Research on Metaverse Functional Scenarios for Future Learning Centers

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Abstract

Purpose/Significance: Technological advancement drives transformations in the modes of learning, exchanging, and disseminating human civilization, wisdom, thinking, and experience, thereby introducing new changes to the organizational structures, resource services, and interaction patterns of learning centers, and giving rise to the concept of future learning centers. Methods/Process: Based on case studies of learning center construction both domestically and internationally, as well as theoretical discussions on future learning center development, this paper analyzes the developmental trends and current challenges of future learning centers. Combining the theoretical foundation of "knowledge exchange theory" with advances in metaverse-related technologies, it proposes the concept and construction pathway of a "Dynamic Intelligence-Generating" future learning center. Results/Conclusion: This construction model leverages metaverse technology to build from three dimensions: physical space, virtual space, and resource services. It emphasizes flexibility and human-machine collaboration during construction, achieves dynamic perception and intelligent upgrading in service delivery, and integrates with technological progress in long-term operations to advance learning model innovation. Overall, by focusing on mature models, explorable models, and innovative models, it realizes a knowledge exchange space that integrates virtual and physical elements and is co-constructed by humans and machines, aiming to provide references for future learning center construction.

Full Text

Research on the Metaverse Scenario Configuration for Future Learning Centers

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Abstract

[**Purpose/Significance**] Technological advancements are driving transformative changes in how human civilization and wisdom, as well as thinking and experience, are learned, communicated, and disseminated. This evolution necessitates new organizational forms, resource services, and interaction models for learning centers, giving rise to the concept of future learning centers. [**Method/Process**] Based on an analysis of domestic and international learning center construction cases and theoretical discussions on future learning center development, this paper examines emerging trends and current challenges. Grounded in "knowledge exchange theory" and recent metaverse technological developments, we propose the concept and construction pathway of a "dynamically intelligent generative" future learning center. [**Result/Conclusion**] This construction model leverages metaverse technologies to upgrade offline spaces, online spaces, and resource services. It emphasizes flexibility and human-machine collaboration during construction, achieves dynamic perception and intelligent upgrading in service delivery, and integrates technological progress into long-term operations to advance learning model innovation. Overall, by implementing mature, exploratory, and innovative models, it realizes a virtually-integrated, human-machine co-constructed knowledge exchange space, providing a reference for future learning center construction.

Keywords: Metaverse, Future Learning Center, Dynamically Intelligent Generation, Knowledge Exchange
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1. Discussion and Development of Future Learning Centers

1.1 Policy and Theoretical Discussion

In recent years, the concept of "future learning centers" has been frequently discussed in educational circles, becoming a hot topic. In July 2021, the Ministry of Education and five other departments issued the "Guidelines on Promoting New Infrastructure Construction in Education to Build a High-Quality Education Support System," proposing a "new infrastructure system focusing on information networks, platform systems, digital resources, smart campuses, innovative applications, and trusted security," characterized by "technological iteration, integration of software and hardware, data-driven approaches, collaborative integration, platform consolidation, and value empowerment" [3]. In December 2021, Wu Yan, Director of the Department of Higher Education at the Ministry of Education, proposed at the academic symposium "Inheritance and Innovation: A New Journey for Modernizing University Libraries" that "universities will be encouraged to pilot the construction of 'future learning centers' based in libraries," integrating literature resources and reconstructing spatial processes to build smart learning spaces that encourage team-based, collaborative, and thematic learning, transforming libraries into information service centers, student learning centers, and teaching support centers [1]. Subsequently, the "Key Points of Work for the Department of Higher Education in 2023" explicitly stated: "Explore and advance pilot programs for future learning centers, leveraging the advantages of university libraries to integrate various learning resources and utilize new-generation information technology to create new types of grassroots learning organizations that support the transformation of learning methods" [4]. Utilizing digital resources and smart technologies to build new educational infrastructure and future learning spaces has become a key direction for universities and libraries to explore and upgrade educational and learning models.

Numerous discussions have emerged regarding future learning spaces and learning center organizational models. Zhu Yongxin discussed future learning centers, learning models, and educational organizational patterns in *Future School* [5]. D. Radcliffe et al. proposed the PST framework (Pedagogy-Space-Technology framework) to examine how learning spaces, teaching methods, and technology influence learning, and discussed learning space construction and evaluation [6-7]. As early as the 1970s, Christ and Enright proposed that "learning centers" could function as a service, with Peterson adding specific content including library services; Keating & Gabb transformed the "learning center" model into a "learning commons," emphasizing the academic support role of libraries [8]. Some research on future library development aligns with visions for "future learning spaces," including Montgomery and Miller's view of libraries as spaces for collaborative learning and group interaction beyond service provision [9], Wu Huiru's perspective on university libraries as cultural, social, and leisure spaces on campus [10], and Wu Jianzhong's view of libraries as knowledge exchange and sharing spaces in the digital age [11]. Consequently, the construction of "future learning centers" and "smart libraries" is considered to be "two hearts with one mind," mutually reinforcing each other, with highly compatible spatial layouts, functions, and service targets [8,12-14].

1.2 Domestic and International Practice and Exploration

Since the concept of "future learning centers" was explicitly proposed, many domestic universities have completed or are planning and constructing future learning centers, often integrating library upgrades and renovations. Foreign universities have explored this area earlier, providing valuable reference cases.

Foreign university "learning centers" exhibit diversified planning concepts and construction approaches. Some institutions build upon existing writing centers, language learning centers, or innovation and entrepreneurship centers, while others develop specialized facilities in collaboration with specific departments or disciplines. Library-based learning center construction aligns with domestic research perspectives, primarily focusing on functional differentiation or integration through spatial renovation and the introduction of technological hardware and software, while encouraging discussion, collaboration, and technological practice in learning activities.

In terms of service models, foreign university learning centers can be categorized into two types. The first is service-oriented with weak spatial presence or entirely online operation, including centers providing training and courses, academic seminars, teaching tutoring, and career counseling, such as Harvard University's various teaching and learning centers [15]. The second focuses on providing offline practice equipment and multimedia activity spaces, allowing teachers and students to reserve spaces and rent equipment, clearly oriented toward offline communication and practical learning. For example, the North Carolina State University Library, opened in late 2013, was already equipped with experimental interactive spaces such as a game laboratory and teaching and visualization laboratory [16], and over the subsequent decade gradually expanded to include various discussion and practice spaces such as innovation labs and digital media labs, opening over a hundred spaces across multiple campus libraries for reservation by teachers and students [17]. This model has become a common innovation center construction pattern in American universities, such as the Innovation Space at California State University, Long Beach, built in the basement of the university library, featuring a 360° cinema, 3D printing room, podcast studio, XR lab, and laser cutting equipment, which both supports STEAM curriculum teaching and is open to campus use [18]; Kansas State University converted the first and second floors of its Hale Library into innovation labs containing 11 innovation spaces (including 2 planned), such as recording studios, immersive screening rooms, AI studios, and maker spaces [19].

Among domestic universities, the University of Science and Technology of China [20-21], Shanghai International Studies University [8], Xi'an Jiaotong University [13], Xi'an Jiaotong-Liverpool University [22], the National Cybersecurity Academy (jointly established by Wuhan University and Huazhong University of Science and Technology) [23], Beijing Institute of Technology [14], Sichuan University [12], Peking University, and Shanghai Jiao Tong University [24] have all explored this concept to varying degrees. Some universities renovated libraries or built new ones before the future learning center concept gained prominence, with many designs and attempts aligning with this concept. Additionally, East China Normal University and Shandong University [25] have conducted research and discussions on future learning center construction.

Comparatively, new library construction and major library renovations enable more thorough exploration of future learning centers, such as the comprehensive dynamic and functional zoning planning of the Bao Yugang Library at Shanghai Jiao Tong University and the National Cybersecurity Academy Library, and the integrated smart library system platform of the latter [23]. Some universities have achieved in-depth renovation in specific areas, such as Xi'an Jiaotong University's deep integration of library resources to provide knowledge graph-based digital resource services and learning navigation, and personalized customization of the library portal for teachers and students [13]; Xi'an Jiaotong-Liverpool University established a "Learning Mall," partnering with international universities and enterprises such as MIT, Apple, Microsoft, and Huawei to create a comprehensive and innovative platform supporting lifelong learning for students [22]. Some universities have conducted discipline-specific learning center construction based on their own disciplinary characteristics and needs, such as Shanghai International Studies University's scenario-based design for future learning center construction in foreign language institutions based on multilingual, interdisciplinary, and cross-cultural education needs [8].

2. Current Status and Obstacles in Future Learning Center Construction

"Future learning center" style learning space construction has been discussed and practiced both domestically and internationally. Domestic explicit discussions on "future learning centers" are primarily represented by papers published after 2021. Although these studies have not provided a clear definition of "future learning centers," they share common visions and plans. Generally, future learning centers in universities are envisioned as smart, efficient, convenient, and comfortable learning exchange spaces and resource repositories that provide intelligent, personalized, and open learning and communication experiences through digital technology, electronic resources, cutting-edge equipment, and offline space renovation, combined with disciplinary characteristics and the needs of teachers and students. Based on current cases and theoretical proposals, future learning center construction can be roughly divided into three models: the "Smart Library" model, the "Innovation Space" model, the "Thematic Center" model, and the Metaverse model (see Table 1) [26].

Table 1: Overview of the Four Models for Future Learning Center Construction

Model	Description	Example Cases
Smart Library	Upgrades based on library space and services through spatial reorganization, smart equipment installation, and integration of online and offline resources to create a learning space centered on resources and services.	National Cybersecurity Academy Library [23]: Through eight functional zones and dynamic/static separation between floors, combined with intelligent book management and self-study application systems, it constructs a future learning space based on library space, resources, and smart services.
Innovation Space	Focuses on introducing advanced hardware equipment, flexibly configuring spaces, and complementing with workshops, related courses, and multimedia exhibitions to create hands-on and innovation-encouraging learning spaces.	California State University, Long Beach Innovation Space [18]: By centrally deploying hardware such as 3D printers, laser cutters, and XR development equipment, it constructs a technology practice space.
Thematic Center	Establishes non-generic spaces based on university or departmental disciplinary characteristics and needs, equipped with relevant hardware and software facilities, which can provide specialized services while accommodating general functions to a certain extent.	University of Science and Technology of China Language Learning and International Exchange Center [20]: Through spatial and hardware arrangements with multimedia all-in-one machines and movable furniture, combined with English learning resources and English major teaching assistants, it provides a language proficiency enhancement space for students, also used for international student cultural activities and foreign faculty academic exchanges, achieving thematic space utilization.

Model	Description	Example Cases
Metaverse	Characterized by immersive learning and experiences, creating lifelike learning spaces for learners through virtual reality and holographic projection.	East China Normal University Future Learning Center Construction: Learner-centered, highlighting individual initiative and creativity in learning spaces. Assists teachers and students in building personal learning spaces and creating learning assistants; constructs immersive learning spaces for multimodal experiences.

These four models each have distinct construction priorities and application functions, reflecting different emphases among institutions regarding learning resources and infrastructure, technological practice and research innovation, and disciplinary development and skills training. They also demonstrate common aspirations for future learning: introducing advanced technology, upgrading learning spaces, expanding learning resources, and ultimately achieving educational and learning model innovation. This points the way for future learning center construction while presenting multifaceted challenges for universities, including obstacles in space transformation, resource integration, and effective facility utilization.

(1) Obstacles in Offline Space Transformation and Upgrading

Future learning centers require substantial offline space, including areas for discussion and exchange, functional spaces for cutting-edge technology equipment, and multi-purpose activity spaces. However, most current university teaching buildings and library spaces are nearly saturated, making it difficult to allocate large amounts of space. Many current construction cases rely on opportunities presented by new library construction or renovation, such as Shanghai Jiao Tong University's Bao Yugang Library, North Carolina State University's Hunt Library, and the National Cybersecurity Academy Library. These projects achieve high-quality results but lack generalizability. Space shortage may be the first major difficulty for many universities establishing future learning centers.

Furthermore, future learning centers are typically planned as long-term spaces. However, facing rapid technological development and changing information exchange patterns, one-time high-cost space transformation and equipment upgrades may face new renovation demands within a few years. The future upgrading of physical facilities has also become a concern in current construction.

(2) Obstacles in Learning Resource Integration and Organization

Future learning centers not only provide learning venues but also massive learning resources, enabling learners to freely and fully utilize them. This requires universities to continuously acquire new learning resources while improving the accessibility of growing resource collections—the more resources accumulated, the stronger the demand for accessibility. As technology guides the transformation of learning models and content, learners' retrieval habits and knowledge needs will also change. The organization model of learning resources and information content will greatly influence knowledge acquisition efficiency. This demands orderly integration and intelligent, personalized services for learning resources, posing challenges to universities' learning resource management technologies and human resources. For example, Xi'an Jiaotong University conducted deep processing of course materials and resources, using knowledge graphs to display knowledge associations and developing a knowledge forest navigation learning system to help students clarify knowledge structures. This system was led by an expert team from the School of Electronic and Information Engineering, demonstrating its high technical requirements.

(3) Obstacles in Teaching and Learning Model Reform

The purpose of constructing future learning centers is to enhance learning efficiency and quality through technology introduction and facility upgrades, achieving learning model innovation. However, facility upgrading and teaching reform complement each other. On one hand, advanced hardware and software facilities bring opportunities and inspiration for teaching and learning changes. On the other hand, only with concepts of future learning and education can these facilities be fully and creatively utilized for effective future learning center planning and construction. Currently, some future learning centers are limited to following technological development, compensatorily meeting learning and usage needs that have long existed but remained unfulfilled, without maximizing the use of cutting-edge technology to lead or even transform teaching and learning methods. Some universities, based on past experience, worry about low facility utilization rates after upgrades, which is also related to the lack of adjustment in teaching content, models, and assessment methods alongside hardware upgrades. How to break through traditional teaching and learning models to build truly future-oriented learning centers while using facilities to drive adjustments in learning models and systems, exploring educational upgrades, is the real challenge facing future learning center construction.

3. Metaverse Scenario Functions of the "Dynamically Intelligent Generative" Future Learning Center

The role of future learning centers is to provide a scene and resource repository for exploring and realizing future learning, using technological means to liberate the content and form of teaching and learning, and organizing learning resources and activities with optimal learning outcomes as the goal. This vision aligns with the "knowledge exchange theory" proposed by China's library community in the 1980s. From the library perspective, knowledge exchange theory posits that the essence of library activities is social knowledge exchange, which operates at three levels: exploring patterns of how subjects absorb and utilize knowledge, examining libraries' use of social knowledge exchange laws, and investigating the internal mechanisms and working principles of library knowledge exchange [27]. Knowledge exchange content can be divided into two categories: "explicit knowledge" that can be externalized, articulated, and recorded, and "tacit knowledge" that is difficult to externalize, such as skills, experience, insight, values, and mental models [28]. Current library services have promoted explicit knowledge exchange through classification, subject indexing, and catalog organization, while the promotion of tacit knowledge exchange can seek breakthroughs in the digital and network era.

Future learning centers continue the library's function in knowledge exchange regarding learning resource organization and provision, while their educational and learning functions enhance and expand the knowledge exchange process. At the level of knowledge exchange, future learning centers need to both explore and advance learning models (first level) and adjust and update themselves according to learning and knowledge exchange needs (second level), while also developing theories and models about future learning center construction and development itself (third level). In terms of knowledge exchange content, future learning centers not only enable explicit knowledge exchange through rich resources but also facilitate tacit knowledge exchange through teaching processes and learning activities via experience, discussion, collaboration, and practice, enhancing exchange efficiency and quality through technological tools and scenarios.

Metaverse technology is an excellent tool for strengthening knowledge exchange at different levels and content. In recent years, "metaverse" has become a hot social topic, and the application of "metaverse technology" in libraries, museums, and other cultural institutions, as well as in some school education, has become an exploration of immersive, experiential education and "AI+" education [29]. The term "metaverse" originates from literature and film, with its core value focusing on scenarios characterized by "intelligence," "interconnection," and "virtual-real interaction," centered around the comprehensive application of technologies such as cloud computing, IoT, big data, AI, and mixed reality. This paper proposes the construction of a "dynamically intelligent generative" future learning center that upgrades space, resources, and services through metaverse-related technologies. It uses technological tools and scenarios to enhance knowledge exchange effects, drives learning model transformation through technological progress, and simultaneously explores and promotes the evolution and updating of future learning centers themselves through intelligent technology—a dynamic, intelligent, and continuously evolving future learning system. On one hand, by utilizing IoT, big data, AI, and virtual-real interaction technologies, the "dynamically intelligent generative" future learning center can flexibly utilize resources, intelligently match needs, and achieve self-renewal and upgrading based on technological progress and demand changes, enabling dynamic response and intelligent services for learning models and learner needs.

On the other hand, as related technologies advance and future learning center service levels improve, learning models and knowledge exchange methods will continuously transform, with the continuously upgrading future learning center playing a dynamic, intelligent guiding, promoting, and supporting role. Through technological progress and intelligent perception and feedback, future learning centers can achieve both self-renewal and continuous motivation and support for learning model transformation, thereby truly realizing the promoting effect of technological development on education and knowledge exchange transformation.

3.1 Flexible Organization, Intelligent Construction

The construction of "dynamically intelligent generative" future learning centers will be closely integrated with IoT, AI, and virtual-real interaction technologies, flexibly organizing space, human, and technological resources to overcome current difficulties in space and resource organization. This approach enables human-machine collaboration during construction, resulting in virtual-real integrated, intelligently interconnected outcomes that provide a facility foundation for intelligent services and continuous updates.

3.1.1 Learning Space and Equipment IoT IoT technology has gradually been applied in building smart campuses in recent years. For example, the University of California, Berkeley built a campus-wide connectivity network for transportation, facilities, environment, and safety by cooperating with key facility suppliers [30]; South China University of Technology deployed IoT nodes and communication nodes in its Guangzhou International Campus, enabling complex applications such as security linkage, green energy saving, and smart classrooms [31]. Future learning center construction can also incorporate IoT technology. When large contiguous areas cannot be obtained for centralized construction, IoT technology can support distributed development by utilizing available spaces in different libraries, teaching buildings, and activity areas, using sensing devices and network communications to monitor space and equipment usage, achieving unified IoT-based management.

Learning space and facility IoT will facilitate hardware usage and management. After intelligent connectivity, distributed future learning centers can support teachers and students in viewing and reserving spaces through a unified website, enabling efficient and convenient resource utilization. In management, IoT can monitor specific equipment usage, enabling intelligent monitoring and response for energy management, equipment maintenance, and safety hazard monitoring. Additionally, IoT systems help collect relevant data to analyze teachers' and students' learning and usage habits, thereby developing related teaching courses and guidance, and optimizing facility configuration and spatial organization.

3.1.2 Multi-functional Intelligent Spaces The various models of future learning center construction reflect diverse needs in university education.

Multi-functional intelligent spaces can meet learning needs across different disciplines and functional orientations within limited spaces through flexible hardware/software configuration and learning resource updates, while achieving sustainable upgrading through resource renewal. Multi-functional intelligent spaces can use general-purpose hardware paired with different software or content to enable different functional uses. For example, when multiple disciplines require equipment operation practice, virtual reality, augmented reality equipment, and simulation software can be combined to simulate different equipment; when multiple projects have exhibition needs, projection equipment can be used for digital exhibitions with different content displayed in time slots or rolling presentations. Additionally, space equipment can be paired with diverse input interfaces, operating systems, and movable furniture to meet more varied needs. Multi-functional intelligent space construction is not limited to any single form and can be diversely designed according to teacher and student needs, functional integration, and technological development, such as building multimedia-equipped, soundproof discussion spaces that can also serve as meeting spaces, job interview spaces, and online examination spaces; or building immersive exhibition spaces featuring giant screens and surround sound that can also serve as immersive interactive teaching and learning spaces.

Domestic and international cases have already attempted different types of multi-functional space construction. China Jiliang University used distributed virtual reality technology to create a virtual simulation learning space where virtual learning content can be integrated with real classroom environments. The learning space is applicable to multidisciplinary teaching, such as simulating livestock slaughter quarantine operations or displaying Ming and Qing dynasty furniture environments; virtual teaching facilities and content can be adjusted according to needs [32]. The Innovation Studio at North Carolina State University Library installed projection screens, touchless interactive interfaces, and other interactive facilities, supporting the upload of audio, video, external links, and programming content for display, achieving space multi-functionality through open content and interactive media [33].

3.1.3 Online Virtual Spaces Against the backdrop of mainstream remote and digital services, virtual space and online service construction is essential. Virtual spaces can supplement solutions for insufficient offline space, provide more remote services, and achieve continuous learning and resource upgrading through iterative updates of virtual content. Universities can cooperate with technology companies to create virtual learning spaces that replace or supplement offline functions, such as online exhibition spaces, immersive learning spaces, simulation practice and experience spaces, and remote discussion and meeting spaces. In June 2022, the School of Animation and Digital Arts at Communication University of China held a "metaverse" graduation ceremony and graduation exhibition, using virtual reality, natural interaction, and 3D reconstruction technologies to build campus landmark buildings and space-themed planetary exhibition halls, with graduates interacting online as "astronauts"—a comprehensive attempt at virtual space utilization [34].

3.1.4 Human-Machine Collaborative Resource Organization and Aggregation In the digital library era, many university libraries have completed integration of campus learning resources and accumulated substantial digital resources. However, these resources have not been fully integrated according to learning cognition and usage habits to provide intelligent and personalized services, posing challenges for resource management framework upgrades, technological advancement, and deep resource aggregation. Given the scale of university learning resources and limited personnel, human-machine collaborative resource organization and aggregation is essential. Resource management institutions such as libraries can cooperate with technology teams and commercial companies providing learning resources to customize technical solutions based on campus resources and usage needs, using AI tools for metadata cleaning, keyword extraction, topic clustering, and generating linked data and knowledge graphs for learning resources. Discipline experts, library and information science experts, and technology experts can collaborate to achieve overall upgrading of learning resource management.

3.2 Dynamic Sensing, Intelligent Services

Intelligent services are a crucial component of "dynamically intelligent generative" future learning centers, primarily reflected in learning resource acquisition and utilization. Big data and AI technologies can provide intelligent and personalized services for teachers and students based on orderly resource integration; digital human and AIGC technologies can efficiently produce widely usable learning resources based on teaching needs and revolutionize teaching and interaction methods. Related technologies can assist future learning center resource construction, enabling it to cooperate with campus human and resource levels during the construction phase, meet teacher and student needs during the service phase, and support long-term efficient content production and intelligent interaction, achieving dynamic matching between learning resources and demands.

3.2.1 Intelligent Resource Recommendation and Learning Customization Intelligent recommendation and content customization services are already common in social media and e-commerce, and learning resources can serve learners through similar methods. Libraries can link with academic affairs information or establish personal interest and learning profiles for teachers and students. Based on users' borrowing history and preferences, reading interests, departments, and grade levels, relevant learning resources can be pushed to users, with AI tools generating themed booklist recommendations. Alternatively, based on teacher and student needs and available resources, intelligent learning plans can be formulated with supporting materials, thereby lowering the threshold for accessing learning resources and improving resource supply-demand matching and utilization efficiency. Xi'an Jiaotong University Library has already attempted this, supporting users in customizing portal websites to independently add commonly used resources and services; the library can recommend collection resources through keywords based on readers' search history [13].

3.2.2 Digital Humans and Generative AI Participating in Learning Content Production Digital human technology and generative AI have developed rapidly in recent years. Future learning centers can introduce these technologies to achieve rapid response and intelligent generation of learning resources to meet learning demands. As early as 2018, a primary school in New Zealand introduced an AI-driven digital human teacher into the classroom [35]; CNKI is also cooperating with some university teachers to use digital humans for online course recording. As technology further matures, universities can use digital humans and generative AI for course production, utilizing virtual teachers for automatic content generation and AI-generated materials for video production, reducing workload for teachers and technical staff as well as hardware costs and space occupation. Digital human technology can also be applied in extensive teaching and guidance scenarios, such as new student education, safety popularization, and information literacy education, or paired with AI-driven cores to build "digital intelligence humans" that serve as knowledge retrieval and Q&A assistants for teachers and students, providing personalized learning and research assistance.

3.3 Educational Exploration, Intelligent Upgrading

The core of "dynamically intelligent generative" future learning centers lies in dynamic response and intelligent updating, which requires multiple factors to jointly facilitate. Qiao Lili et al.'s "digital intelligence human" agile governance path provides inspiration for its realization. The "digital intelligence human" agile governance path achieves resilient fault tolerance and agile response through an interactive decision-making model of "multi-source heterogeneous big data + new AI algorithms + domain expert wisdom." In the cultural education field, intelligent social experiments can be used for progressive phased evaluation, feedback, and adjustment of intelligent education scenario design plans and models, with relevant data analyzed through "digital intelligence human" interactive decision-making to obtain relatively forward-looking and compatible metaverse implementation standards for education [36].

The "digital intelligence human" path has great reference significance for the planning, construction, and use of future learning centers. If future learning centers hope to achieve sustainable updating and development, they must also make relevant preparations. In the early stage of future learning center construction, universities can conduct experimental activities or learning experiences using existing equipment and spaces, while combining recent campus learning space and resource usage data and teaching data for "digital intelligence human" model analysis as a reference for future learning center planning. After construction and launch, based on usage data records from learning spaces and equipment IoT, online virtual space and digital resource usage, student academic information, and teacher-student interview feedback, the "digital intelligence human" interactive model can be further used for analysis as a basis and reference for future educational exploration and future learning center optimization. At different stages, analysis themes will be divided into two parts: first, what needs exist in current learning models, whether existing facilities and services can meet these needs, or how to transform to meet them; second, whether transformed facilities and services can meet relevant needs and provide unexpected services, offering leading resources and services that align with learners' cognition and habits while providing guidance. Only through systematic work in large-scale data collection and analysis, agile feedback and scientific optimization, educational observation and theoretical exploration, can future learning centers maximize their role, guiding learning model upgrading and educational transformation through technological upgrading and learning space reconstruction.

4. Construction Path for Metaverse Scenarios in Future Learning Centers

Constructing a "dynamically intelligent generative" future learning center based on metaverse technology cannot be achieved overnight. It requires multi-faceted internal and external preparation, including technological development, hardware and software supply development, campus technology and talent support, and teaching model transformation exploration. It also requires combining short-term, medium-term, and long-term work, gradually exploring while constructing in phases. The table below outlines the construction path for "dynamically intelligent generative" future learning centers, from short-term technological groundwork, pilot construction, and distributed development, to medium-term space and platform linking, deep resource integration, and personalized intelligent services, and finally to long-term knowledge exchange metaverse and AI digital human learning assistants. As metaverse technology continues to mature, the resource openness and service intelligence of future learning centers will continuously strengthen, and their self-adaptation and updating capabilities will continuously improve, gradually becoming a virtually-integrated, human-machine co-constructed knowledge exchange space.

Table 2 The Construction Path for Metaverse Scenarios in Future Learning Centers

Phase	Construction Project	Category	Content
Mature Models	Multi-functional Intelligent Space: Discussion & Activity Space	Offline Space	Utilize existing small classrooms or library discussion spaces, equip with flexible, user-friendly projection and audio equipment, movable furniture, and sound-proofing to enable multi-purpose use: multimedia discussion/meeting space, activity rehearsal space, examination/interview space.

Phase	Construction Project	Category	Content
	Multi-functional Intelligent Space: Exhibition & Immersion Space	Offline Space	Utilize existing large classrooms or exhibition halls, equip with giant screen projection or large displays, spatial stereo audio, movable display boards, and soundproofing, combined with developing immersive content and teaching exploration to enable multi-purpose use: immersive exhibition space, experiential teaching space, immersive reading/learning space (with movable furniture).

Phase	Construction Project	Category	Content
	Virtual Space: Online Exhibition	Online Space	Build online virtual exhibition spaces that can combine offline and metaverse exhibition forms to display digital collections, student research results, graduation works, etc.
	Virtual Space: Knowledge Exchange	Online Space	Build online learning exchange spaces combining online libraries, study rooms, chat rooms, etc., for online discussion and knowledge exchange.

Phase	Construction Project	Category	Content
	Smart Resource System 1.0	Resource Service	Based on existing campus learning resources, conduct discipline-based and thematic organization, attempt to use AI technologies for topic clustering and keyword extraction, and develop tools to assist resource retrieval and knowledge system construction.

Phase	Construction Project	Category	Content
	Teacher-Student User Digital Identity	Resource Service	Integrate with campus information network systems such as library accounts and academic affairs information accounts to build learning profiles for teachers and students; establish digital identities with real-name authentication for virtual space usage.

Phase	Construction Project	Category	Content
Exploratory Models	Multi-functional Intelligent Space: Interactive Course Space	Offline Space	Utilize a few classrooms or library discussion spaces to build VR/AR/XR and other interaction-based virtual-real interactive spaces, combined with developing interactive content, simulation courses, and interactive content design courses, enabling multi-purpose use: interactive course space, interactive exhibition space, interactive content development.

Phase	Construction Project	Category	Content
	Future Learning Center IoT	Offline Space	Based on campus functional space and hardware facility construction, conduct future learning center IoT construction; if other intelligent networks exist on campus, they can be integrated into the smart campus framework.

Phase	Construction Project	Category	Content
	Smart Resource System 2.0	Resource Service	Conduct fine-grained deep integration of campus learning resources while integrating with external resources, such as: cooperating with external learning resource providers for unified fine-grained retrieval; connecting campus resources with internet resources for one-stop search; providing intelligent services like learning resource recommendation and content customization.

Phase	Construction Project	Category	Content
	Teacher-Student Personal Learning Space	Resource Service	Based on teacher-student user digital identities and data, develop personal learning spaces where users can access all online resources, smart services, and IoT services through their personal identity and space, achieving personalized content integration, service usage, and learning planning; digital identity supports campus knowledge-based social networking and academic achievement claiming.

Phase	Construction Project	Category	Content
	Digital Human + AIGC Studio	Resource Service	Based on technology development status and campus needs, accumulate learning resource materials, build digital human images and AIGC styles suitable for the university, and establish a digital human + AIGC studio for fast and efficient production of teaching content.

Phase	Construction Project	Category	Content
	Online Virtual Learning Center	Online Space	Based on short-term pilot experience and campus needs, scale up and systematically build different functional online virtual spaces, connecting them into an online virtual learning center; connect virtual spaces with smart resource systems to achieve knowledge linkage in teaching, learning, and exchange; incorporate virtual space usage and content development into teaching and practice projects.

Phase	Construction Project	Category	Content
Innovative Models	Digital Human Learning Assistant	Resource Service	Based on teacher-student usage habits and personal profiles, combined with technology development status and campus needs, equip teachers and students with AI-driven digital human learning assistants linked to campus and external learning resource networks and smart campus IoT, becoming learners' 24/7 learning assistants.

Phase	Construction Project	Category	Content
	Knowledge Exchange Metaverse	Virtual-Real Interaction	Fully integrate smart campus, smart resource systems, online virtual learning centers, and personal learning spaces; teacher-student users enter the knowledge exchange metaverse with digital identities to freely access knowledge and resources; place smart devices in offline spaces supporting users to access metaverse online spaces anytime to retrieve learning resources or conduct exchanges; AI digital humans assist metaverse space operation and management.

Phase	Construction Project	Category	Content

Conclusion

As technology develops and learning resources continue to expand, future learning centers have become one solution for learning activities' spatial and resource environment needs, as well as an experimental path for universities to explore educational development and learning model evolution. Domestic and international theoretical discussions and practical attempts on this topic have produced different perspectives and models due to cultural backgrounds, disciplinary characteristics, and actual conditions, while also reflecting some common aspirations and shared problems. This paper proposes the construction concept of "dynamically intelligent generative" future learning centers, combining recent cutting-edge technological developments with educational practice cases. The "dynamically intelligent generative" future learning center utilizes metaverse-related technologies for flexible organization and human-machine collaboration during construction, dynamic sensing and intelligent upgrading during service delivery, and uses technological progress to drive learning model transformation while continuously achieving self-renewal and upgrading in response to changing demands. The construction of "dynamically intelligent generative" future learning centers requires multi-faceted preparation including technological development, talent cultivation, research exploration, and teaching experimentation. This paper proposes a relevant construction path with planning and suggestions for short-term, medium-term, and long-term construction. As intelligent and interactive technologies continue to develop, learning models and knowledge exchange patterns will constantly change. Future learning centers need to leverage technological development and human wisdom with agile response and continuous updating capabilities to consistently lead and support future learning.

At present, with metaverse-related technologies still in their infancy, we remain some distance from a true future learning center metaverse scenario. However, the continuous updating of university teaching spaces, libraries, laboratories, and innovation and entrepreneurship bases over recent decades, along with improvements in teaching quality and research levels, have fully demonstrated how technological development drives and promotes knowledge exchange, as well as the interactive relationship where knowledge exchange and technological development complement each other. The new round of technological and information revolution brought by metaverse-related technologies will trigger a new round of educational revolution and knowledge exchange revolution, while the revolution brought by intelligent technology will generate continuous self-sustaining changes and replacements, with technology and knowledge becoming each other's source and living water.

The functional design of metaverse scenarios for future learning centers foreshadows an era of barrier-free exchange and boundless learning, where technology will help knowledge traverse layers of barriers including space, media, cognition, and information noise to reach learners' minds with minimal friction. Learning will no longer be confined to any medium or form but will become an open-world game satisfying curiosity and thirst for knowledge, attracting each learner to hold their own map, cross the boundaries between real and virtual, and delve into every corner to absorb knowledge, experience, and wisdom. From a historical perspective, each technological leap has brought disruptive transformation to education. The integration of future learning centers and metaverse technology will not only open a new chapter in knowledge exchange but also create new transformative momentum, continuously elevating human knowledge exchange methods and cognitive patterns.

Under the mutual promotion of technological progress and knowledge exchange, every learner can pursue wisdom unbound, innovate courageously, and seek truth on their learning journey. This is both a challenge and an opportunity, and the true meaning of future learning.

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Note: Figure translations are in progress. See original paper for figures.