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Article

Educational Metaverse Empowering Teaching Innovation in Environmental Art Design

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Abstract: The metaverse, fusing virtual reality, augmented reality, mixed reality, and AI, is profoundly transforming education. From this perspective, we applied the metaverse to the education of environmental art design and examined its advantages and challenges. On the basis of the results, we propose implementation strategies and prospects of the metaverse in education. By creating immersive virtual learning environments, conducting virtual design project practices, promoting cross-regional sharing of teaching resources, and customizing personalized learning paths, the metaverse in education boosts students' interest and innovation, enhances practical skills, and overcomes traditional teaching limitations. The results of this study show that the educational metaverse offers rich, interactive, and efficient learning experiences, which help cultivate professionals with innovative thinking and practical abilities and propel the innovative development of environmental art design education.

Keywords: Educational metaverse, Environmental art design, Virtual teaching, Design practice, Teaching resource sharing

1. Introduction

As the next stage of digital innovation, the metaverse is transforming diverse fields, especially education. By transcending the spatial and temporal constraints of traditional teaching, the metaverse enables immersive, interactive, and collaborative learning experiences amd facilitate the integration and sharing of educational resources. These are relevant to environmental art design, an interdisciplinary discipline that combines art, science, and technology, and requires students to develop a theoretical foundation alongside extensive practical experience and innovative thinking. Conventional educational models, however, remain limited by physical space, resource availability, and the inability to fully meet the diverse and evolving needs of learners.

Therefore, it is necessary and timely to explore the application of the metaverse in environmental art design education. Its immersive visualization, real-time collaboration, and personalized learning pathways directly address the shortcomings of traditional teaching methods, offering new strategies for cultivating creativity, operational competence, and interdisciplinary innovation. By examining how metaverse-based teaching models with virtual simulation experiments, resource-sharing platforms, and competition-integrated learning enhance student engagement, improve practical skills, and foster innovation. The results provide a reference for teaching reform, demonstrating that the metaverse can serve not only as a supportive tool but as a dynamic digital ecosystem that drives talent cultivation in environmental art design.

In China, the significance of this research is underscored by national policy initiatives. The educational metaverse has been identified as a key project in China Education Modernization 2035, and in 2023, the Ministry of Education, together with four other departments, issued the Development Plan for the Integration of Virtual Reality and Industry Applications. This plan sets a 2026 target of 1,000 universities piloting metaverse education, with environmental art design highlighted as a priority area. Such policies provide strong momentum for the digital transformation of environmental art design education, positioning the metaverse as a cornerstone of future teaching models.

2. Metaverse in Education

2.1. Metaverse

Metaverse is a virtual digital world that parallels and interacts with the real world. This concept first appeared in science fiction, and it has gradually developed into an ecosystem that is built on the basis of the integration of multiple technologies. Metaverse

adopts technologies such as virtual reality (VR), augmented reality (AR), and AI to provide users with an immersive, interactive virtual space. In this space, users can create their virtual identities, engage in social interactions, economic activities, and cultural creation (Dionisio & Gilbert, 2013).

In 2022, the market size of China's educational Metaverse industry reached USD 1.1 billion, mainly driven by the accelerated digital transformation in education, the convergence and advancement of underlying technologies, and strong policy support from the government. Between 2018 and 2023, China's metaverse in the education market size increased from USD 630 million to 1.38 billion, with a compound annual growth rate of 17%. This indicates that the integration of the metaverse in education is increasing rapidly (Cui et al., 2026).

The potential of the metaverse in education is huge. It provides students with a highly immersive, naturally interactive teaching environment that integrates reality and fiction, helping to stimulate students' curiosity, imagination, and creativity. The metaverse enables educators to build virtual classrooms, laboratories, historical scenes, and others, whereas providing students with a richer and more intuitive learning experience. At the same time, the metaverse fosters the integration and sharing of educational resources and promotes education exchanges and cooperation on a global scale (Williamson et al., 2021) (Fig. 1).

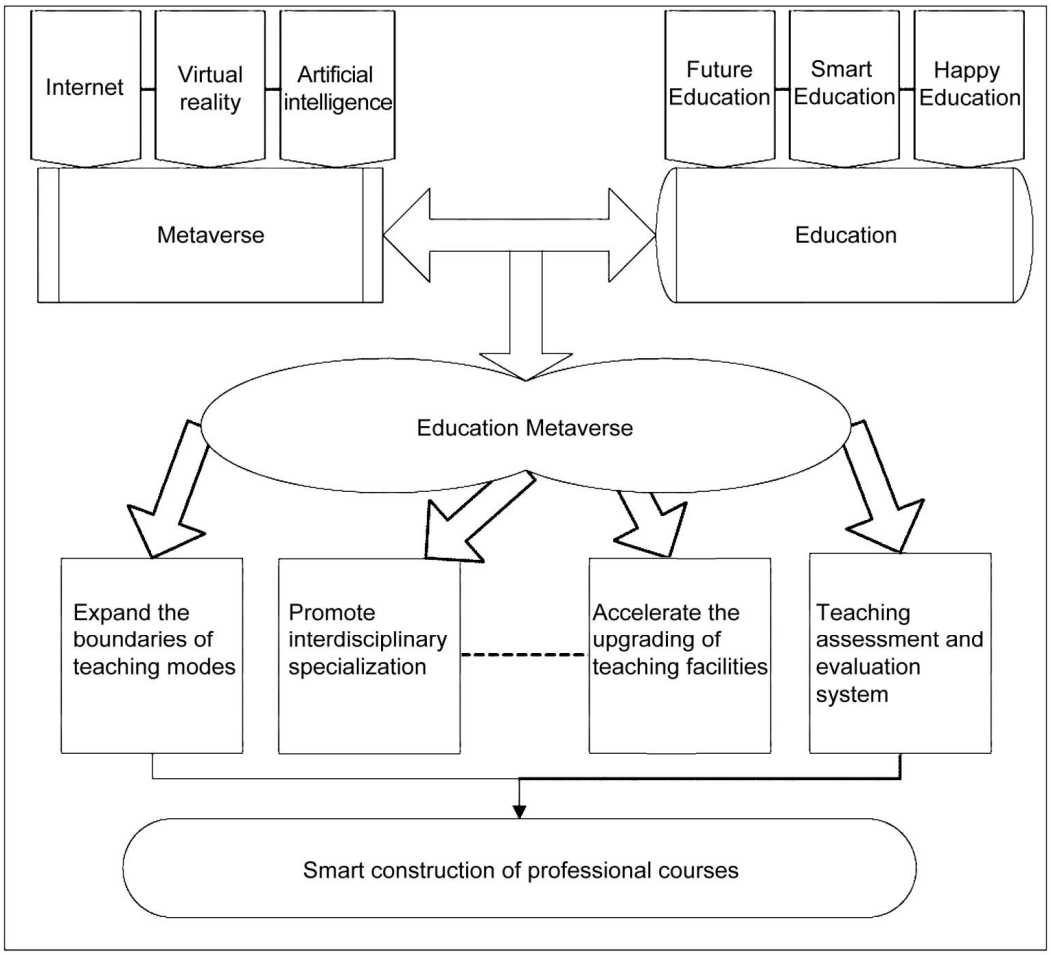

Fig. 1. Metaverse in education.

There are numerous ways in which the metaverse is applied to education, offering significant opportunities for disciplines such as environmental art design. Virtual simulation teaching, for example, provides students with immersive environments in which they can experiment and refine their skills. In the residential space design course using the metaverse, students can employ 3D modeling and simulation software to construct virtual residential spaces, testing different spatial configurations, such as open-plan versus compartmentalized layouts, and observing their impact on both functionality and aesthetics. They can also simulate the application of diverse materials and color schemes, thereby gaining a vivid understanding of how design elements interact. This approach not only strengthens technical proficiency but also deepens comprehension of design principles.

Beyond simulation, the metaverse facilitates cross-regional resource sharing and collaboration by removing geographical barriers. Leading universities and design institutions can upload high-quality courses, case studies, and expert lectures to metaverse

platforms, enabling students from different regions to access cutting-edge knowledge and engage with advanced technologies. Collaborative projects further enhance this potential, as students form virtual design teams that expose them to diverse perspectives and methodologies, broadening their horizons while cultivating teamwork and communication skills.

AI plays an essential role in the educational metaverse, particularly in personalized learning. AI algorithms analyze students' learning behaviors, design preferences, and skill levels to generate customized learning paths and targeted content recommendations. For instance, a student with a strong interest in landscape design is guided for relevant courses, tutorials, and projects. AI-powered virtual tutors provide real-time feedback, helping students overcome challenges and improve outcomes.

The advantages of educational scenarios in the metaverse are closely related to the construction of virtual environments and interaction technologies. Virtual environments, created through VR, provide digital spaces for exploration and learning, whereas interaction technologies, such as voice recognition, gesture recognition, and eye tracking, enable natural engagement with these environments, enhancing effectiveness and experience (Tang, 2021). Virtual simulation laboratories exemplify this application. Since 2013, China's Ministry of Education has promoted the development of virtual simulation teaching resources, culminating in the Experimental Space platform in 2018. By 2020, 728 virtual simulation courses were included among the first batch of national first-class undergraduate courses, covering 61 professional categories (Song et al., 2024).

For the integration and sharing of educational resources, the metaverse consolidates courses, teaching materials, and multimedia resources into digital formats accessible to students worldwide (Mystakidis, 2022). Online teaching platforms play a vital role in this process. Since 2013, China's Ministry of Education has driven the development of digital teaching resources through the Experimental Space platform and the National Smart Education Public Service Platform, initiated in 2022. and provides one-stop access to high-quality online courses. Universities and education departments of local authorities have collaborated with ed-tech companies, leveraging platforms such as China University Massive Open Online Course, Super Star Group's e-platform, and Zhihuishu to expand course offerings. The COVID-19 pandemic further accelerated this transition, prompting universities across China to adopt online teaching at scale, strengthen digital resource management, and achieve seamless integration between online and offline instruction.

2.2. Metaverse in Environmental Art Design Education

The metaverse offers unprecedented opportunities for innovation in environmental art design education. One of its most significant contributions is the construction of virtual classrooms and laboratories. In realistic and immersive environments, students interact with and explore design concepts that transcend traditional limitations. Through VR and AR equipment, they experience the effects of different styles, materials, and color combinations and come to understand design principles. The metaverse enables the simulation of diverse scenarios, ranging from interior decoration and landscape design to urban planning, enabling students to test designs, observe outcomes in real time, and refine their approaches. This reduces the cost and risk associated with physical experimentation while fostering innovative thinking and practical ability. The metaverse's capacity for resource sharing is also transformative. As a vast educational repository, the metaverse provides teaching materials, courseware, video tutorials, and design cases anytime and anywhere. Such platforms enhance student learning efficiency and promote collaboration among educators. Students engage with exemplary works from leading designers worldwide, gaining insights into varied methodologies, while simultaneously sharing their own projects to receive feedback and inspiration. This exchange of ideas stimulates creativity and strengthens motivation.

Pedagogical strategies within the metaverse empower students as innovators and practitioners. The metaverse provides a space for free creation, where students can experiment, revise, and gradually refine their design skills. Virtual design projects and competitions organized in the metaverse encourage students to showcase their talents, collaborate with peers, and develop essential competencies such as teamwork, communication, and problem-solving. These experiences cultivate both creative independence and collaborative resilience. Teaching and feedback mechanisms are redefined through metaverse integration. Real-time interaction enables instructors to monitor student progress, provide immediate guidance, and facilitate collaborative problem-solving among students. At the same time, diversified evaluation systems provide interactive records, creative outputs, and participation in competitions. These features enable an understanding of student development and support personalized guidance.

The application of the metaverse in environmental art design education demonstrates broad prospects and significant potential. Through immersive classrooms and laboratories, resource integration and sharing, creative empowerment, and innovative evaluation mechanisms, the metaverse enriches the theoretical and practical dimensions of the discipline in teaching and learning.

3. Teaching Model and Challenge of Metaverse in Environmental Art Design Education

3.1. Teaching Model

The curriculum of environmental art design education encompasses a wide range of foundational knowledge for students with theoretical depth and practical competence. Core courses include the history and methodology of architectural design, indoor and outdoor spatial design, expressive drawing techniques, ergonomics, craftsmanship, and architectural model making (Zhao et al., 2022). Students engage with digital environment design and specialized software applications relevant to architectural contexts and study the history of Chinese and foreign arts and crafts, as well as design-related disciplines such as aesthetics, psychology, and public relations. These courses establish a theoretical framework to cultivate practical skills through experimental work, including investigations into material properties and construction processes related to environmental and spatial design (Zunic et al., 2025).

In environmental art design, case analysis is integrated with project-based practice. Projects, such as urban park design or landscape greening planning, enable students to apply classroom knowledge in authentic contexts to better understand environmental design principles and methodologies (Jurayev, 2020). Case studies complement this experiential learning by showing students successful and unsuccessful design examples, enabling them to refine their design thinking and strengthen their practical abilities (Zhai et al., 2022).

The alignment of theoretical instruction with practical application is important. Universities have adopted innovative teaching models, such as 3+1 talent training, in which students devote three years to theoretical coursework on campus before engaging in metaverse-based virtual projects during their final year. In this model, students relate academic learning with societal needs and consolidate knowledge to enhance capacity for real-world problem solving through immersive, practice-oriented experiences (Uddin et al., 2025).

3.2. Challenge

The implementation of the educational metaverse in environmental art design education relies on VR, AR, and AI. Despite their promise, these technologies remain limited in both maturity and accessibility. In terms of technical development, prolonged use of VR devices causes dizziness, disrupting the continuity of learning. Current VR scene construction also lacks real-world detail and realism, particularly in simulating natural landscapes where light, shadow, and material textures are inadequately rendered. Similarly, AR technology sometimes misaligns virtual objects and real-world environments, which undermines students' ability to evaluate designs accurately. AI-based design assistance often lacks depth and originality, failing to meet the complex demands of professional learning.

Accessibility is another challenge, as VR and AR devices remain costly, limiting large-scale adoption in universities and educational institutions. Furthermore, their operation requires technical proficiency. However, many teachers and students are not sufficiently trained to use it, resulting in underutilization of available equipment. To address these issues, coordinated efforts between universities and enterprises are required. Universities must leverage their academic resources to investigate technical bottlenecks, such as developing advanced rendering algorithms to enhance realism in VR or improving AR registration accuracy. Enterprises, in turn, must incorporate educational requirements into their research and development agendas, accelerating technological iteration, reducing device costs, and enhancing usability. Government support is essential, with research funding, tax incentives, and industry–university–research cooperation platforms fostering innovation, resource sharing, and the broader adoption of metaverse technologies.

The effective operation of the educational metaverse depends on the availability of high-quality educational resources, including virtual teaching environments, design cases, and professional instructional videos. Resource integration, however, presents obstacles. Diverse formats and inconsistent standards across institutions undermine compatibility, and copyright complexities discourage openness. Many resources are not available due to intellectual property protection, and the absence of incentive mechanisms limits collaboration. To address these challenges, universities and enterprises must establish unified standards for resource production and develop resource libraries. Government intervention is essential in the collaboration, with policies clarifying copyright ownership and promoting reasonable use in educational contexts. Incentive mechanisms, such as resource-sharing reward funds, can encourage broader participation and ensure sustainable integration of educational resources.

Student experience is critical in the educational metaverse. Current virtual environments often lack sufficient interactivity and realism, with physical feedback effects poorly simulated. For example, moving furniture models in a virtual space does not replicate realistic collision dynamics, impairing students' ability to judge spatial layouts. Interaction technologies such as voice recognition, gesture recognition, and eye tracking also present low accuracy and response delays, reducing the fluidity of design discussions and hindering personalized learning guidance. Enhancing student experience requires continuous technological innovation, including the development of advanced physics engines to simulate real-world laws and the application of deep-learning algorithms to improve recognition accuracy. Student feedback must be continually collected and used to identify usability issues, which can be used by enterprises to refine products accordingly. This iterative process ensures that the educational metaverse meets the learning needs of students in environmental art design.

4. Case Studies

4.1. Residential Space Design

The Residential Space Design course integrates online video instruction with virtual simulation, combining digital and physical learning environments into a comprehensive teaching model. Course delivery is structured as pre-class preparation, in-class practice, and post-class evaluation, as a new pedagogical approach of learning–competition integration based on virtual simulation experiments (Fig. 2).

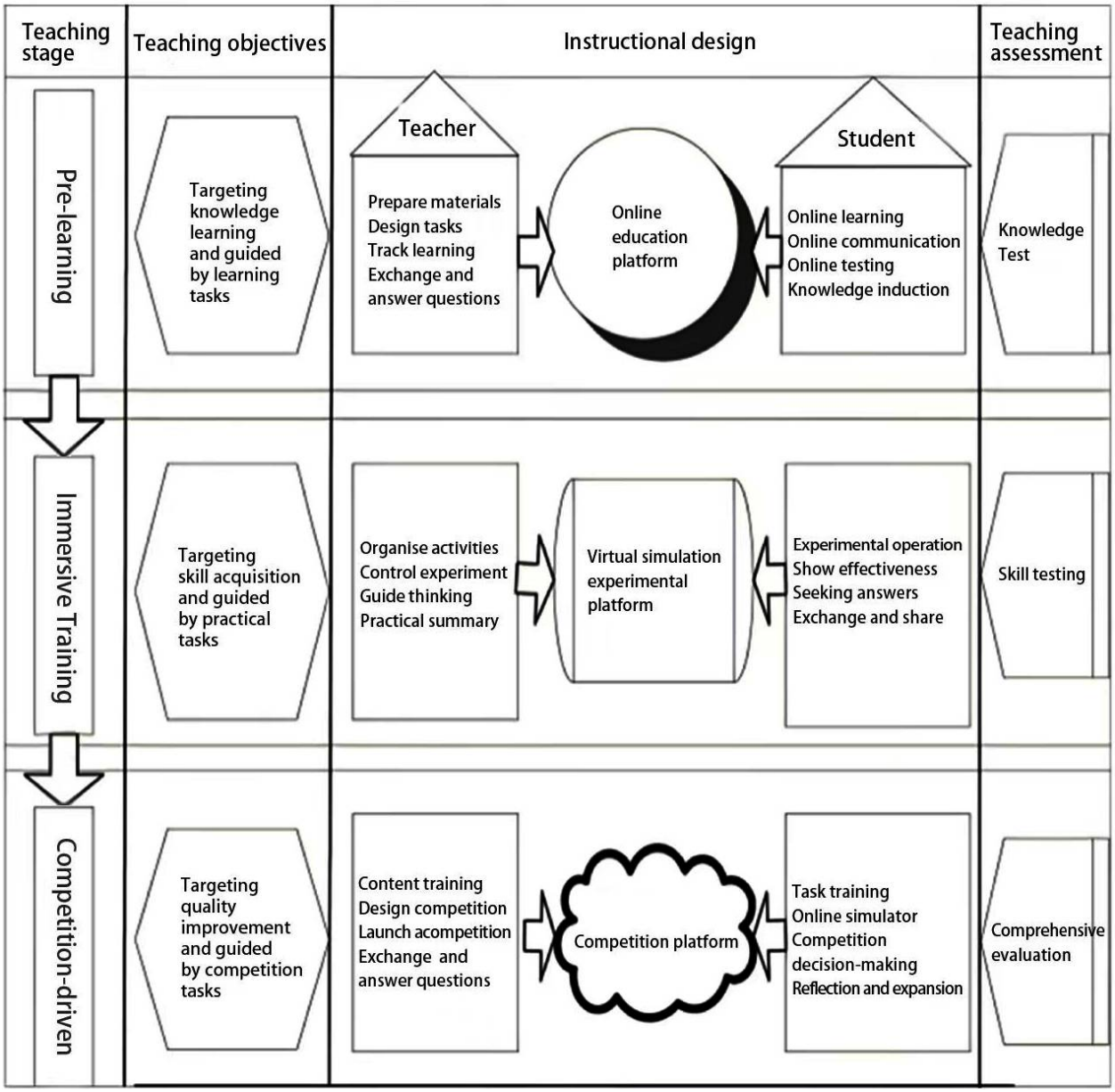

Fig. 2. Professional course construction.

In the first stage, pre-class learning is conducted through the online education platform, where teachers modularize course content into digital resources such as videos and courseware. These materials are used to acquire foundational knowledge and skills, and the platform is utilized by instructors to monitor learning behaviors, address difficulties, and supervise task completion. Students engage in autonomous study, followed by unit tests to assess comprehension. When introducing interior design styles, teachers provide digital resources covering stylistic development, characteristics, and applications, which students study independently before completing exercises to reinforce understanding.

The second stage emphasizes collaborative practice and discourse during classroom sessions. Guided by practical tasks, students engage in virtual simulations to internalize knowledge and enhance operational skills. Building on pre-class learning, they apply learned concepts on three-dimensional modeling platforms developed through school–enterprise cooperation. Through the simulations, students experience the design process of residential spaces, refine their understanding through experimentation, and optimize solutions through teacher guidance and peer collaboration.

The third stage focuses on multidimensional evaluation through extracurricular competitions. In the interior design simulation system, teachers assess student performance and encourage participation in local and national environmental art design contests. These activities consolidate and expand knowledge and foster professional practice. Students are guided to identify gaps in their learning, engage in team-based discussions, and refine their skills through iterative evaluation. Students participate in competitions to test their knowledge and stimulate creativity, teamwork, and problem-solving, ensuring that students develop both technical expertise and professional resilience.

4.2. Teaching Effectiveness

Through the integration of virtual and physical classrooms, a new teaching community can be formed in the metaverse. Environmental art design courses increasingly employ virtual reality and related technologies to construct immersive, situational, and experiential learning environments to enhance student engagement. In the residential space design course, traditional instruction results in low levels of student attention since it focuses on the knowledge delivery of design principles, styles, and methods. In contrast, the simulations of residential space design in animation increased student attention rates by nearly 80%, demonstrating the capacity of immersive visualization to stimulate interest and deepen comprehension of professional knowledge.

Virtual simulation experiments improve students' operational abilities. By enabling students to conduct professional practice in real time, the experiments strengthen practical application skills with reduced educational costs. In the living space design course, Internet-based project simulations are used for students to grasp and practice the design process. Compared with traditional design exercises, participation in simulation projects increased by 50%, whereas practice costs were reduced by 65%. This demonstrates the efficiency and accessibility of simulation-based teaching in cultivating applied skills. Learning with competition fosters innovation and creativity. In professional courses, participation in online competitions and innovation programs is encouraged for students to apply course knowledge in broader contexts. In the residential space design curriculum, students actively participate in design contests and entrepreneurship training competitions. Over the past three years, 70% of students have engaged in university-level competitions, 30% in provincial and municipal contests, and 10% in national competitions. These experiences consolidate knowledge and cultivate innovative thinking, teamwork, and resilience, ensuring that students are prepared to meet the demands of professional practice in environmental art design.

5. Implementation and Prospects

5.1 Implementation

For the promotion of the educational metaverse in environmental art design education, coordinated efforts across technology, resources, student experience, and policy are required. From a technological perspective, continuous investment in research and development is essential. Therefore, universities must integrate expertise from computer science, art design, and education to address technical bottlenecks. For instance, AI is used to optimize designs by analyzing the datasets of cases through machine-learning algorithms to offer students creative and feasible design suggestions. Enterprises apply cutting-edge technologies to education to improve the maturity and stability of metaverse platforms, reducing costs and expanding accessibility.

It is essential to integrate and share educational resources. Therefore, a unified resource management platform must be established to break down barriers among universities, enterprises, and institutions. Strict review mechanisms must be constructed to ensure quality and standardization. In the mechanism, universities must provide high-quality course materials, whereas enterprises need to provide practical design cases and technical expertise. Such integration enriches the learning environment, offering students diverse resources that broaden their horizons and strengthen their professional competence.

The student experience must remain central in the implementation of the metaverse. Appropriate virtual scenes must be constructed for details and realism by employing advanced rendering and VR technologies to simulate interior spaces and natural landscapes with high fidelity. Enhanced interaction technologies, such as optimized gesture recognition and voice interaction, must be employed for students to express design ideas more naturally, improving both efficiency and engagement. Related policy is indispensable for the sustainable development of the metaverse in education. Governments must introduce tax incentives, loan support, and subsidies for enterprises and universities engaged in metaverse education to protect user rights and ensure the development of the metaverse.

5.2 Future Prospects

The metaverse is reshaping environmental art design education, evolving from a supplementary tool into a dynamic digital ecosystem that cultivates creativity, autonomy, and immersive learning. Students freely explore diverse virtual environments from ancient architectural ruins to futuristic urban planning scenarios and understand design concepts across time and styles through the stimulation of innovative thinking. Collaboration is also redefined in the metaverse. Students engage in large-scale design projects through real-time virtual cooperation, share ideas, and refine designs without geographical and temporal constraints. Through such collaboration and engagement, teamwork and communication, the demands for professional practice can be satisfied. Personalized learning becomes a hallmark of metaverse education. AI-driven systems in the metaverse tailor learning paths to individual progress, interests, and abilities, recommending specialized courses, classic cases, and practical opportunities. Students with a strong interest in landscape design deepen their expertise by engaging with targeted resources that support specialization in areas such as ecological planning, garden and park design, and sustainable urban landscapes.

The metaverse in environmental art design education fosters interdisciplinary integration. By integrating computer science, materials science, and psychology into environmental art design, the metaverse cultivates experts equipped with technical expertise and innovative capacity. Such interdisciplinary synergy offers new vitality to environmental art design for innovation, diversity, and global relevance.

6. Conclusion

The metaverse is transforming education into an immersive, interactive, and collaborative ecosystem. Especially in environmental art design education, realistic virtual scenes and rich digital resources enable students to better understand design principles and master essential skills, such as spatial layout, material selection, and color coordination, than in traditional educational methods. Real-time collaboration functions in the metaverse break geographical barriers, enabling seamless communication between teachers and students while fostering teamwork across diverse learning communities (Burbules et al., 2020). In the pedagogy, the metaverse supports personalized and project-based learning. AI-driven customization of the metaverse tailors content to students' interests and abilities, stimulating creativity and engagement. Virtual projects enable students to experiment, iterate, and refine design solutions and cultivate problem-solving skills essential for professional practice. The intelligent evaluation and data analytics in the metaverse provide multidimensional feedback, helping students identify strengths and weaknesses and develop more effective study plans.

The development of education using the metaverse is promising, but challenges remain in technological maturity, data security, and privacy protection. With continued advancements in VR, AR, and AI, and supportive policies and regulations, the metaverse can play a central role in environmental art design education. Its immersive visualization, collaborative platforms, and personalized pathways will not only enhance teaching quality and learning outcomes but also drive innovation in talent cultivation. The metaverse fosters creativity, autonomy, and interdisciplinary integration in a dynamic digital world. Students can explore diverse virtual environments, collaborate on large-scale projects unconstrained by geography, and pursue specialized learning paths tailored to their interests, such as ecological planning, sustainable urban landscapes, or digital design innovation. Moreover, cross-disciplinary knowledge drawn from computer science, materials science, and psychology is integrated to cultivate experts capable of advancing innovative approaches in sustainable landscape design, ecological planning, and diversified environmental art practices.

The metaverse is an unprecedented tool for environmental art design education, since it enables creativity, global collaboration, and sustainability-focused learning. Educators must pay attention to the ethical, environmental, and accessibility implications of integrating the metaverse into education, ensuring that virtual experiences are meaningfully connected to real-world knowledge and practice. By maintaining the balance between virtual experiences and real-world knowledge, the educational metaverse serves as a transformative driver of teaching reform to cultivate capable designers who address the technological, social, and sustainability challenges of the twenty-first century.

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