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REVIEW ARTICLE

Metaverse Services in Computing and Engineering Education

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Abstract Amid the digital revolution, this research explores a groundbreaking topic—the potential impact of metaverse services on the future of computing and engineering education. The transformative potential of metaverse services in education is a beacon of the future, promising new learning modes in digital environments. This work poses two questions: Will metaverse services affect computing and engineering education learning? If so, to what extent has computing and engineering education adopted metaverse services in its curricula? To address these queries, the authors researched several metaverse activities affecting computing and engineering education. The new concepts of metaverse services, metaverse education services, and metaverse education service space are presented and analyzed. This research also discusses the influences of metaverse and services on computing and engineering education. The research showed a transformation toward metaverse service education in the evolving digital era. Academic and industry professionals must recognize the critical need to prepare students and graduates for the digital era adequately. The future is coming whereby metaverse, higher education, and services will generate a new destiny for computing and engineering education with new learning modes in digital environments. The transformative potential of metaverse services in education cannot be overstated, and the academic and industry communities must recognize and embrace this phenomenon.

Keywords metaverse education, metaverse services, computing and engineering education, digital era, digital transformation of higher education

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1 Introduction

The digital era has brought many advances, challenges, and opportunities to people worldwide. New electronic and digital advances appear almost daily through new technologies, particularly in learning situations in schools, colleges, and universities. These digital advances affect how students live, study, and communicate. Students are becoming very dependent on technology, specifically digital technology. Digital services and metaverse agents are becoming part of everyday life.

1.1 | Metaverse Services

Discussing some of the digital services and metaverse agents that affect students and human life would be helpful. People already live in these environments. For example, consider the decline in the use of cash. People use credit cards, bank payment agents, and other means of fiscal exchange until a cashless society comes. Many teachers no longer use paper textbooks, which have transitioned to electronic books. Some students now employ electronic devices to learn, such as smartphones. Metaverses and educational services represent the future of university learning, especially those specializing in computing and engineering. Therefore, these students must develop digital skills to contribute to the digital field. Competency-based computing and engineering education in the digital era have been analyzed and discussed to cultivate these students in the future (Impagliazzo & Xu, 2024).

The term "metaverse" was initially presented by the science fiction author Neal Stephenson in his 1992 novel *Snow Crash* (Stephenson, 1992). Metaverse is a portmanteau of the Greek prefix "meta" (meaning "beyond") and the suffix "verse" (short for "universe"). It refers to a universe that is beyond the one we

currently know. Matthew Ball explains metaverse as:

A massively scaled and interoperable network of real-time rendered 3D virtual worlds which can be experienced synchronously and persistently by an effectively unlimited number of users with an individual sense of presence, and with continuity of data, such as identity, history, entitlements, objects, communication and payments (Ball, 2022).

Additionally, Mark Zuckerberg claimed:

In the metaverse, you'll be able to do almost anything you can imagine—get together with friends and family, work, learn, play, shop, create—as well as completely new experiences that don't fit how we think about computers or phones today.

He later announced "Meta" as the new name for his Facebook company (Zuckerberg, 2021).

Metaverse is to become a digital life and workspace of a new social ecosystem. This virtual universe interacts and links with the reality world, including digital avatars, digital natives, virtual-reality symbiosis, and other related entities. Metaverse includes artificial intelligence (AI), blockchain, edge computing, 5G and 6G, Big Data, cloud computing, augmented reality (AR), virtual reality (VR), mixed reality (MR), extended reality (XR), non-fungible tokens (NFTs), Internet of Things (IoT), and digital twins.

In metaverse, social activities and business processes are based on the sequences of workflow or service processes. Hence, it is necessary to introduce services into metaverse ecosystems to realize, schedule, and govern activities and behaviors, leading to metaverse services. Metaverse services refer to a series of massive, complicated digital services formed by virtual services and virtual-reality mixed services through service convergence across multi-domains, multi-networks, and multi-worlds, dealing with the business of digital avatars, digital twins, and digital natives in metaverse interconnected with the physical reality world (Xu, 2022a).

1.2 | Research Questions

This paper presents two research questions to address metaverse service transformations in computing and engineering education. The authors address the following research questions for this study.

(1) Will metaverse services transform computing and engineering education into the future digital era?

(2) If so, to what extent has computing and engineering education adopted metaverse services in its curricula?

2 Metaverse and Education

It would be beneficial to expand the metaverse theme. In metaverse, everything is realized by the digital elements or building blocks in virtual space. These building blocks in virtual space can be called metaverse-ware or simply meta-ware. These blocks may be complicated digital entities, elements, agents, or objects made by software and hardware of digital technologies for metaverse.

2.1 | Metaverse Properties

The properties of metaverse include immersion, identity, economy, and governance (Gong, 2022). The first property, *immersion*, represents user experiences in metaverse that provide a presence or quasi-reality feeling, including the five senses of vision, hearing, tactile feel, smelling, and taste. The second characteristic is virtual *identity* or avatar, where users can interact with multiple digital avatars having virtual identities in metaverse. These avatars function as digital agents of metaverse to accomplish a task. Digital twins are examples of this virtual identity. The third characteristic is a virtual *economy*. Many trades and economic activities occur in metaverse, forming a metaverse's virtual economy as a new form of a digital internet economic ecosystem. Blockchains and cryptocurrencies are examples of elements in a virtual economy. The fourth characteristic is *governance* surrounding a virtual society. Such order implies that no powerfully centralized government exists where metaverse operates by decentralized community governance.

Eight key technologies are required to operate metaverse, including human–machine interaction and smart terminals, AI, digital games and entertainment, network and cloud computing, edge computing, blockchain and NFTs, symbiosis, and decentralized governance (Lee et al., 2021). The first technology contains efficient and intelligent *human–machine interaction and smart terminals*. The second technology is *AI*, encompassing the theory and development of computer systems capable of executing tasks requiring human intelligence, such as visual perception, speech recognition, decision-making, and language translation. *Digital games and entertainment* are the third technology. Here, the computer attempts to duplicate human interaction or amusement in a virtual world. The fourth technology is *network and cloud computing*, where large servers store all data and content needed in metaverse. The fifth technology is *edge computing*, a networking technology that moves computing and storage closer to the devices that produce information

for its users. Wireless spectrums such as 5G and 6G and the IoT are examples of this technology. *Blockchain and NFTs* stand for the sixth technology. *Symbiosis* is the seventh metaverse technology, representing a close, long-term relationship between two or more biological species. As a manifestation of metaverse, VR symbiosis represents a performative, multi-user, and multi-sensory VR installation that can redesign the human body to allow a participant to embody a post-human or even nonhuman reality. The eighth technology is *decentralized governance*, which reflects the fourth characteristic of metaverse. Here, governance becomes a model where value independence occurs over shared resources. A virtual decentralized governance system would present multiple challenges for designers and developers.

Figure 1 illustrates metaverse, showing seven layers of its key elements (Radoff, 2021). As the basic layer, its infrastructure makes it possible to develop a human–machine interface, a decentralization mechanism, spatial computing, creator economy, discovery, and experience. Note that each of the seven layers involves some elements of the critical technologies already discussed. This thinking represents a futuristic view of computing.

2.2 | Metaverse for Education

In metaverse, various businesses, activities, and behaviors are connected and interact with each other between the digital virtual space and the reality world. Thus, converged services become more complicated and interoperable across multiple networks, domains, and worlds. This extension of Big Service in metaverse is called metaverse services. These services are massive and complicated digital services that deal with the business of avatars, digital twins, or natives in metaverse interconnected with the physical world and are sometimes called Big Service 2.0 (Xu & Wang, 2023).

In education, metaverse provides enabling technologies to support education, such as a 5G or 6G network, XR-based immersive interaction, Big Data analysis, new educational resources, field ecosystems, blockchain-based attestations, and real–virtual fused learning spaces. Metaverse provides a new environment to develop smart education through the construction environment of real–virtual fused learning fields, the information environment of educational data and resource services, the experience fields or scenes for embodied learning, and new cultural environments of learning communities between real and virtual worlds. Hence, metaverse provides new building elements to reshape education using multi-modal educational resources, scene-based immersive learning, embodied learning, intelligent learning tools, adaptive teaching, learner communities, virtual teachers and assistants, and Big Data-based assessment.

Metaverse is an enabler of higher education and presents five new forms within a higher education environment, including experience, agent, models, resource, and service. The first new form is the *experience* that involves immersive learning, quasi-reality feeling, embodied knowledge, scene-based

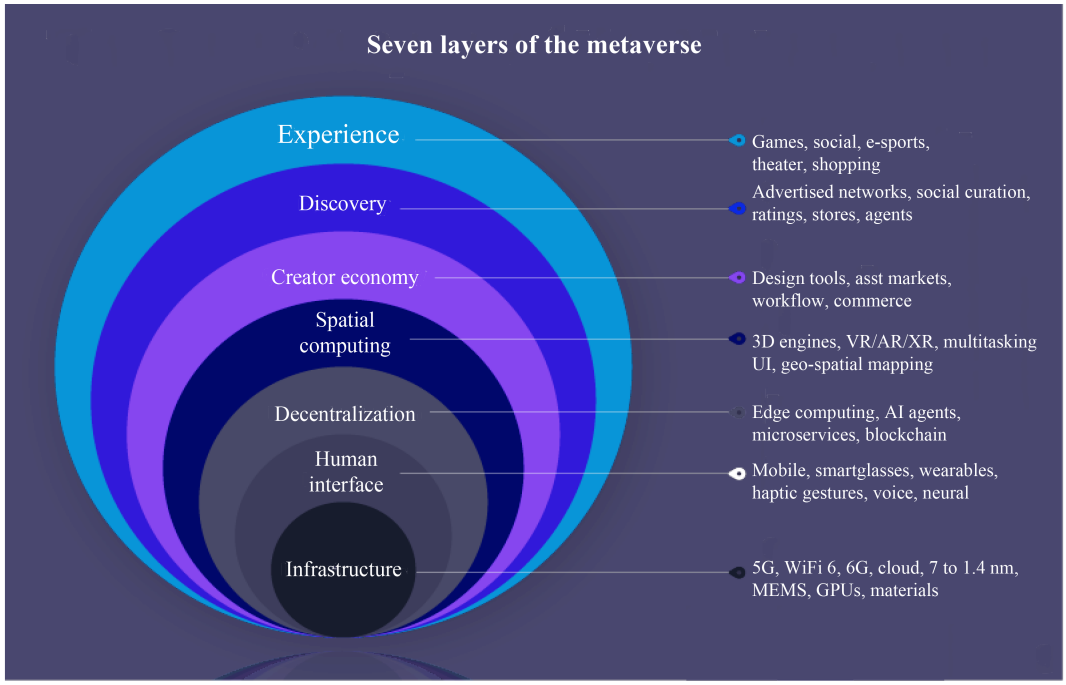

Figure 1 Seven layers of metaverse (from Radoff, 2021). VR = virtual reality, AR = augmented reality, XR = extended reality, UI = user interface, AI = artificial intelligence, MEMS = micro-electro-mechanical system, GPUs = graphics processing unit.

learning experience, and multi-modal perception based on VR, AR, and MR technologies. The second new form is an *agent* that generates multi-forms of learners and their partners, including digital avatars, digital twins, learning companions and assistants, and virtual–real mixed learner communities. The third form consists of *models* that deal with immersive embodied learning, deep interactive learning, virtual simulated experiments, participatory learning projects, and game-based learning. The fourth form, *resource*, consists of meta-ware-based education resources, scene-based teaching resources, smart learning tools and platforms, and multi-modal perception devices. The last form is the *service* that promotes service-oriented education, virtual learning assistants, digital avatars, digital twin-based learning, and learner-oriented adaptive teaching. These five forms establish the framework for higher education learning in metaverse environments (Xu, 2022b).

Metaverse education is an advanced phase of smart digital education and e-learning that facilitates education by providing a student-centric learning space for cross-time-space, immersive, interactive, and collaborative learning experiences using metaverse technologies.

Virtual fusion and AI enhance learners' perception, memory, and ability, improving educational efficiency and effectiveness. Metaverse education services enhance academic experiences and efficiency by offering intelligent services within a metaverse environment, thereby boosting teaching quality, value, and effectiveness.

2.3 | Metaverse Characteristics and Higher Education

Nine characteristics worth exploring are related to metaverse services concerning higher education. These include real–virtual fusion, immersive learning experience, time-space extension, enhanced intelligence, teaching model diversity, increased learning interests, individualized education, adaptive services, and objective education (Xu & Li, 2023). In metaverse education, *real–virtual fusion* integrates educational stakeholders in the real world with digital avatars, twins, and natives in virtual space to perform space-continued educational activities efficiently. At the same time, an *immersive learning experience* constructs various learning scenes to help students have deep, immersive, and embodied learning by interacting with virtual people and things in a metaverse environment. Various AI, VR, AR, and MR techniques form a basis for these learning scenes.

Metaverse education also utilizes *time-space extension*, which builds a learning environment over time and space to provide real–virtual mixed reality scenes for deep, immersive learning and improve teaching effectiveness. This leads to *enhanced intelligence* by applying AI-enabled tools and knowledge-based methods to support teaching and learning activities across real and virtual worlds improving learning efficiency and effectiveness. *Teaching model diversity* is another characteristic whereby metaverse education can support diverse teaching models, such as immersive, experienced, interactive, and game-based teaching, to improve education efficiently and effectively. Such activities prove conducive to *increased learning interests* where metaverse education develops various interesting educational games in virtual space to amplify participants' intrinsic motivation and encourage students to pay more attention to learning activities.

Another characteristic is *individualized education*, where metaverse education builds a personalized learner profile and a digital avatar or learning companion to meet the learner's needs and provide accurate and individualized adaptive learning strategies. *Adaptive service* is another characteristic whereby metaverse education integrates educational resources from multiple domains in real and virtual worlds to offer an adaptive total service solution to diverse learners on demand. Finally, *objective evaluation* for metaverse education applies AI, Big Data, and multi-dimensional information to assess teaching and learning performance and effectiveness objectively.

Metaverse services can reshape higher education and university experiences from teaching, learning, and serving. In *teaching*, metaverse provides a time-space continued education platform with scene-based immersive, interactive, individualized, and adaptive teaching approaches facilitated by virtual teachers and virtual teaching assistants (TAs) (Xu, 2022b). In *learning*, metaverse delivers a virtual environment with open and personal embodied learning space for students with rich real–virtual mixed learning resources, massive open online courses (MOOCs), intelligent and interactive virtual MOOCs (IMOOCs), open metaverse courses (OMCs), digital avatars and twins, virtual learning companions, and learner communities across real and virtual worlds. The management area is where metaverse provides multi-dimensional Big Data and visual context-aware management and decision systems for digital universities to manage, operate, and evaluate educational facilities, activities and processes, outcomes, and effectiveness. In *services*, metaverse provides student-centric multi-modal educational services, including natural and virtual learning scene construction, intelligent learning tools, knowledge-based learning service resources, and immersive learning facilities and services. Therefore, metaverse is critical in reshaping and advancing higher education in teaching, learning, management, and services.

3 Metaverse Service Space

In general, metaverse services involve complicated digital entities formed by virtual services and virtual–reality entities. The following highlights some of these characteristics.

3.1 | Concepts

A metaverse service space (MSS) is an open, continuous, quasi-realistic, virtual, or virtual–real fused living or working space based on metaverse. The MSS provides activities, processes, and services for the virtual–real fusion society to establish a customer-centric, cross-space-time, immersive, interactive, and collaborative living or working world for enhancing customer satisfaction through metaverse services. Metaverse services' behavior, processes, and activity space can be analyzed by structuring and formalizing metaverse service, decomposing and refining its spatial components, and describing its functions and performance. The MSS can be decomposed into several sub-spaces or sub-classes based on service functionality, business domains, regional locations, communities or organizations, service platforms, and other valuable areas (Xu, 2023a).

The composition of metaverse service space can take many forms with related subspaces. For example, a functional composition of MSS content may include a customer's personal and communal life spheres with a provider and group collaboration space. It may contain activity and composition spaces and service knowledge resource spaces. All these would function with metaverse service support platforms, service management platforms, and service assurance systems.

It is possible to decompose an MSS into four service environments: consumer, provider, resource, and platform. The *consumer* environment would contain the customer's personal and community-related life space, generating a metaverse activity space. One would expect to find a group collaboration space and a service composition space for the *provider* environment. The *resource* environment would service knowledge and resource spaces. Support and management platforms and an assurance system would be part of a service *platform* environment (Xu & Wang, 2023).

3.2 | MSS Directions and Applications

There is much promise in the MSS and its applications. People can acquire new experiences through scene-based immersive interaction, service sense, and cognition of real customers with digital twins and natives. The promise also includes a new convergence of methodology and digital modeling: MSS-based service convergence methods. One can expect new governance with reliable operation and evolution mechanisms of a decentralized metaverse society with value-based operations and management. There is also the promise of quality assurance where service quality evaluation and assurance are fused in the MSS, where blockchain assures credits, privacy, and security, and where Big Data-based services perform and monitor.

The climate is ripe for new research directions and topics on metaverse services. One area is the architectures and constitution of meta-ware-based metaverse service ecosystems, which are essential for MSS environments. Another research area consists of continually evolving VR, AR, and MR. Coupled with generative pre-trained transformers (GPTs), these areas can provide GPT-based immersive service customer requirements perception and acquisition for diverse digital twins and virtual humans in metaverse and MSS. Hence, they become essential components of the expected customized service process and optimization driven by complicated metaverse events in MSS. Such a service requires a matching-based metaverse service methodology for the digital agents in MSS where the blockchain and NFT-based value model-driven design, development, and evolution of software or meta-ware service systems become operational in a metaverse environment with multiple real–virtual resource-based cloud service platforms and metaverse service bases. The quality of service (QoS) and performance monitoring, evaluation, and assurance of metaverse service systems would utilize Big Data analysis methods for intelligent metaverse services in real–virtual mixed worlds (Xu, 2023a).

One promising application is the realm of smart metaverse education services and space. In this context, metaverse education has become an advanced phase of smart digital education and e-learning. It facilitates education by providing a student-centric learning space for cross-time-space, immersive, interactive, and collaborative learning experiences through metaverse technologies such as real–virtual fusion and AI to enhance learner's perception, memory, and ability and improve educational efficiency and effectiveness (Xu & Li, 2023). Metaverse education services provide intelligent metaverse services to educational activities and processes, benefiting teachers, students, and learners in a metaverse environment. This approach improves learners' experiences and learning efficiency and elevates teaching value. Metaverse education service space can also apply metaverse technologies in an open, continued, virtual or real–virtual, and mixed quasi-reality space, facilitating education activities and processes. This enables the establishment of a student-centric, cross-time-space, immersive,

interactive, collaborative learning space, ultimately improving education efficiency and effectiveness.

3.3 | Smart Metaverse Education and Services

It is possible to foresee MSS delivering smart education and services. In a metaverse environment, virtual or quasi-real teaching scenes are constructed to realize scene-based classes or experiments for teaching and learning. Teachers and students can enter virtual or quasi-real scenes and interact with digital avatars, virtual men, virtual things, and virtual elements in the scenes to experience immersive, interactive, visual, and touching teaching and learning (Xu, 2022b; Xu & Su, 2024). Every learner owns a smart learning companion as a learner's digital assistant. Like a soft service robot, the smart learning companion has the learner's profile and attributes, learning demands, and behaviors. It can help the learner make a study plan and schedule, order required education services and learning resources, and support learning activities. For example, virtual teachers and TAs play essential roles in a metaverse education environment. Virtual teachers can work with real human teachers together or teach students independently. Virtual TAs can support teachers in auxiliary teaching tasks or provide one-to-one question-and-answer sessions for students to improve learning efficiency. Additionally, digital avatars can provide customized services and adaptive solutions to problems. Such activity can occur synchronously or asynchronously, whereby collaborative learning can optimally occur in a personalized manner.

Smart education has much potential, whereas virtual space and scene-based metaverse education upgrade online education. In the online metaverse education space, multiple intelligent agents, including virtual teachers, virtual assistants, digital avatars, and learner companions, engage in online classes together to provide immersive, interactive, and interesting game-based learning services for online learners' collaborative learning. Quasi-reality training is also possible. Metaverse education systems can establish simulated quasi-reality fields and devices of production or experiment to support the learner's professional training. Utilizing cross-area distributed virtual or virtual–real mixed training fields or laboratories, remote collaborative or joint professional training for particular objectives can be efficiently performed (Xu, 2022b & 2023b).

4 Metaverse Services in Educational Domains

Understanding metaverse educational services' content, service space, and potential research areas is essential for their long-term effectiveness (Xu, 2022b & 2023b). The following addresses these three areas.

4.1 | Content of Metaverse Educational Services

The content of metaverse educational services consists of five elements: education for learners, education for providers, learning content, educational assurance, and educational platform (Xu, 2022b). The first element, *services for learners*, provides learner-centric services for teaching and learning, including individualized services for learner profiles and knowledge graphs, digital avatars, requirement acquisition, learning companions, and assistants. The second element, *education for providers*, denotes the services for teachers, virtual teachers, and education providers, including virtual educational resources and facilities, intelligent support tools, virtual TAs, learning scenes, and education center services. The third services for *learning content* provide teaching content and knowledge, including MOOCs, IMOOCs, OMCs, virtual simulation experiments, virtual-based courseware, course-based knowledgebase, and the maintenance of knowledge bases and educational databases. Providing such provisions would require *educational assurance* services which is the fourth element. The *educational assurance* services offer facility assistance for operation management and assurance of educational ecosystems, including virtual time and space governance, quality assurance, standards, and facility maintenance. The fifth element is that *educational platform* services would be needed to provide third- and fourth-party service platforms to support activities of metaverse education ecosystems, registration and management of users, service providers and resources, education value, and assessment. For better understanding, Figure 2 illustrates a service-oriented education model, while Figure 3 depicts a metaverse educational service network. These diagrams specifically demonstrate how *educational platform* services support and manage various educational resources and services.

4.2 | Metaverse Educational Service Space

Metaverse educational service space applies a metaverse in an open, continued, virtual, or real–virtual mixed quasi-reality space. This space provides services for educational activities and processes to establish a student-centric cross-time and immersive, interactive, and collaborative learning space that seeks to improve education efficiency and effectiveness using metaverse educational services (Xu, 2022b).

Figure 4 depicts an illustration of a metaverse

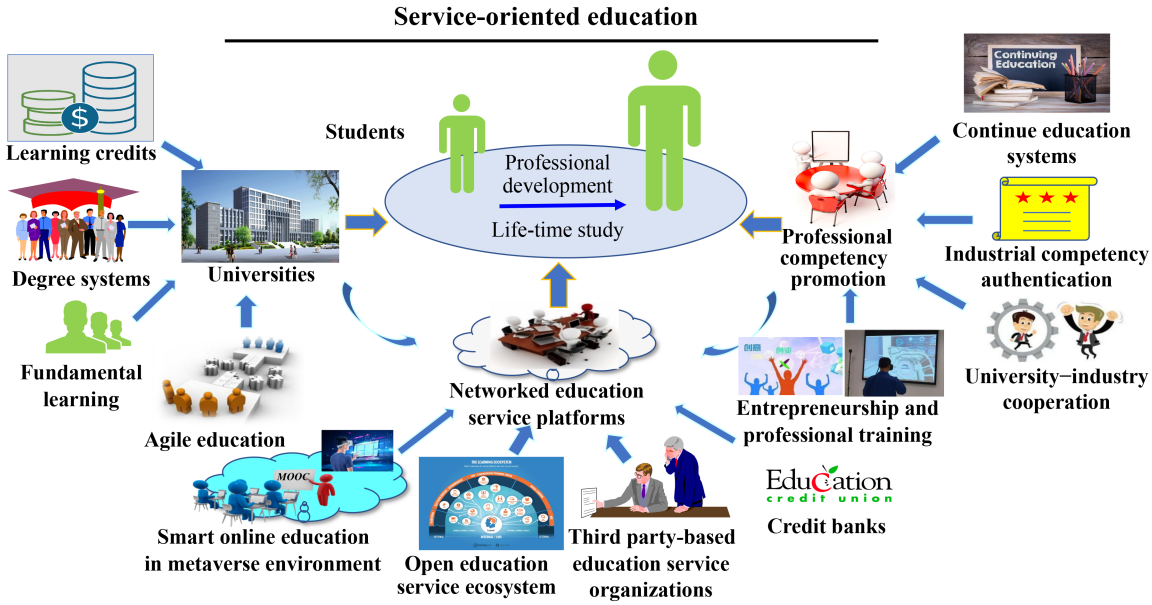

Figure 2 Service-oriented education.

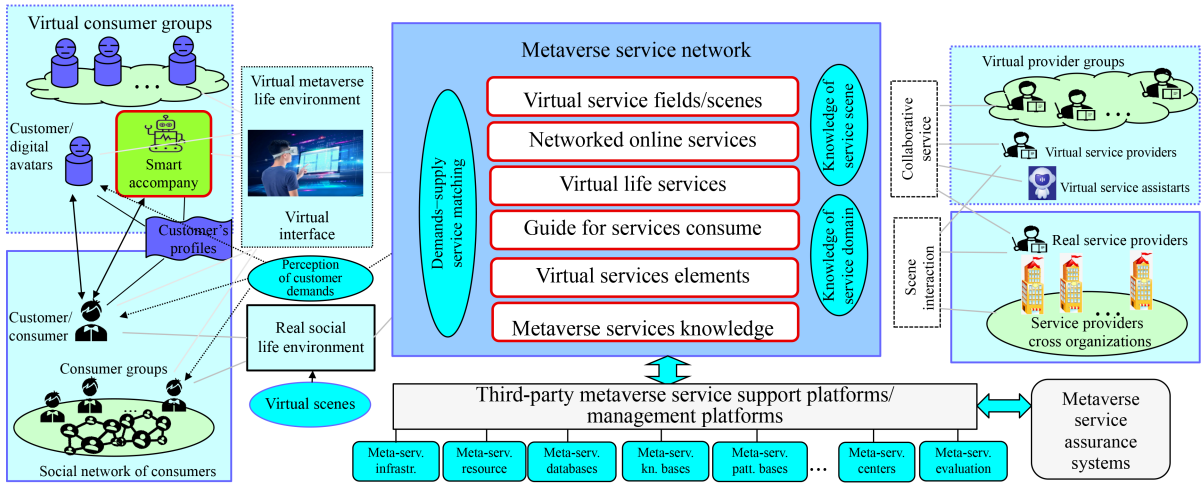

Figure 3 Ecosystem of metaverse services. Meta-serv. = Meta-service, infrastr. = infrastructure, kn. = knowledge, patt. = pattern.

educational service space. The functional constitution of this service space includes a learner and community learning space and a metaverse classroom and scene-based teaching space that generates a learning environment. A metaverse teacher and co-teaching space and a metaverse teaching integrated service space form the teaching environment. A metaverse education resource space and a metaverse education knowledge space form the resource environment. A metaverse education service management platform, education service support platform, and education service assurance system form the platform environment.

Learning service environments. The learning service environment supports self-learning ability through co-learning activities and discussions. This space consists of a virtual–real fused learning environment for individual learners, collaborative learning environment for groups, learner's profile, and knowledge graph. It also features competent learner's assistants, learning support tools and facilities, virtual seminar rooms and chat rooms, a digital blackboard, a learner's community network, and other related tools. The learner is also subject to a metaverse class and scene-based learning space that provides reality teaching scenes and platforms in metaverse for real and virtual teachers' teaching activities and students' embodied study in different scenes. This space consists of virtual and virtual–real mixed classrooms with diverse scenes, a virtual learning interface, a metaverse classroom, teaching facilities, educational content related to virtual scene elements, XR-based devices, and the environment.

Teaching service environments. This teaching and co-teaching space supports teachers' interactive

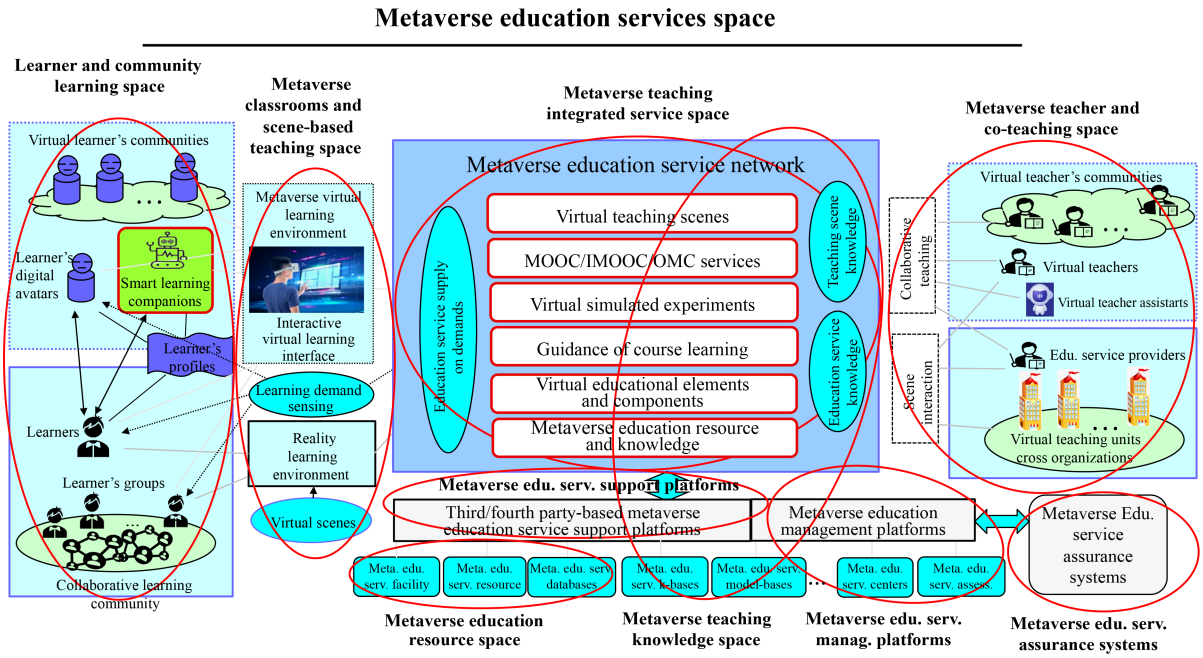

Figure 4 Metaverse education service space. Meta. = metaverse, edu. = education, serv. = service, k = knowledge, assess. = assessment, manag. = management.

and collaborative teaching activities. It includes AI-generated content (AIGC) to enable virtual teachers and TAs in a metaverse environment. This space comprises teacher profiles, virtual teachers, virtual TAs, teachers' virtual communities, smart teaching support tools and facilities, scene-based interactive teaching facilities, 3D digital blackboard, virtual teaching seminar rooms, virtual experiment laboratories, and other related service entities. As an integrated service space, it becomes a service network to provide various integrated educational services for metaverse education with rich entities, services, resources, activities, and facilities related to metaverse education services. These include virtual teaching scenes services, MOOCs and OMCs teaching services, virtual simulated experiment services, knowledge body and course learning guidance, virtual educational elements and components, metaverse education processes, and activity support tools.

Service resource environments. This service resource space contains the elements and infrastructure related to MSS activities and processes. These include meta-ware for teaching scenes, essential virtual teaching-supported devices and simulated experiment elements, databases of metaverse education, model and pattern bases of MSS, and other related elements. Additionally, the service knowledge space plays the role of knowledge base and knowledge pool of metaverse education services. This space contains knowledge bases of metaverse education and teaching activities, major-oriented knowledge bodies and graphs, scene-based specification and knowledge, multi-modal knowledge graphs for teaching and learning, the definition of a special MSS and its scope, and other related knowledge bases.

Service platforms. Metaverse education service support platforms enable the configuration and operation of services in metaverse service space based on a decentralized architecture. They consist of the third- and fourth-party service platforms and their interface, service registration and system operation monitoring and governance, a service convergence mechanism, multi-platform interaction, and an immersive interaction port of MSS. The education service management platforms monitor and manage the MSS, including service stakeholders, agents, processes, resources, credits, standards and specifications, digital property, and finance. This platform would be integrated with the metaverse education service support platforms which work with the service assurance systems to ensure the steady and safe operation of the MSS. They also contain service quality assurance, safety and privacy protection, reliability assurance, MSS evolution, and maintenance mechanisms.

4.3 | Research on Metaverse Educational Services

It is proper to question the changes brought by metaverse. Seven issues concern the scientific problems of metaverse educational services, including law, principles, requirements, approaches, methods, services, and assessment. One could ask about the new changes in higher education *law* affected by metaverse. For *principles*, what are the latest characteristics and mechanisms of metaverse education? For *requirements*,

how do students sense and achieve the learner's objectives and learning requirements in a metaverse education environment? One could also address learning *approaches* and ask how we might build the virtual learning elements, components, resources, and environment to develop new strategies and models for metaverse education. This would involve different *methods* to find efficient ways to provide adaptive educational service solutions based on dynamically sensing learners' purpose in a metaverse education environment. It might also involve new *services*, such as applying metaverse education to provide customized, optimized educational service solutions on demand for massive individualized learners. Finally, it may be necessary to generate new assessment forms to evaluate learning effectiveness in a metaverse education environment.

Much research remains open on metaverse educational services. For example, the principle of scene-based immersive learning in a metaverse environment and the constitution and evolution law of metaverse education service space are open topics. Digital avatar-based learning requires cognition, analysis, and the expressions of learner profile models. This is achieved through collaborative, interactive, and immersive teaching and learning methods with virtual teachers, TAs, and learning companions based on real–virtual fusion scenes. Massive and individualized learner-oriented research is needed for demand-supply matching methods for active customized service solutions. This includes the awareness of the advancement and optimization of metaverse education service methodologies. Research is needed on collaborative learning methods and intelligent support techniques in metaverse environments. Metaverse education service evolution and restructuring methods based on the dynamic status of learners and resources require exploration, as do the comprehensive assessment metrics and methods of metaverse education services.

5 Discussion and Results

This work has presented developments in metaverse educational services that will soon exist in learning and teaching domains. Metaverse efforts should quickly become central to computing and engineering education.

5.1 | Importance of Computing and Engineering Education

One outcome of this study is the skill development of a digital workforce. As the world increasingly relies on technology, digital literacy has become a necessity and a prerequisite for both personal and professional success. To address this need, computing and engineering education should equip individuals with the skills to navigate and contribute to the digital landscape. This includes providing knowledge for advanced learning and fostering the dispositions needed to be influential contributors to society. Such education also encourages critical thinking and problem-solving, enabling students to analyze and solve complex problems proficiently. Furthermore, computing and engineering education promotes innovation and creativity. The digital era flourishes on inventive thinking and fosters innovation that fuels technological advancements and economic growth. Students must have modern tools to find digital solutions to contemporary issues. In addition, future job markets will demand a workforce with strong computing skills. Fields such as AI, cybersecurity, and metaverse services are becoming integral to various industries. Therefore, it is urgent to prepare students with in-depth exposure to these areas to ensure they can meet the demands of the evolving job market.

However, computing and engineering education promises require much effort and perseverance. Metaverse services provide ways to learn and teach in a virtual world. Incorporating these new learning approaches is essential to ensure that all students can benefit from this new world that is upon them. The rapid evolution of technology challenges educators to keep computing and engineering curricula relevant. The promises of a functional metaverse education space are necessary to ensure students attain current applicable skills to become effective contributors to society. In an educational metaverse space, computing and engineering education can generate student success in an ever-changing society. Such immediate access will become indispensable for learning and advancing technology for society's betterment.

5.2 | Addressing the Research Questions

This study presented two research questions in Subsection 1.2. The first research question is as follows.

(1) Will metaverse services transform computing and engineering education into the future digital era?

The answer is entirely in the affirmative. The extensive discussions on metaverse educational services in chapters two, three, and four justify this response. There is sufficient evidence and research to show that metaverse support services in computing and engineering education are here and will remain in effect in the future. There is no rational reason to suspect these services to vanish. Therefore, this effort satisfies the first research question, confirming the presence and future relevance of metaverse.

The second research question assumed the

affirmative on the first research question. Its statement is as follows.

(2) If so, to what extent has computing and engineering education adopted metaverse services in its curricula?

Metaverse services discussion supports the promise of curricular adaptation to such education. However, although some metaverse tools and services are available, such as intelligent teaching support tools and online services, universities have yet to embrace the full benefits of such services. Hence, the second research question remains open for research and investigation.

6 Conclusions

The findings of this empirical study provide vital insight into the use of metaverse educational services in the digital era. They show that metaverse education brings significant changes to daily life and education and will reshape higher education. Smart metaverse education services provide substantial theoretical and technical support for developing metaverse education, digitalized higher education, and e-learning.

Teachers and administrators need to recognize this change, adapt to it, and utilize it now and in the future. The new vision should be:

Metaverse + Higher education + Services → New modes and spaces for higher education

Some believe this future is coming; others believe this future is already here.

Despite the enthusiasm and boundless technologies, adopting metaverse educational promises is not guaranteed. Computing and engineering programs must adopt this new notion and incorporate metaverse services into their curricula. Educational institutions, computing and engineering organizations, and governmental agencies must be prepared to embrace these promises and provide the necessary funding to make them a reality.

Metaverse will significantly change social ecosystems and the service space by creating ample space for developing metaverse services that will play an essential role in a metaverse world and evolve into new forms of services with new features. Metaverse services will become a new realm within a more colorful and marvelous service world. Metaverse service space facilitates a good platform for analyzing and developing the ecosystem of metaverse services, which will improve the quality of people's digital lives and future work.

More work is needed to monitor the future metaverse services in education. It will take human endurance and fiscal support to bring metaverse services to fruition. The digital era is changing rapidly, and the world cannot wait to see what happens. Professionals must act now to make metaverse educational services an integral part of the digital era in which we live. The future is bright; the future is coming. Educators must enter a metaverse service space to create new services and a new future for their students.

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