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# An Empirical Study of A Smart Education Model Enabled by the Edu-Metaverse to Enhance Better Learning Outcomes for Students

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**Abstract:** The Edu-Metaverse, a vast ensemble of different technologies, has initiated a great and unprecedented change in the field of education. This change has been effected through the following Edu-Metaverse characteristics: embodied and multimodal interaction; immersive teaching scenarios, which can accelerate learning and skill acquisition; and the emergence of AI-enabled agents. In comparison to traditional classroom teaching models, smart education is a collaborative and visual model that adopts the latest AI technologies to reach a learning outcome. However, a problem that should be considered is how a smart education model, enabled by the Edu-Metaverse, can be developed to enhance better learning outcomes for students. Such a model should highlight smart pedagogy in the context of the Edu-Metaverse, together with a smart teaching environment, multimodal teaching resources, and AI-enabled assessment. In this study, we focused on the teaching of college English to 60 students from Zhejiang Open University. We investigated the effectiveness of a smart education model, which was empowered by the Edu-Metaverse, in enhancing better learning outcomes for the students, using a combination of qualitative and quantitative research. After the one-semester-long experiment, questionnaires were sent out to complement the interview findings. It was found that the students who engaged in the smart education model in the Edu-Metaverse yielded higher scores in oral English, vocabulary and grammar, reading comprehension, English-to-Chinese translation, and writing than those who engaged in traditional instruction. Therefore, this study suggests that a smart education model enabled by the Edu-Metaverse, which is characterized by a highly immersive experience, multimodal interaction, and a high degree of freedom for resource sharing and creation can help learners to realize deep learning, develop their capacity for high-order thinking, and help them to become intelligent individuals in an online learning space. In order to facilitate this smart learning, we make the following suggestions for educational institutions: (1) teachers should improve the design of teaching scenarios, (2) teachers should focus on learning assessment that is based on core literacy, and (3) teachers' knowledge of the architecture of the Edu-Metaverse should be enhanced.

**Keywords:** Edu-Metaverse; smart education; empirical research; learning outcomes

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## 1. Introduction

The digital transformation of education is considered an essential component of higher education, enabling such academic institutions to face the challenges of the knowledge-driven digital transformation of society in the 21st century [1]. With the incorporation of information technology in teaching–learning practices, "the metaverse" began to be introduced into education [2]. Consequently, this has become a popular research focus. This term was originally coined by an American author named Neal Stephenson, in 1992, in the science fiction novel *Snow Crash* [3]. As the metaverse was subsequently applied in the educational field, the concept of the "Edu-Metaverse" appeared. It refers to a virtual reality, or a digitized space, which parallels the real world and is expressed through a collection of intelligent digital technologies, such as Internet of Things (IoT) technology, blockchain technology, computing technology, artificial intelligence technology, augmented reality (AR), virtual reality (VR), and mixed reality (MR) [4]. For example, Internet of Things technology provides strong support for multimodal smart classrooms [5] through its interactive nature. This technology can give users a comprehensive experience of multiple sensory channels—such as sight, touch, and sound—between the real world and the virtual world, through which multimodal data, through biometric sensors, can be obtained [6]. In addition, artificial intelligence technology enables the emergence of an array of digital colleagues, data mining, and human–computer collaborative assessment in education [7]. Therefore, it can be said that the multimodal interactivity, new immersive forms of team collaboration, and the highly realistic teaching scenarios of the Edu-Metaverse are bound to reshape the education ecosystem and have important theoretical and practical significance in promoting the transformation of smart education.

Smart education is a new teaching model that is being used to develop smart learners by optimizing the teaching process through coherently adopting the latest AI technologies and human interactions [8]. However, along with the benefits of digital education, such as smart education recognition, its weaknesses (e.g., students' inability to concentrate) are also being debated [9]. According to Marketing [10], traditional teaching is still very popular, as the physical contact it enables with teachers, the interpersonal relationships it encourages with different study companions, and the easy access to equipment offered by traditional teaching are difficult to realize through an online class. In addition, according to the author of [11], traditional teaching is more effective in increasing students' test scores. However, even though traditional teaching has some advantages, there is no possibility of completely moving back to a traditional pattern in the digital transformation of educational settings. This fact inspires researchers to continue conducting research that could help to improve digital education and that could help to avoid its disadvantages. As a result, in this study, we constructed a smart education model, enabled by the Edu-Metaverse, in which a smart teaching environment was reconstructed, multimodal teaching resources were developed, smart pedagogy was optimized, and AI-based assessments were utilized. In addition, the study has given empirical evidence of the effectiveness of this research model in enhancing better learning outcomes for students, in the context of Zhejiang Open University.

In this study, the current status of the Edu-Metaverse and the significance of a smart education model that has been empowered by the Edu-Metaverse are analyzed in detail and are discussed in Section 2. In Section 3, we discuss our construction of a model of smart education, enabled by the Edu-Metaverse. In this section, our theoretical framework for the model, the ecological teaching environment, the multimodal teaching resources, and the whole teaching process of smart pedagogy in the Edu-Metaverse are discussed. In Section 4, we provide information about the participants in the research and about the research design. In Section 5, we discuss the results of our data analysis, including data from the questionnaire, interviews, and the teaching experiment. In Section 6, we discuss and name some of the factors obtained through the data analysis and make some recommendations based on this. In Section 7, we briefly summarize our study and highlight future directions of study in this area.

## 2. Potential of the Edu-Metaverse in the Reconstruction of a Smart Education Model

### *2.1. Current Status of the Edu-Metaverse*

In recent years, we have seen tremendous progress in the technology applied to education, especially with the appearance of the Edu-Metaverse. In addition, research has also been carried out to prove its great potential in online education. Geping et al. [4] argued that the metaverse will upgrade online-merge-offline education by reshaping the curriculum resources, teaching methods, and certification mechanisms. Yuefan et al. [12] proved that online-merge-offline learning spaces, which are based on the metaverse, have connected structural conditions and multimodal content storage structures and can provide immersive learning experiences. Furthermore, Barry et al. [13] and Wenxiao et al. [14]

have proved the effectiveness of embodied learning, contextualized teaching, personalized learning, and gamification learning in the Edu-Metaverse field. In addition, some teaching models in experimental teaching [15] and PE teaching [16] have been constructed based on the metaverse and have explored its effectiveness.

According to a review of the prior studies in this field, the majority seem to have focused on the idea of technology-driven education; however, this study has sought to highlight the connection or interaction of all the technologies, rather than their combination. We have also explored how the Edu-Metaverse could revolutionize smart education, to stimulate learners' wisdom.

### 2.2. Current Status of Smart Education

Smart education has progressed through three stages. The first stage was centered on the theoretical foundations of smart education and resulted from the appearance of the flipped classroom, the online learning platform, and maker education. For example, Ronghuai (2014) [17] proposed three realms of smart education: the smart learning environment, new teaching models, and the modern education system. The second stage concentrated on the effectiveness of a smart teaching model. Shaochun et al. (2020) [18] and Xi et al. (2021) [19] analyzed new directions and strategies for the construction of smart classrooms. Jijian et al. (2021) [20] stated that the "multi-mode and human-machine collaboration" teaching model, based on MR, can better cultivate students' innovative thinking. Xiaochun (2020) [21] suggested that the multimodal smart classroom could cultivate students' self-learning abilities, which could also strengthen their learning satisfaction. Su et al. (2021) [22] argued that a modality learning environment, modality resources, multichannel interaction, and evaluation systems should be prioritized in the construction of modality-smart classrooms. The third stage of smart education is being explored from the perspective of constructing a more intelligent educational environment and designing smarter teaching methods. This learning environment and the teaching methods aim to recognize learners' characteristics and learning contexts to intelligently generate optimally adapted learning activities and to guide learners in making the right decisions, thus promoting their development [23].

### 2.3. The Use of the Edu-Metaverse in Smart Education

In the era of artificial intelligence, the channels through which people perceive external information are becoming more and more multimodal, through a combination of the senses: sight, touch, smell, sound, and taste [24]. The establishment of such sensory simulation systems in the virtual world is the basis of the metaverse [25]. With the development of modern information technology, teaching materials are gradually being empowered by technologies—for example, hard-copy teaching contents can be presented through 3D images, video, animation, audio, and VR, which can stimulate the multisensory perception of learners, such as visual, tactile, and auditory senses, as much as possible. However, these are primary exploration and shallow immersive experiences, in which the learners observe the virtual world, primarily through a computer. Furthermore, emerging technologies—such as holographic technology, which is an example of extended reality—are accelerating the utilization of technologies in more educational scenarios, which means that these emerging technologies have become a crucial part of education. The way in which the teaching contents are represented, the way in which teachers and students interact, the way in which teachers and students interact with the platform, and the way in which teachers and students interact with learning resources are all becoming more multimodal, giving learners a greater sense of embodiment, presence, and identity [26]. For example, interactive whiteboards, with their powerful functions in editing resources, increase the enjoyment and motivation in lessons, for both teachers and students, by providing a more varied, creative, and dynamic use of teaching resources. This use of interactive whiteboards was a primary attempt to generate high levels of multimodal interactions between teachers and intelligent devices. With AI-enabled classrooms, new classroom models, such as digital co-teachers and human–machine collaboration, have emerged. A co-teaching classroom is the practice of pairing AI-assisted virtual teachers—such as artificial intelligence, educational robots, and AI-enabled digital tutors—with real-world teachers. Together, they share the responsibilities of planning, organizing teaching activities, and assessing students. In a co-teaching setting, the real teachers are mainly accountable for the cultivation of students' comprehensive development in the aspects of instrumentality, sociality, meaningful rationality, and higher-order thinking development. This co-teaching classroom model can be described as "an attempt to construct smart education based on multimodalities at an intermediate level" [19]. In July 2019, the Department of Mobile Learning of Beijing Normal University, together with the VR/AR+Education Lab and China Mobile, completed a science lesson entitled "The Secret of the Rainbow". The lesson was completed in a 5G environment, using artificial intelligence technologies such as AR glasses and smart learning pens. The science lesson was taught to students in Shenzhen, Beijing, and Guiyang through holographic projection [22]. This form of teaching should be an advanced attempt to provide students with an immersive learning experience through the collaborative work and seamless connection of teachers and various hardware and software devices in an intelligent teaching field. Actually, it has been proved that using AR in a smart education model can encourage students' learning satisfaction and effectiveness [27].

The research discussed above has presented the development of the Edu-Metaverse applied in smart education. In the beginning, some technologies were developed independently; therefore, the use of these technologies in education was thought to be only a primary attempt. Nonetheless, the Edu-Metaverse, a new type of convergence service, has recently evolved in tandem with the rapid development of modern technologies. This is where the Edu-Metaverse reshapes a smart education model: its technological integration allows for embodied and natural social interactions and multisensory interactions [28]; its "virtual–real connection" system [29] transcends space and time, presents a high sense of presence and immersion, and enhances the learning experience of learners; its diversified forms of teaching activities make it possible to cultivate wisdom-oriented talents through the concept of "doing things well, doing good things, and completing things with the most appropriate strategies" [23].

First, the Edu-Metaverse is a complex of various intelligent digital technologies. Cloud computing technologies and 5G can guarantee the fluency of learners' online interactions. Furthermore, VR/AR/MR, the brain–computer interface, Internet of Things technology, and other interaction technologies will move us into the stage of multisensory channel integration instead of the interface interaction stage, which will certainly reshape the way that learners interact with each other. Therefore, a smart education model in the Edu-Metaverse could break down the boundaries of various learning places and could connect learners, teachers, experts, and their avatars inside and outside the school, through self-organized learning communities. Second, a smart education model, which is empowered by the Edu-Metaverse, will enable a sense of immersion, which will contribute much to the learning experience. According to Almirall (2022) [30], carrying out some teaching activities in the metaverse is much closer to doing them in the real classroom. From a technical point of view, the metaverse exists on four levels: holographic construction, holographic simulation, integration of virtuality and reality, and the linkage between virtuality and reality [29]. However, no matter what level the current technology enables, the ultimate goal is to improve the learning experience. In the Edu-Metaverse, the learning content and activities can be freely transformed from real to virtual and back to real, in a cycle [31]. At the same time, learners are promised free and equal collaborative learning, knowledge sharing, and co-creation in the cyberspace. The whole learning process is ubiquitous, informal, intelligent, innovative, and effective. For example, wearable devices—one of the applications in augmented reality—enable learners to observe learning resources that are difficult to explain in fields that require continuous practice, to perform instructive activities that are difficult to experience in the real world, to carry out creative transformation, and to edit various learning scenarios. All of these actions could enhance learners' sense of embodiment and presence, could help them to realize their cognitive transfer, and could significantly improve their learning. Third, the goal of a smart education model in the Edu-Metaverse is to cultivate an intelligent individual who possesses the basic behavioral wisdom and a better value orientation to successfully accomplish tasks and who develops the innovation wisdom to innovate the optimal solution to different tasks under different scenarios by integrating, innovating, and constructing knowledge [32].

## 3. The Architecture and Realization of a Smart Education Model Enabled by the Edu-Metaverse

### *3.1. Theoretical Framework*

The theories of flow experience and embodied cognition are comprehended as the theoretical contributors to the sense of presence and embodiment in the Edu-Metaverse [26,31]. The flow experience theory refers to the fact that when people are engaged in a challenging task, which matches their personal skills, they achieve a high level of forgetfulness and extreme pleasure. Actually, it means that the learners enter a state of "flow" when they are fully absorbed in the experiential task [33]. When the teacher designs experiential activities that have clear goals, an integration of action and perception, and moderately challenging tasks, the learners complete the tasks creatively, through their own experience and sense-making, at which time the learners enter the "immersion" state of completing the task. At this point, they withdraw their defenses unconsciously and achieve a state of forgetfulness, until they reach the "peak experience and complete satisfaction", at which point their cognitive and communicative abilities are enhanced.

Embodied cognition theory offers a comprehensive framework for comprehending the idea that the way we move our body, what we touch, or how we are standing can influence or shape our thinking [34]. Therefore, our body or our body's interaction with the physical world constitutes or contributes to our cognition. In addition, in the Edu-Metaverse, virtual reality technology overcomes the spatial and physical limitations of learning and teaching; i.e., an avatar that expresses the learner's self can have immersive experiences that cannot be experienced in the real world, can communicate with other learners, and can touch something in the virtual space, in the same way that their real body could.

In summary, the flow experience theory, developed by Csikszentmihalyi (1975) and embodied cognition theory, serve as the theoretical foundation for the reconstruction of a smart education model in the Edu-Metaverse, which play a vital role in enhancing learners' engagement and in maximizing their sense of an embodied experience [2].

### *3.2. Realization of a Smart Education Model in the Edu-Metaverse*

In the study, a smart education model enabled by the Edu-Metaverse has been constructed (shown in Figure 1). The smart teaching environments in the context of Edu-Metaverse make full use of various technologies and the three characteristics of the Edu-Metaverse to achieve the integration of multimodal resources, and the implementation of smart pedagogy as well, enabling embodied and immersive interaction and collaboration between on-site students and off-site students and realizing AI-based and human collaborative assessment.

#### 3.2.1. The Construction of Smart Teaching Environments

Teaching environments, the teaching content, teachers, and students constitute the teaching system, which is defined as the diverse locations, cultures, and contexts in which teachers teach. The internet, IoT technology, blockchain technology, interactive technology, and various other technologies—including smart learning pens, VR/AR/MR, holographic projection, digital twins, and other artificial intelligence technologies—have helped digital teaching environments to evolve into smart teaching environments. This suggests that the Edu-Metaverse has provided a new perspective for exploring and reshaping the teaching environment, in which an immersive experience, AI-enabled supporting service, and data-driven teaching design can be provided for the students (shown in Figure 2).

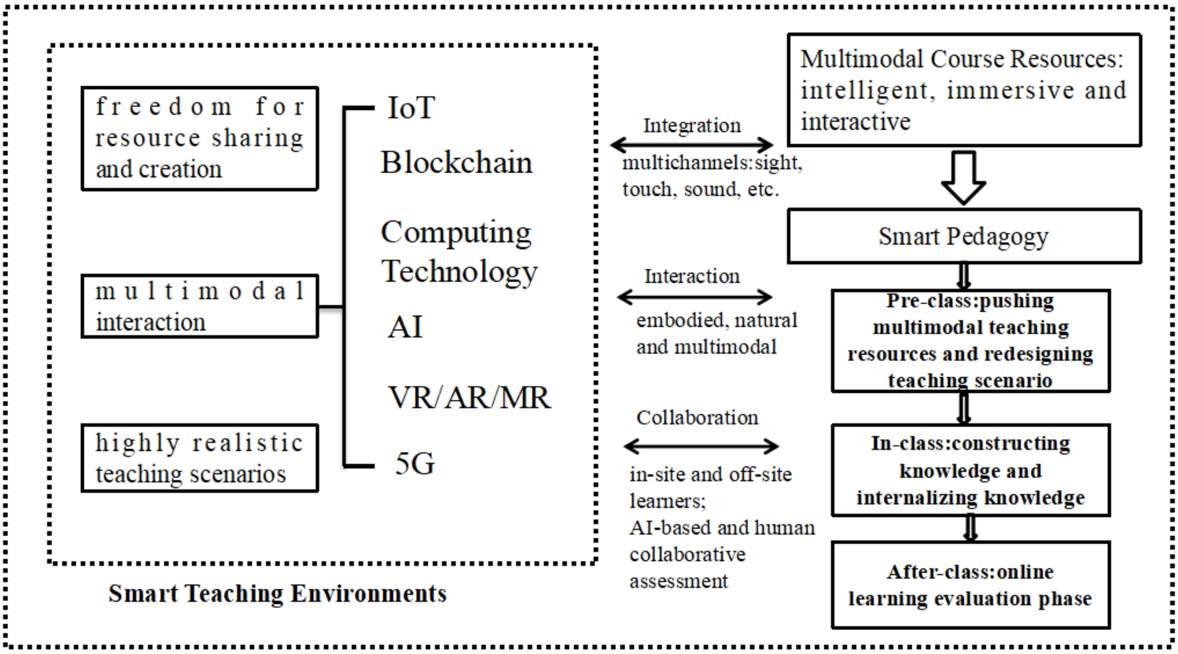


**Figure 1.** A Smart Education Model Enabled by the Edu-Metaverse.

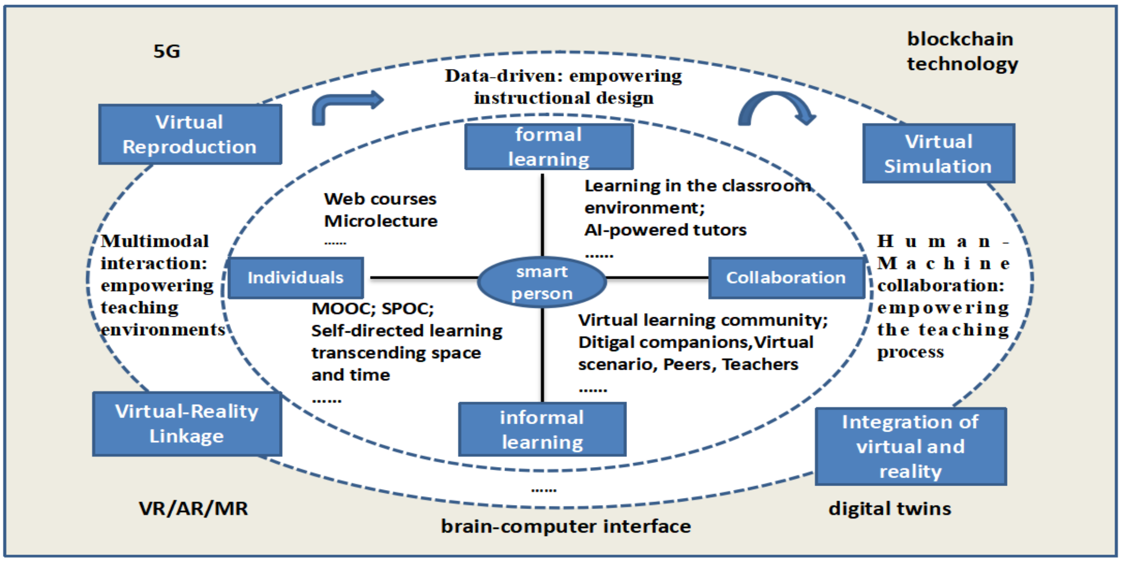


**Figure 2.** Smart teaching environments in the Edu-Metaverse.

Figure 2 shows that the teaching environment of a smart education model—a seamless connection between online, offline, formal learning, and informal learning—is to focus on creating a continuous and individualized digital learning space for the learners, who can choose suitable and convenient learning terminals according to their current situation. First of all, the integration of various emerging technologies is the cornerstone of the development of the new ecological teaching environment that is necessary for a smart education model. In the intelligent environment, learners are engaged in an intelligent and immersive interaction with the teaching environment and course resources; however, it is necessary to simplify the interactive port and reduce the cognitive pressure on learners. Second, by integrating and analyzing various learning behavior data of learners on MOOC, SPOC, and other online platforms, or in the classroom environment, the teaching process can be optimized after a data-driven diagnosis and a precise, visual, real-time evaluation; i.e., precision teaching is achieved through refining the teaching design on the basis of the data. Finally, various technologies in the Edu-Metaverse are involved throughout the entire teaching process, maximizing the embodiment of the human–machine collaborative intelligence [35]. The emergence of intelligent study companions, intelligent tutors, holographic teachers, and virtual teachers has contributed much to the teaching process, as they have increased human teachers' availability for more productive, value-added tasks. For example, intelligent tutors can provide learning guidance services, while teachers are responsible for creating the teaching design; machines can identify students' learning emotions through their behavior data, expressions, and movements, while teachers can extend emotional care based on this diagnosis. In addition, teachers can also create and dynamically edit the teaching resources and evaluation tools, while machines can automate the grading process. All of this reflects that both humans and machines can perform their respective functions, thus achieving human–machine collaborative intelligence.

Therefore, as mentioned above, the smart teaching environment is based on the empowerment that is given by the various technologies within the Edu-Metaverse. For example, it features data-driven teaching designs and a human–machine collaborative intelligent teaching process. It also revolves around multimodal interactions to, ultimately, realize an intelligent learning ecology—which strikes the balance between teaching methods, technology, and social culture—to satisfy the need for intelligent talent development.

#### 3.2.2. Multimodal Course Resources

In the multimodal smart classroom, course resources are no longer limited to text-based resources. Various emerging technologies in the Edu-Metaverse can be employed to develop intelligent, immersive, and interactive multimodal course resources [36]. For example, wearable devices enable learners to truly immerse themselves in VR/AR courses, from a subject or bystander perspective. Course resources in the visual modality, such as pictures, charts, and text, can convey meaning effectively. In addition, language, images, sounds, movements, and other channels can also be used to stimulate students' multisensory responses. Therefore, we can employ multiple forms to present the same teaching resources. This encourages students to participate more actively in the teaching process, whilst also satisfying the learning styles and needs of different learners.

From the perspective of learner participation, various multimodal course resources in the Edu-Metaverse have evolved. They have evolved from the limited operation, experience, and perception of course resources, to a flow experience of course resources, and, finally, to the most ideal state, in which the learner is completely immersed in them. Seen from the learning perspective, course resources are divided into the following categories: (1) basic learning materials—e.g., course descriptions, syllabuses, reference materials, lesson plans, PPTs, and homework—which are oriented towards imparting knowledge; (2) inspirational learning materials—e.g., various situational tasks designed by teachers—which check whether learners have internalized the knowledge they have acquired; and (3) the creation of the materials, where the teachers and students jointly edit and create multiple task scenarios, and where learners are guided to identify the connection between various types of knowledge before exploring the optimal solutions to real-world problems. This last category of resources realizes knowledge transfer and enables the development of in-depth knowledge.

#### 3.2.3. Smart Pedagogy in the Context of the Edu-Metaverse

According to [37], the learning methods of smart classrooms can include the following: teacher-centered lecturing, which mainly involves imparting teaching knowledge and skills; learner-centered group work; individual adaptive learning; and teacher–student collaborative knowledge development. No matter what type of learning method is adopted, the Edu-Metaverse could revolutionize the learning method. For example, rapid progress is being made in holographic projection technology, which enables teachers to connect on-site learners with off-site learners, so that students from different places can participate as equals in the real-life course interactions. Courses such as VR/AR courses can restore the real virtual scene as much as possible. Virtual reality role-play exercises and simulations have become common, enabling learners' avatars to learn in highly realistic, game-play learning scenarios. In addition, learners have the option to experience the appropriate scenes according to their own preferences, enabling learning to occur naturally. Other examples are the MOOC and SPOC courses, which enable learners to choose courses of interest independently and to transform into virtual learners who can cooperate, explore, and share resources with other learners remotely, and who can face the challenges posed by the learning process with each learner and teacher. In this way, collective wisdom can be achieved by integrating the intelligence of people with smart technology.

Obviously, in a smart education model, the whole teaching process is changed because of the use of multimodal interaction, immersive forms of team collaboration, and the highly realistic teaching scenarios of the Edu-Metaverse (shown in Figure 3).

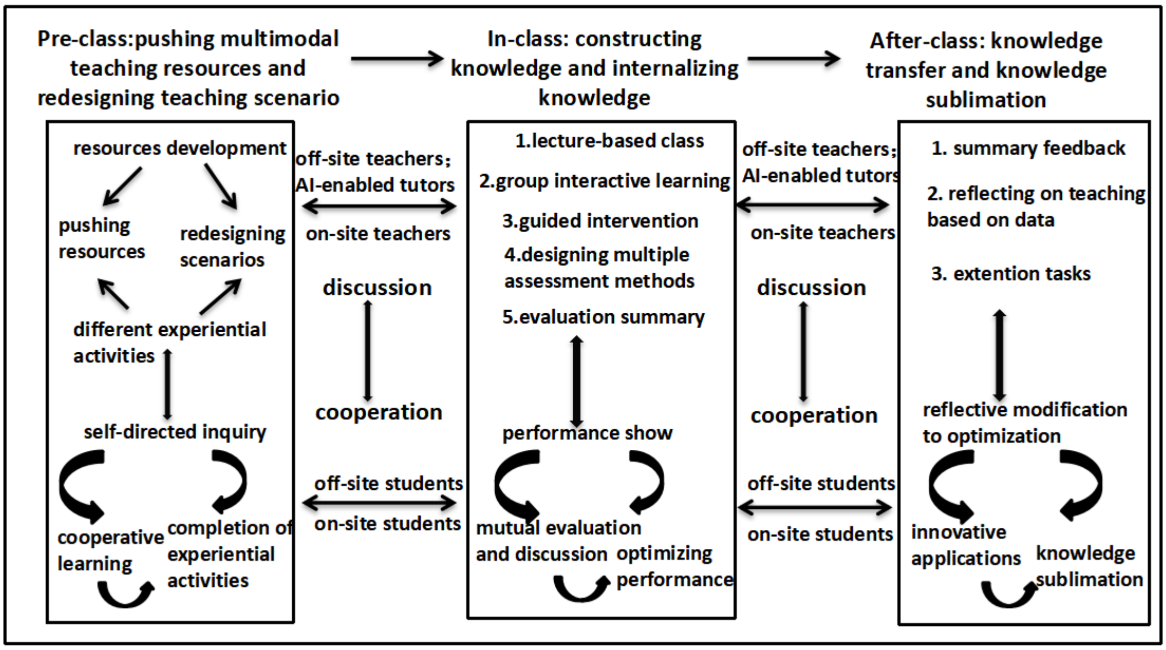


**Figure 3.** The detailed teaching process of smart pedagogy in the Edu-Metaverse.

Figure 3 reveals that the teaching process includes three stages, and the details are as follows:

In the first stage, multimodal learning resources are recommended and various interactive activities are designed before class.

A smart education model in the Edu-Metaverse can enable learners to engage in deep and meaningful learning, and the first stage of deep learning is to attract learners' interest in their studies. According to [23], recommending and integrating various course resources is the current technological literacy that teachers must acquire. The teacher offers learning resources through e-learning platforms such as PPTs that are embedded in interactive activities, VR/AR courses, and audio/video resources to stimulate learners' interest in learning by experiencing various sensations. For example, Hangzhou University of Electronic Science and Technology launched a VR course, Language and Intercultural Communication Training for International Volunteers of the Asian Games. In this course, teachers can recommend that learners practice English with AI characters and other online learners. This course can use augmented reality to test learners' skills in specific scenarios and to reinforce best practices in language and intercultural communication. In addition, this VR course offers a higher level of overall engagement by immersing students in their learning and by offering a greater opportunity to learn by doing.

In the second stage, knowledge construction and knowledge internalization are promoted in class.

At this stage, the teacher will conduct the first lesson of the term to introduce the teaching objectives, course framework, course resources, learning process, and related e-learning platforms, and will use the questionnaire to conduct a survey on students' personal information, learning objectives, learning habits, and online and offline learning attitudes to better understand the learners. In addition, the learners are divided into several groups, according to their wishes and actual ability levels. Different tasks and activities are designed according to the students' learning levels, and they can then conduct self-directed learning or cooperate with other learners to finish the tasks. Prior research [38] has identified that social interactions, collaborations with other students and tutors, and a good learning climate may influence the students' learning outcomes positively and enhance e-learning satisfaction.

Due to the prolonged COVID-19 pandemic, students sometimes cannot attend school; therefore, DingTalk Live Classroom has become a popular choice. Instead of having classes in a real classroom, the teachers can carry out lecture-based classes, which mainly focus on introducing knowledge and skills, to allow the students to finish the construction of new knowledge. At the same time, DingTalk Live Classroom is also a place where teachers and students can cooperate with each other to deepen their understanding of knowledge by means of sharing and discussing the tasks completed by the students outside of the classroom. In addition, holographic technology can expand the real world, allowing off-site teachers or experts to be on hand to assist in the classroom. The learners are able to achieve meaningful and deep learning through interaction with off-site experts, peers, and distance learning partners.

The most critical stage of deep learning is the practical application of knowledge, i.e., the internalization of knowledge. With prior knowledge, learners can creatively explore their optimal scheme in multiple contexts (e.g., role-play, mind mapping, presentations). Through the stimulation of learners' auditory, tactile, and visual systems to collaboratively engage in the experiential activities designed by the teacher, the learners have been able to build enduring memories and have further promoted the rational application of knowledge in different contexts.

The Edu-Metaverse provides more space and possibilities for learners to interact with various contexts, including interactions with real teachers, virtual assistants, real learners, and virtual peers. In addition, they can interact with the environment through various modes of interaction (e.g., auditory, tactile, and visual) and multimodal human–computer assistance. In this way, learners can independently explore and find the optimal solutions to their problems. With the joint empowerment of the wisdom of the teachers and students, and the intelligence of technology, learners can grow into intelligent individuals: they can improve their competence in the high-order thinking skills, problem-solving skills, and collaborative learning skills necessary for the real world; they can establish correct values of human interaction; and they can develop creative potential.

In the third stage, the knowledge transfer and sublimation after class are realized.

In the process of completing the task, teachers, AI-powered tutors, experts, and peers can assist learners when they need help, or can provide nudges based on the data analysis or observations. Moreover, learners will continuously reflect in order to enable them to arrive at the optimal solution to the task and, thus, complete the knowledge transfer and sublimation.

In the Edu-Metaverse, AI-based assessment has not only changed the nature of teaching evaluation and feedback, but it is the basis for improving teaching through the accurate collection of multifaceted information. First of all, the assessment subjects are diversified, including teachers, peers, and AI technology. Technologies such as automatic speech recognition (ASR), face recognition technology (FRT), and action recognition technology (ART) can analyze and evaluate teachers' and students' classroom behaviors. At the same time, data visualization is utilized to present the results. Second, the assessments conducted in terms of content have changed from traditional teaching process evaluations to an assessment of teachers' and students' emotions. The former assessment mainly revolves around the teaching content, teaching design, and teaching methods. However, the AI-based assessment can analyze the teachers' behaviors—such as the frequency of their multimedia usage, their emotions, and also their high-frequency words and knowledge points. Essentially, the teachers' teaching behaviors undergo a detailed, quantitative statistical analysis. Besides the students' levels of engagement, their interactions with the teacher and their mood swings can also be analyzed through AI technology; therefore, the assessment shifts from the evaluation of the knowledge transfer to the teachers' and students' emotions. This shift aims to facilitate the improvement of good teacher–student relationships and to create a positive classroom atmosphere, both of which are conducive to high-quality learning outcomes. Third, there are two types of performance evaluation for students: formative and summative. The former focuses on the process of students' learning. This is the process of gathering students' performance data, analyzing them, and using the results to provide feedback to improve learning. This type of assessment can be conducted through AI-based assessment, which can be communicated to the teacher in a constructive manner, thus enabling them to refine their performance and enhance their professional development. Furthermore, students' performance strengths and areas for improvement can be identified through this.

## 4. Methodology

### *4.1. Participants*

The study was conducted in 2021, and the four-year class from Zhejiang Open University consisted of 60 undergraduate students majoring in Humanities. College English was the course that we used to test whether a smart education model enabled by the Edu-Metaverse was effective. One group, which consisted of 30 students, was specified as an experimental group, whereas the other was a control group and also consisted of 30 students. Before the experiment, a pre-test was used to evaluate the two groups' English proficiency. The pre-test questions, which were conducted using the Xunfei online test system, included vocabulary and grammar, reading comprehension, English-to-Chinese translation, and writing. The questions on English-to-Chinese translation and writing were completely marked by artificial intelligence and were finally reviewed manually by three teachers, with the mean taken as the final result. The speaking part of the pre-test was tested using the FIF oral training platform, including word reading, sentence reading, and role play. It was also tested by artificial intelligence. Independent sample t-test results showed that there were no significant differences between the two groups ($t = 0.041$, $p = 0.342 > 0.05$); i.e., the students in the two groups had the same level of English proficiency.

### *4.2. Research Instruments*

The research instruments included pre- and post-tests, interviews (shown in Appendix A), and a questionnaire (shown in Appendix A). The post-test measured whether the students' command of the English language had been improved through the smart education model enabled by the Edu-Metaverse. The pre-test and post-test had the same questions and were scored the same way. The post-test was assessed by means of MANCOVA. Moreover, a questionnaire and interviews were conducted with the experimental group at the end of the experiment. The questionnaire was composed of 18 items, grouped into four dimensions, which were classified as follows: (1) teaching environment—4 items; (2) multimodal materials—4 items; (3) teaching process and assessment—4 items; and (4) learning satisfaction—6 items. In addition, an open-ended question about suggestions for the present trial model was included. All of the questions on the questionnaire were constructed using a five-point Likert scale, ranging from "strongly disagree" to "strongly agree". The collection rate and the effective rate were 100%. At the same time, the reliability of all questionnaire items was assessed by means of Cronbach's alpha scale. It yielded a Cronbach's alpha coefficient value of more than 90% (0.934), indicating strong conformity to proceed with the study. The validity of the questionnaire items was evaluated through

KMO and the Bartlett test. It yielded KMO value = 0.721 > 0.7, and the significance of Bartlett's spherical test was $p = 0.000 < 0.05$, signifying that these statistical data are suitable for analysis. The interviews involved the gathering of information about the students' subjective attitudes towards a smart education model, based in the Edu-Metaverse, and the problems they encountered during their studies.

### 4.3. Study Process

The lessons for the control group and the experimental group were delivered by the same teacher. The control group adopted the traditional pattern and lasted a term. The teacher presented knowledge to the learners in person, during three periods each week. First, the teacher explained the new words and analyzed the text, mostly using PPTs and talking methods. Second, the teacher asked one of the students to explain their ideas on a topic related to the text provided, and other students were asked to listen and wait for their turn. Third, students were asked to recite some sentence structures or complete some assignments. After the class, the teacher took the assignments related to the text they had learned, such as writing, translation, and reciting new words. This was the way the teacher handled the teaching of each text. On the other hand, the experimental group adopted a smart education model, in the context of Edu-Metaverse.

#### 4.3.1. Pre-Class: Pushing Multimodal Teaching Resources and Redesigning Teaching Scenario

Before the class, the teacher offered the crafted, interactive learning materials to the students and assigned them a task of practicing oral English in the FIF oral training system, including role play, and reading the words and sentences related to the text. Second, the teacher designed different activities according to the students' proficiency in English. For beginners, the teacher encouraged them to practice natural spelling, phonetic symbols, and one-sentence interpretation. For intermediate learners, tasks included word recitation, passage interpretation, and topic writing—these materials were related to the text. The advanced learners were also encouraged to finish writing and translation, but using topics that served as extensions. Each type of learner organized a team, with several outstanding learners organizing discussions and regularly pushing the resources. Third, the teacher asked the students to prepare a presentation on a topic related to the text. She sent QR codes on the e-learning platform (DingTalk) and asked the students to draw lots by scanning QR codes to decide whether or not they needed to share their process for completing the task with the class. The students were encouraged to cooperatively create their presentations using a platform for creating animations, such as the YoHa interactive movie platform. In summary, the teaching scenario was designed with instructional needs in mind, and learners identified the problems and explored the ways to solve them by means of self-directed inquiry and cooperative learning.

#### 4.3.2. In-Class: Online Student–Teacher Interaction Phase

In-class time (through DingTalk Live Class), MindManager, PPTs with various interactive activities, and videos were recommended to students analyzing whole texts. For example, to deal with an article, "5 Suggestions for Making Houses Greener", the teacher showed a video about how houses were environmentally friendly and energy-efficient and encouraged students to co-author a task through collaborative file sharing in the DingTalk system. In this, they had to outline the ways in which houses were environmentally friendly in the video. In this way, the students' in-depth understanding of this topic was strengthened. Then the teacher used explicit teaching to provide relevant sentence structure, such as "Plants provide you with oxygen necessary for survival", and guided the learners to gradually generalize the constructs, such as "provide sb with sth". Other similar phrases were output by the students, such as "supply sb with sth", "furnish sb with sth", "give sb sth" or "give sth to sb", and "offer sb sth" or "offer sth to sb". Therefore, the task emphasized the learners' co-acquisition of language forms, meanings, and functions. Moreover, the teacher created a virtual real-life context by asking the students to talk about how a washing machine saves energy. The students collaborated with each other to complete this task. For example, the students learned that Western people prefer to use dryers directly; however, in order to save energy, "nature's dryer" was suggested. With this task, the learners could improve their language skills and acquire corresponding socio-cultural knowledge at the same time. In fact, as learners completed the task, teachers and peers provided constant feedback and guidance based on their observations, and learners reflected and revised to move closer to the optimal response to the task.

In addition, we had students come to school once a month to take a class using the smart classroom. First, we used VR glasses for content introduction, which allowed the students to feel an immersive experience by stimulating their sense of sight and hearing, thus allowing them to be fully engaged in the learning task, as seen in Figure 4. At the same time, the smart classroom allowed on-site students, off-site students, and off-site teachers of Zhejiang Open University to attend the same class and cooperate with each other to complete an experiential task assigned by the teacher. VR courses offered in this monthly smart class could be regarded as an extension of the regular classes. In this way, the learners' interest and attention was aroused by the immersive scenario designed by the teacher. Learners also constructed new concepts through real or virtual experiences and entered the stage of deep learning.

#### 4.3.3. After-Class: Online Learning Evaluation Phase

In a smart education model enabled by the Edu-Metaverse, the evaluation subjects, evaluation contents, and evaluation methods were made multimodal. The evaluation contents included online self-test assignments and non-test assessments. The online self-test assignments were self-tested on a network college English course platform, where the students could find real-time communication tools, AI-enabled tutors, and an online testing system for self-tutorials and reference after the class. The platform implicitly monitored the learning process of the students and provided visual feedback to the teacher. From this, the teacher could understand the strengths and weaknesses of each student, provide personalized tutoring, and make timely adjustments to the teaching schedule. Furthermore, the teacher designed follow-up reading and interpretation exercises on the FIF oral training platform and evaluated them in real time, using the AI evaluation system. On www.pigai.org, a Chinese writing platform, the teacher designed writing exercises and speech training on the topic content. In the assessment, the machine focused on assessing grammar, syntax, and vocabulary, while the teacher focused on assessing the more complex written content such as layout, argumentation, and rhetoric. At this stage, the learners could acquire the target constructs, create deep knowledge, find the best balance between the target constructs and self-creativity through interaction with various evaluation subjects and self-reflection and gradually complete the transfer and advancement of knowledge. As to non-test assignments, the students were encouraged to use performances—e.g., shows, speech, drama, and role-play—to present their learning results. All of these performances could be evaluated by teachers, experts, peers, and AI and could then be put into their own portfolios, together with their contributions in the pre-class stage and in the student–teacher interaction phase.

After one semester of the teaching experiment, both the experimental group and the control group took part in a test, using the same questions as those that were used in the pre-test.

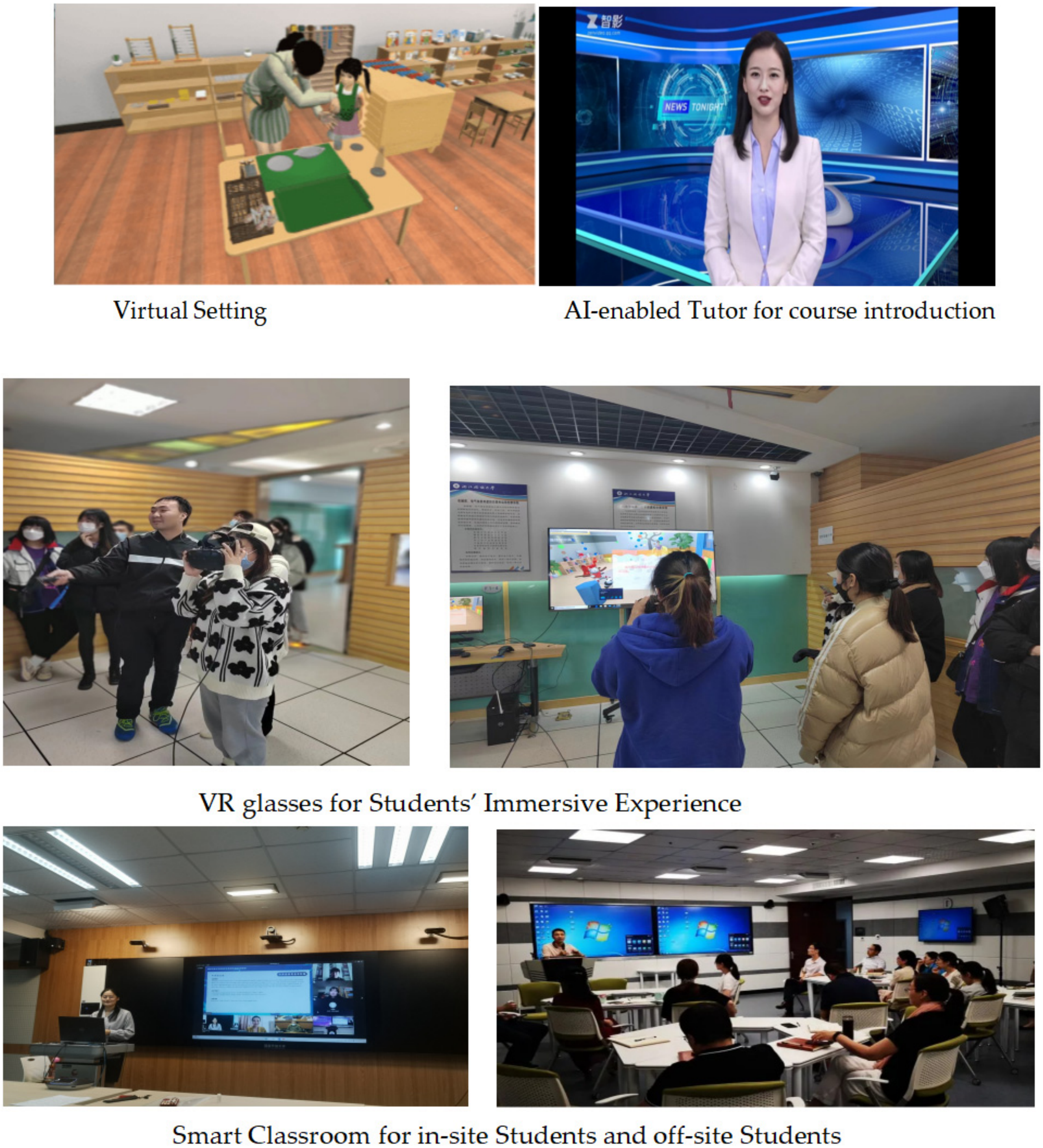


**Figure 4.** Screenshots of Smart Class.

## 5. Results

### *5.1. Results of Post-Test*

In examining the effectiveness of a smart education model enabled by the Edu-Metaverse on enhancing students' learning outcomes, the research model was assessed by means of MANCOVA. The results showed that P (Sig.) values were less than 0.05, indicating the differences between the experimental group and the control group were considered statistically significant, which supported and affirmed the study that a smart education model enabled by the Edu-Metaverse can significantly enhance the learning outcomes for the students in comparison to traditional teaching pattern (see Table 1). To investigate the most influential components of the learning outcomes, a comparison of all the sub-components was conducted. The results showed that the students engaged in the experimental group yielded higher scores in oral English (reading, role play, translation), vocabulary and grammar, reading comprehension, and writing than those in the control group (F = 146.887, 60.392, 98.130, 88.989, 57.290, 133.641 P (Sig.) = 0.000, 0.000, 0.000, 0.000, 0.000, 0.000 < 0.001). In addition, the overall results of the experimental group were considerably higher than those of the control group (F = 150.612 P (Sig.) = 0.000) (see Table 2). Among all the sub-components, the students in the experimental group made the most progress in oral English, and in writing, which supports the role smart tools, such as the FIF oral training platform and www.pigai.org play in English teaching. Therefore, the results revealed a substantial difference between the test scores of the experimental group and the control group, which affirmed that the students' learning outcomes had been improved through the use of a smart education model enabled by the Edu-Metaverse.

**Table 1.** Multivariate tests [a].

| Effect | | Value | F | Hypothesis df | Error df | Sig. |
|---|---|---|---|---|---|---|
| Intercept | Pillai's Trace | 0.995 | 1763.860 b | 6.000 | 53.000 | 0.000 |
| | Wilks' Lambda | 0.005 | 1763.860 b | 6.000 | 53.000 | 0.000 |
| | Hotelling's Trace | 199.682 | 1763.860 b | 6.000 | 53.000 | 0.000 |
| | Roy's Largest Root | 199.682 | 1763.860 b | 6.000 | 53.000 | 0.000 |
| Groups | Pillai's Trace | 0.769 | 29.477 b | 6.000 | 53.000 | 0.000 |
| | Wilks' Lambda | 0.231 | 29.477 b | 6.000 | 53.000 | 0.000 |
| | Hotelling's Trace | 3.337 | 29.477 b | 6.000 | 53.000 | 0.000 |
| | Roy's Largest Root | 3.337 | 29.477 b | 6.000 | 53.000 | 0.000 |

a. Design: intercept + the experimental group and the control group; b. exact statistic.

**Table 2.** Post-test comparison of students' learning outcomes.

| Source | Dependent Variable | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Group | Reading | 212.817 | 1 | 212.817 | 146.887 | 0.000 |
| | Role Play | 43.350 | 1 | 43.350 | 60.392 | 0.000 |
| | Translation | 64.067 | 1 | 64.067 | 98.130 | 0.000 |
| | Vocabulary and Grammar | 114.817 | 1 | 114.817 | 88.989 | 0.000 |
| | Reading Comprehension | 129.067 | 1 | 129.067 | 57.290 | 0.000 |
| | Writing | 166.667 | 1 | 166.667 | 133.641 | 0.000 |
| | Overall Results | 4116.817 | 1 | 4116.817 | 150.612 | 0.000 |

### *5.2. Results of Questionnaires and Interviews*

The questionnaires and interviews revealed that most of the students were satisfied with the application of a smart education model enabled by the Edu-Metaverse in English learning. In relation to the teaching environment, 88% of the students stated that their interactions with the technological infrastructure; smart learning platforms, such as the FIF oral training system and www.pigai.org; and the course contents had definitely influenced their learning behavior. They also reported that smart learning platforms were very useful in providing access to instructional materials and enhancing their engagement in the activities. They also agreed that DingTalk and a network college English course platform allowed them to better communicate with other peers. With regard to the multimodal materials, 86% of the students admitted that multimodal course materials had played a vital role in enhancing their motivation. With video lessons accessed at home, they had more freedom to customize when and where to learn. In the VR course, they were immersed in the learning context, and thus they could construct their knowledge with this experience. With collaborative file sharing in DingTalk, they also appreciated co-authoring and editing features of some multimodal resources. As to the whole teaching process and its assessment, 90% of the students supported the monthly smart class because they had more opportunities to immerse themselves in learning English and engage in high-order thinking projects. In addition, their social interaction and collaboration with their teacher and peers through technology-based communication tools had positively influenced their learning outcomes, as each learning group functioned as a community with common goals and with a sense of identity and belonging in the process of cooperation, rather than as a temporary place for finishing a certain task. In total, 90% of the students argued that AI-based assessment did provide them with the following: constant feedback, the support they needed, a way to identify their learning difficulties, and the progress they were making towards their learning goals. However, 10% of the students mentioned that sometimes the intelligent scoring was not accurate. For example, you could not obtain a high mark in FIF oral training platform because of your accent; www.pigai.org could not discern whether or not the essay was off-topic or not; and the comments on the article focused more on grammatical errors and less on content and essay structure. With respect to learning satisfaction, 92% of the students believed that their involvement and attention had been improved, especially in speaking skills, writing skills, and reading ability. Writing skills were improved, which was closely related to the machine's adaptive recommendations, automatic review, and extended prompts. Reading ability was also increased, which was attributed to the immersive virtual-scenario design, in which students were more engaged through the process of practice–innovation–internalization. Students also highlighted that this research model helped them to further master how to better use the smart learning platforms or APPs to learn English and that the virtual teachers on the platform could give them timely feedback on some regular learning issues. Ninety-two percent of the students appreciated that the teacher issued tasks tiered by everyone's English ability and pushed personalized learning resources to make learning less stressful. This finding demonstrated consistency with the data from the previous exam. Out of all the students, only 3% could not adapt to the new model and preferred to have in-person lectures, rather than sit through a monotonous online presentation, in which their attention would wander to texting or snacking, for example.

## 6. Discussion

### *6.1. Improve the Design of Teaching Scenarios and Pave the Way for New Knowledge*

Echoing the central role of the Edu-Metaverse in education, the extensive utilization of augmented reality and virtual reality in teaching–learning practices has proved to be effective [39]. Augmented reality and virtual reality, two types of the Edu-Metaverse, open up a vast realm of possibilities for developing educational scenarios that are highly realistic, overcoming the spatial and physical limitations of teaching and learning, and requiring continuous practice and experience, which enables teachers and students to realize knowledge construction, situational cognition, and knowledge internalization and transfer in immersive and interactive activities. However, there is still much room for improvement in the current development of educational scenarios. On the one hand, it is limited by the immature, underlying supporting technology [40] and the relatively high implementation cost of the Edu-Metaverse, which is still in its infancy in many aspects [5,41]. For example, low levels of interaction between humans and computers stymie its future progress, virtual reality integration is less than authentic, multichannel natural interaction can often only achieve one or two sensory channels, and VR/AR hardware devices are inconvenient to carry [42]. On the other hand, the absence of front-line teaching staff and curriculum designer participation makes it impossible for information technology companies to integrate knowledge contexts and virtual contexts to design meaningful teaching scenarios that meet the teaching needs of students [43]. This study advocates for the re-innovation of the teaching scenarios according to the teaching content, and for the launch of teaching resources that are customized for multimodal, sensory aggregation. For example, teachers can make use of the knowledge graph to construct the curriculum knowledge system at a deep level. As to the knowledge that can be realized in the real teaching environment, teachers can share it using lectures, PPTs, videos, and other multidimensional displays; however, for practical knowledge that cannot be realized in the real environment, knowledge acquisition can be accelerated through virtualization, which develops immersive and vivid teaching scenarios and which transcends time and space.

However, when designing the teaching scenarios, teachers should attach great importance to the creative consciousness according to the immersive, interactive, gamification, and personalized characteristics inherent in the Edu-Metaverse, as these help in flexibly affecting students' learning, helping teachers to achieve a profound understanding of the teaching content, teaching methods, and information technology. This enables human–machine collaborative teaching to be more accurate, more intelligent, and, ultimately, more able to develop advanced thinking in learners.

### *6.2. Focus on Learning Assessment, Based on Core Competency, from the Perspective of the Edu-Metaverse*

In relation to the most influential components of a smart education model in the Edu-Metaverse, the highest satisfaction was found to center on learning assessment, including formative assessment and AI-based assessment. This finding demonstrates coherence with the findings of previous research, which suggests that learning assessment plays an important role in teaching–learning practices [44,45]. Traditional teaching is knowledge-oriented, and knowledge only changes physically in this process. Therefore, traditional score-oriented assessment only focuses on students' evaluation and ignores the education of students [45]. The core of a smart education model is to cultivate talents with good value orientation, solid thinking skills, and strong initiatives. In other words, smart teaching should revolve around the development of core competencies, transforming knowledge into competency, and turning knowledge into the key literacy and ethics, which are essential for students [32]. The advantage of the "perception, connection, computing, and disposal" of intelligent technology in the Edu-Metaverse [45] is that it provides convenient support in evaluating students' core literacy. For example, 5G and IoT technology enable the perception of the whole teaching process in real time, no matter where the learning happens—on campus or off campus, online learning or offline learning—and no matter what type of learning is taking place—formal learning or informal learning—so as to ensure the comprehensiveness and objectivity of the data. As the authors of [46] believed, comprehensive data collection is the only way to accurately describe and analyze the learning situation of students. With the increasing use of intelligent technology in teaching, teaching is more inclined to multichannel, multitask, and multisymbolic modalities of experiential communication activities. In this process, learners' action thinking, graphic thinking, and symbolic thinking are all stimulated, and the multimodal data generated in the process are all meaningful. For example, audio, video, pictures, text, learners' psychology (facial expressions and gaze duration), learners' physiology (learner's own learning interest), and basic information (such as learner gender, learning motivation, style, and goals) are all related to the development of learners' core literacy. As a result, the computing technology in the Edu-Metaverse ensures that these multimodal data are quantifiable and that the evaluation is scientific and efficient. The Edu-Metaverse enables visual presentation technology, which can craft a digital profile of learners. As a personalized learning evaluation feedback tool, it not only serves the assessment function but, more importantly, also presents the essence of improvement in educating people. Therefore, in a smart education model, we should be oriented to enhancing the core literacy of the students when assessing the learning process of learners.

### *6.3. Enhance and Improve Teachers' Knowledge Architecture in the Edu-Metaverse*

Regarding the whole process of a smart education model in the Edu-Metaverse, we discovered that teachers must see a process of dynamic development in knowledge acquisition [47]. Furthermore, they must be able to create a teaching environment that integrates virtual and reality, customizes multimodal teaching resources, carries out learning assessments, and adapts to human–machine collaborative teaching in the Edu-Metaverse [48], all of which contribute to students' learning satisfaction. Information technology companies do provide smart platforms, technological tools, and multimodal teaching resources, however, it is the teacher who plays the key role in solving the problem of how to implement the teaching process collaboratively and creatively. Teachers are expected to know how to choose the most suitable smart education tools, according to the specific teaching content and teaching activities, and how to provide diversified learning support in the restructured teaching space, while being able to create an immersive teaching scenario that satisfies the need of teaching and learning. As an irreplaceable teaching designer, teachers should know how to edit, create, and integrate teaching resources, and how to use reasonable teaching resources to guide learners' independent inquiry learning and cooperative learning before class. This will help them to develop concepts and constructive acquisition through multiple and immersive interactions during class and to internalize knowledge through reflection after class. The whole teaching process is inseparable from teachers' data literacy, which is one of the essential qualities of teachers in the Edu-Metaverse. Data literacy helps a teacher to perform better teaching design, reflection, research, and all-around evaluation of students [49]. According to Rogers' concept of "free learning", one can achieve twice the learning result with half the effort through self-driven learning and fully emotional dedication to immersive and free exploratory learning. Therefore, meaningful learning can be better promoted only when teachers become the companions of learners in the learning process, experience the challenges together with the learners, and solve the problems together with them. In conclusion, in a smart education model enabled by the Edu-Metaverse, teachers must improve their own knowledge structure and strive to become the builders of an ecological teaching environment, the practitioners of multimodal smart pedagogy, the analysts of multimodal learning data, and the empathizers and companions of students' learning. In other words, the teacher is no longer just a teacher as a craftsman, but also a thinking designer, a data analyst, a learning facilitator, and an educator of the students.

## 7. Conclusions

The results of the current research offer empirical evidence and confirm that a smart education model, which is empowered by the Edu-Metaverse, significantly enhances better learning outcomes for students, when compared to the traditional education methods. The ecological teaching environment, multimodal course resources, and smart pedagogy, in the context of the Edu-Metaverse, all contribute to the improvement of students' learning outcomes on the one hand, while on the other hand, they help to expand students' active participation in learning and to cultivate an intelligent individual with a better value orientation. In this regard, it is essential to apply this research model to different types of education, such as vocational education, open education, and general education, so that the cultivation of students' wisdom can be realized at all educational levels. Moreover, governing bodies should organize workshops to cultivate awareness among instructional designers or instructors regarding properly understanding the Edu-Metaverse's technical characteristics, designing teaching scenarios, and avoiding potential legal and regulatory issues concerning the Edu-Metaverse—such as the misuse of students' data—so that they can make the best use of the metaverse for education.

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## Appendix A

**Questionnaire**

1. Teaching environment (4 items)

(1) In the process of English learning, you have completely mastered the use of www.pigai.org, FIF oral training platform, Ding-Talk, and Tencent meeting.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(2) In English language learning, you think these smart platforms can promote my engagement in learning.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(3) These intelligent platforms allow you to better communicate with your peers during the English learning process.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(4) You think the repetitive practice features of these smart platforms help improve speaking and writing skills.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

2. Multimodal materials (4 items)

(1) You think the multimodal teaching resources provided by your teacher help you learn English.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(2) You find multimodal teaching resources very convenient to learn anytime and anywhere.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(3) You really like the immersive experiences derived from some of the multimodal resources.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(4) You really like the co-authoring and editing features of some multimodal resources.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

3. Teaching process and assessment (4 items)

(1) You think the monthly smart classroom can immerse you in the exciting world of VR for learning an English lesson.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(2) You think the model can better facilitate your own communication with other peers, teachers, and experts from different geographical areas.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(3) You think the whole teaching process of the model contributes to the improvement of self-learning skills and the development of higher-order thinking.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(4) You think collaborative human–computer course assessments (e.g., intelligent feedback on speaking, intelligent revision of writing) help improve learning.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

4. Learning satisfaction (6 items)

(1) You believe that the model has facilitated your listening and speaking skills.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(2) You believe that the model has promoted your own reading and writing skills.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(3) You are very satisfied with the push of personalized resources in this model according to your proficiency in English.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(4) You are very satisfied with the real-time Q&A with the virtual teacher in this model.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(5) Since taking this course, you are used to using the English Smart Learning System and other apps.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

(6) You are very satisfied with the teaching model.

1. strongly disagree 2. disagree 3. neutral 4. agree 5. strongly agree

If you have any other comments or suggestions about English teaching, please write them below: [fill in the blank]

______________________________.

**Interviews**

The interviews involved the gathering of information about the students' subjective attitudes towards a smart education model in the Edu-Metaverse and the problems they encountered during their studies.

1. Which part of the smart education model enabled by the Edu-Metaverse are you most satisfied with (teaching environment, multimodal teaching resources, teaching method, or assessment)? Why?
2. Where do you think the model needs improvement?
3. What is the biggest problem you encountered in the learning process?

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