources and learning resources. The scenario usually occurs before and after class. In traditional teaching, teachers provide students with multimedia resources such as text, pictures, and videos. It is challenging to support students to conduct in-depth and exploratory learning as the resources lack interactivity, operability, and accuracy. In the edu-metaverse, the adopted smart education resources are multidimensional and real. For example, 3D technology is applied to render graphics, present dynamic pictures, and enhance the attractiveness of courses to students. In addition, from the resource scenarios, students can collect and analyze data, explore objects in the metaverse, use tools, and leverage the full-life-cycle data monitoring function. Users can interact with the computer via the online resource system to acquire solutions to teaching problems. The scenario integrates rich, comprehensive, and personalized resources, optimizes resource allocation, and promotes resource codevelopment and sharing.

4.2.2. Virtuality-Reality Integration Experience Scenario. Through the virtuality-reality integration experience scenario, students learn through experience, reflection and observation, abstract investigation, and application while being free from the limitations of traditional teaching practices. This scenario is used in class, where students enter the edu-metaverse through wearable devices and human-computer interaction technology. Students engage in multimodal and immersive learning by observing and experiencing. The metaverse provides intelligent analysis, explanations, and conclusions, and students can go through the content repeatedly in the system.

4.2.3. Ubiquitous Spatial Inquiry Scenario. The ubiquitous spatial inquiry scenario combines the real and metaverse learning spaces by breaking down the physical boundaries. Students and teachers enter the edu-metaverse together, where teachers create problem scenarios before class for students to explore the answers and develop hypotheses. In class, teachers put forward the problems to be inquired again, and engage students through organizing interactive activities such as classroom competitions, group discussions, and game-based exercises. Students have free discussions via the metaverse and leverage human-computer interactive equipment to collaborate with each other. Students may keep improving the discussion results, which will be simultaneously reported back to the teachers. Then, teachers put forward improved solutions based on the discussion results. After class, teachers propose new questions. Through two-way feedback, students can verify conclusions and finish learning in a scenario that combines virtuality and reality.

4.3. Applications of Metaverse-Based Smart Education Ecosystem

4.3.1. Evaluation Indicator. The final objective of the smart education ecosystem is to promote intelligent education. It focuses on three key elements, namely, learners, learning design and implementation, and learning effects. Based on the above-mentioned scenarios and characteristics, a model is constructed for scientific and objective evaluation. With the support of the metaverse technology, a smart learning ecosystem with interactive resources, and an intelligent learning environment that combines virtuality and reality, a smart inquiry space will be created. The identities of teachers, students, and schools can be transformed. Students' intelligent learning will be promoted through immersive, experiential, and self-conscious teaching

Table 1: Evaluation indicator system of the metaverse-based smart education ecosystem.

Dimension	Evaluation indicator	Evaluation criterion
Resource ecology construction	Teachers' digital literacy	Can use effective resources collected according to the characteristics of students and provide digital resources for specific learning scenarios to make learning experience more real
	Students' access to information resources	Can edit and share resources via the edu-metaverse
	School resource management	Can effectively manage learning resources and share and disseminate learning resources
Virtual and real symbiotic environment	Creation of virtual and real environments	Can establish virtual and real teaching environments as well as learning spaces with emotional interactions as the core educational content
	Organization of knowledge creation	Can remodel collaborative learning, promote self-learning, and complete teaching objectives in this process
	Emotional engagement in learning	Students can be immersed in learning scenarios by observing and experiencing; can create an immersive experience of teaching and learning
Inquiry learning space	Cooperation and sharing	Can use learning resources for communication and cooperation, and use creative tools for collaborative inquiry learning
	Learning personality portrait	Can perform intelligent data analysis and draw personalized student portraits according to students' learning behaviors and to customize teaching methods

methods. The ecosystem will cultivate intelligent and innovative students, form a new education ecology that highlights students' core competencies, and empower deeper development of smart education. Therefore, the evaluation of the metaverse-based smart education ecosystem should be dynamic and scientific. The factors that affect the smart education ecosystem and the relationship between the factors are to be evaluated and generally applied to the above-mentioned three scenarios.

Based on the above analysis, this study establishes an evaluation system for the smart evaluation system from three dimensions, i.e., resource ecology construction, virtual and real symbiotic environment, and inquiry learning space. (See Table 1).

4.3.2. Application Effect of Metaverse-Based Smart Education Ecosystem. The effect evaluation is to develop an evaluation system based on the above evaluation indicator and then make a relatively objective evaluation of the effect of the smart education ecosystem. The analytic hierarchy process (AHP) method is adopted. It is a quantitative evaluation of the comparative importance of hierarchical elements according to the subjective judgmental structure of a certain object. AHP is a hierarchical weight decision analysis method proposed by Thomas L. Saaty, an American professor at the University of Pittsburgh in the early 1970s [34]. AHP uses matrix eigenvalues and eigenvector operations to help people make group judgments to determine the assignment of certain qualitative variables. It is a systematic and hierarchical analysis method that decomposes the elements related to decision into the objective layer, criterion layer, and plan layer for qualitative and quantitative analysis. This flexible method can simplify complex problems and provide a scientific basis for selecting the optimal solution and is widely used in evaluation. Since the evaluation of the smart education ecosystem involves many interconnected elements, which cannot be quantitatively expressed by data, it is rather complicated and fuzzy. Therefore, the AHP approach is used to establish a model to realize multifactor comprehensive evaluation, as well as systematic analysis of the decision-making process. It follows the general laws of educational evaluation, conforms to the characteristics and requirements of metaverse-based smart education, and is relatively scientific and applicable.

In general, the evaluation has four steps. First is data acquisition. To avoid subjective influence of the AHP method, a total of 156 teachers are selected for the survey, including teaching management officials, discipline leaders, and ordinary teachers from 21 universities and junior colleges in Henan Province. The Likert 5-level scale is adopted, and the results of each indicator are weighted and averaged and then rounded to form a matrix for evaluation. The scale mainly adopts Likert 5-level measurement method, which is relatively easy to design and can be widely applied to multidimensional complex problems or attitudes. The three scenarios of intelligent education ecosystem from the perspective of the metauniverse are suitable for this method, and each respondent can quickly mark his or her own views with high reliability. After the evaluation of the survey object, the results of each index data survey are weighted average and rounded to form a judgment matrix. Second is the identification of evaluation indicators. Based on the authors' teaching experience and previous research, three dimensions of eight indicators are identified. Third is the establishment of a hierarchy. The evaluation system is broken down into a hierarchical evaluation model. The multiobjective decision-making problem is regarded as a system of three goals (criteria), namely, resource ecology construction, virtual and real symbiotic environment, and inquiry learning space, according to the features of the smart education ecosystem. The three goals (criteria) are then decomposed into eight indicators, namely, teachers' digital literacy, students' access to information resources, school resource management, creation of virtual and real environments, organization of knowledge creation, emotional

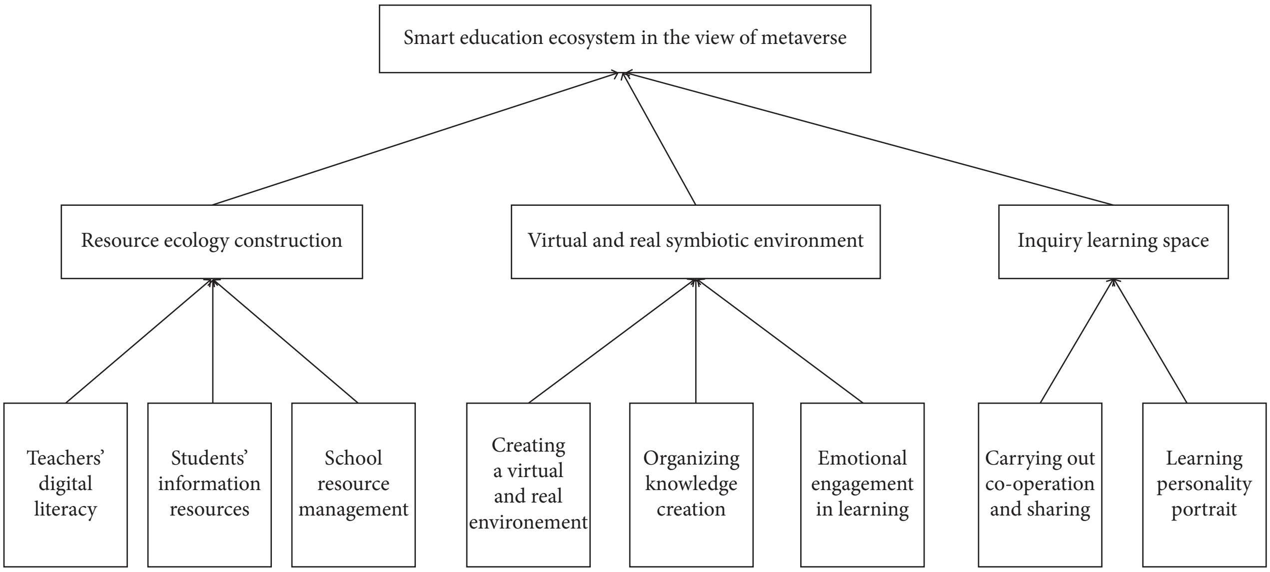

Figure 2: Evaluation system for the metaverse-based smart education ecosystem.

Table 2: Weight of the indicators for the metaverse-based smart education ecosystem.

Smart education ecosystem	Teachers' digital literacy	Students' access to information resources	School resource management	Creation of virtual and real environments	Organization of knowledge creation	Emotional engagement in learning	Cooperation and sharing	Learning personality portrait	Wi
Teachers' digital literacy	1	1/2	1/3						0.0377
Students' access to information resources	2	1	1/3						0.0599
School resource management	3	3	1						0.1426
Creation of virtual and real environments				1	5	3			0.3446
Organization of knowledge creation				1/5	1	1/4			0.0515
Emotional engagement in learning				1/3	4	1			0.1538
Cooperation and sharing							1	2	0.1399
Learning personality portrait							1/2	1	0.0699

engagement in learning, cooperation and sharing, and learning personality portrait. Then, a multilevel and orderly progressive structure evaluation structure model is developed (see Figure 2). Fourth is data analysis and conclusions. The relative importance of each influencing factor of the evaluation indicators is determined by comparing every two indicators, and an evaluation matrix is established. The overall ranking of the indicators is identified, and a consistency test is performed.

Finally, the consistency test is conducted using professional software. The specific test data are as follows: the judgment matrix is constructed according to the evaluation indicator system in Table 1. The Yaahp software is used to obtain the weights of each evaluation indicator (see Table 2). The judgment matrix passes the consistency test, with a CR value of 0.0176. The first-level indicator matrix is $\begin{bmatrix} 1 & 1/2 & 1 \\ 2 & 1 & 3 \\ 1 & 1/3 & 1 \end{bmatrix}$.

The weight indicators are 0.2402, 0.5499, and 0.2098. As can be seen from Table 2, the weight ratio of resource ecology construction, virtual and real symbiotic environment, and inquiry learning space to the smart education ecosystem is 0.2402, 0.5499, and 0.2098, respectively. The influence of virtual and real symbiotic environment is higher than that of the resource ecology construction and inquiry learning space. The weight ratios of the eight specific indicators (teachers' digital literacy, students' access to information resources, school resource management, creation of virtual and real environments, organization of knowledge creation, emotional engagement in learning, cooperation and sharing, and learning personality portrait) are 0.0377, 0.0599, 0.1426, 0.34446, 0.0515, 0.1538, 0.1399, and 0.0699, respectively.

Therefore, first, it can be seen that for the smart education ecosystem, the most important evaluation indicator is the creation of the virtual and real environments. Building infrastructure for the metaverse teaching space is the main task of metaverse teaching. Second, emotional engagement in learning, school resource management, and cooperation and sharing are the next three important indicators. On the one hand, students need to be fully immersed in the virtual environment during learning, and they must learn to cooperate and share in the learning process. On the other hand, schools should improve the codevelopment and sharing of resources so that students can be more active and innovative in the classroom and turn from knowledge consumers to knowledge creators. Last but not the least, learning personality portrait, students' access to information resources, organization of knowledge creation, and teachers' digital literacy are less important in the evaluation. Through analysis and verification, it is proven that the metaverse-based smart education ecosystem changes the traditional way of learning. The teaching activities are student-centered and highlight in-depth immersive experience as well as dynamic interaction and collaboration. Students create knowledge in collaboration and sharing and verify hypotheses and put knowledge into practice after reflection and observation. The process can help students better achieve learning objectives [35, 36]. Thus, the metaverse-based smart education ecosystem is relatively reasonable, scientific, and effective.

5. Conclusion

Using information technologies to promote educational reform has become a consensus for the international community. As the metaverse is gradually developing and its applications are expanding, researchers pay more attention to it and explore its application potential in education for building a learning-oriented society where "everyone can learn things at anytime, anywhere." At present, relevant research is still in its infancy with well-developed theoretical results. Based on the ecological theory, this study discusses the development of a metaverse-based smart education ecosystem in the hope to provide reference for promoting the applications of the metaverse in education.

The metaverse-based smart education ecosystem is student-centered and delivers dynamic and integrated teaching experience by building various education scenarios. With smart computing, it reconstructs the classroom design and realizes in-depth learning and feedback. It further enriches smart education, builds an ecosystem of teaching and learning resources, extends the educational space, and provides the functions of social communication and inquiry learning, thus effectively promoting deep interactions between learners and improving the in-depth learning of learners. The ecosystem balances the ecological niches of students, teachers, society, and schools and forms a new systematic ecosystem and is thus the future direction of smart education reform. However, the system also has certain limitations. The data flow-driven technologies still need to be improved. Real-time acquisition and processing of interactive data between the virtual and physical worlds propose challenges for the computation. The information security of students, teachers, and other users cannot be fully guaranteed, and there is a risk of personal privacy leakage. As students spend most of their time in the virtual world, those with poor self-control ability may develop social phobia, cannot properly handle interpersonal relationships, and cannot adapt to the real world. Besides, anonymous login may induce problems and violations. In terms of the evaluation effect, this paper adopts the analytic hierarchy process and Likert 5-level measurement method. The selection of experts is subjective. Although it can express the attitude of experts, it cannot describe the structural differences between viewpoints by uniformly using equal weights to calculate the weights of indicators at all levels. In future research, different weights can be given to experts according to their positions, working years, and education background, and then the weights of indicators at all levels can be calculated to make them more objective. With the continuous development of new technology, the human society is developing towards the trend of new type, science and technology, diversity, and prosperity. We also need plenty of practice for further application and exploration, constantly set up reasonable and conform to the yuan universe teaching ecological scene, combined with the characteristics of the new technology, especially virtual-reality interaction, etc., which helps to realize the organic unity, virtual and reality, and to meet the needs of wisdom education comprehensive, integrated into the teaching of each link, and strengthen the appeal and effectiveness of the science and education integration. We should optimize the ecosystem evaluation indicators and promote the synchronous development of the "meta-universe + education" related management system and laws and regulations, so as to further extend the scope of application and have universal promotion value and significance.

With the continuous development of new technologies, a large number of new applications need to be explored. There is still a long way to go to fully realize the metaverse-based smart education ecosystem. Facing more opportunities and challenges, we will gradually promote the innovative, benign, and sustainable development of the metaverse-based smart education ecology.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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