

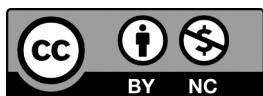
Exploration of Online Classroom Teaching via 3D Modeling

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Abstract: Online classrooms represent the kernel development of online education, which is realized along with the acceleration of digitalization process. The three-dimensional (3D) modeling techniques for online classroom teaching modes are explored in this paper, where the core idea is to create a simulated classroom via 3D animated student models, followed by achieving dynamic interaction between teachers and students so as to deduce scene-related knowledge. While integrating interactivity of conventional classrooms with the spatio-temporal advantages of remote education, a highly realistic virtual teaching environment is established by this style, which not only empowers online teaching but also promotes online transformation of education during the pandemic, facilitates the reform of education, and provides new pathways for prospective diversified development.

Keywords: Online classroom; 3D Modeling; Remote education; 3D animated student models



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1 Introduction

By means of three-dimensional (3D) drawing software, 3D Modeling schemes aim to build up 3D data space and shape spatial models with 3D data (Zheng, 2020). The 3D Modeling-related online classroom teaching calls for integrating 3D animation technology on the foundations of their animation models generated by this technique, where the simulated space of the 3D classroom is established to recreate the tutorial scenes of conventional classrooms. Meanwhile, refreshed forms of online classroom teaching should be well-constructed, while new types of remote education systems need to be shaped to create a harmonic atmosphere of an online classroom with identical dimensions in different locations for both teachers and students.

In accordance with digital simulation of conventional in-class tutorial scenes, a 3D online classroom may integrate relevant techniques such as databases, “Internet Plus”, 3D Modeling, and big data analysis (Ma & Tian, 2020). This

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approach covers major systems of classroom simulation, knowledge database and an enjoyable learning classroom on the foundations of continuously improving the architecture of online teaching, for the purpose of implementing remote online education and providing authentic, convenient and highly efficient support on teaching services.

1.1 Research Background of Online Education

Online education refers to the styles of teaching that deliver knowledge which may cross over time and space via the internet technology, which is also known as remote education or distance education (Ma & Tian, 2020). Such ideas are not conceptually innovative since traditional teaching models are constantly generating revolutions with the advancement of science and technology. As an auxiliary scheme of education, online teaching has been incorporated into classical teaching systems at various levels of schools, which include universities, colleges, middle schools and elementary schools in domestic education systems. With the policy guidance of “Modern Remote Education Engineering”, interactions and integrations are constantly appearing with current online and offline teaching systems.

In the year 2020, the COVID-19 pandemic was spreading on a global scale. Traditional teaching activities were facing up to severe challenging issues in a variety of scenarios. Online tutorials quickly became the core style of teaching in the pandemic period in response to the call of “ensuring teaching and learning undisrupted when classes are disrupted”, launched by the Chinese Ministry of Education. For a while, many types of software for online teaching sprang up like bamboo shoots after rain. As featured with multiple functions as well as profound and flexible content, such software may support large-scale online educational practice and promote the development of the teaching industry. Meanwhile, conventional styles of teaching were surviving unprecedented impacts. Later, regular teaching activities gradually recovered at a pace with regular epidemic prevention and control. The current educational domain demands solutions for a crucial project, which lies in how to promote the deep fusion of online education and conventional education modes. This action not only involves upgrades on teaching efficiency, but also reshapes the ecological layout for future education. Hence, the research topics in multiple dimensions have continuously come out in the past few years.

1.2 Driving Reasons for Online Education

The internal and external factors in developing online education can be summarized into four aspects, which are presented as follows (Shao & Hu, 2020).

(1) Objective foundations: technical support of iterating fundamental network constructions and hardware popularizations.

The essence of exponential growth in online education is the outcome of qualitative alterations from technical accumulations. Observed from modern network evolution, the second-generation (2G) was only capable of loading audio communication and text transmission, 3G had upgraded the speed of the network to the level of Megabits, while insufficient stability of signals was restricting multimedia teaching. The present 4G networks have already achieved 98% coverage of administrative villages with peak download rates as high as 100 Mbps, as a result, solid foundations are established for high-definition video broadcasting and real-time interactive curricula. Besides, the upcoming 5G network to be fully commercialized will further promote applicable scenes such as virtual reality (VR)-based immersive classrooms and holographic projection teaching, which will overwhelmingly reconstruct the border of spatial-temporal education.

Meanwhile, in the aspect of hardware, the popularization of smartphones and panel laptops has eliminated the terminal barriers — sales of tablets soared by 120% year-on-year during the pandemic period. As displayed in the data of some commercial business platform, 65% of the parents purchased tablets for online learning for their kids. Domestic penetration rate of hardware devices has leapt from 38% in 2019 to 71% in 2022, establishing a “one device per learner” educational foundation.

(2) Subjective drive: resonance between the concept of lifelong learning and the educational demands of the new generation.

In the landscape of worldwide competitions, the anxiety of individuals to improve their abilities has inspired expectations for continuous learning. In accordance with the White Paper on Lifelong Learning in China, in the year 2022, the average annual learning investment of the workplace population has reached 5800 yuan, while over 72% of those persons are under 35 years old; “fragmented learning” and “cross-border charging” have become the trends of mainstream. Generation Z students view online education as “necessity of survival” — one survey shows that during the period of epidemic prevention and control, daily use of educational Apps by middle school students had been 2.3 hours a day on average, where their paces of learning were sustained through “check-in communities for learning” and “integration of cross platform resources”. Such kind of inertia on autonomous learning is not only originated from the active response to the “internal competition” environment, but also forced by the acceleration of knowledge updates in the current era. When offline classrooms were suspended, online education may become the primary educational solution for young parents born in the 1990s due to the reusability of resources and flexibility of learning.

(3) Policy engine: regulation guarantee from top-level design to ground-floor execution.

The policy layout of educational informatization in our nation is featured with distinct progression. By the end of the 20th century, the strategy of “rejuvenating the nation through science and education” included the digitalization of education in national planning for the first time. In 2015, the “Opinions on the Construction of Online Open Courses in Universities” were issued, which clearly required the completion of 3000 national-level high-quality massive open online courses (MOOCs) within three years, directly promoting the growth of MOOC platforms from 12 to 110. In 2016, the government of China released the “13th Five-Year Plan for Education Informatization”, which innovatively proposed the “Online to Offline (O2O) Integration” model, requiring more than 80% of universities to carry out reform of blended learning. During the period of epidemic prevention and control, responses to these policies exhibited the characteristics of “national coordination plus local innovation”: the Ministry of Education organized 22 platforms to open 24,000 courses, covering 12 major subjects in undergraduate and college disciplines. Leadership in implementing the “March Online Teaching” model was taken by Guangdong Province, which synchronously supports the digital resource platform entitled “Xiangyun of Guangdong Education”, where the average daily visits exceed 50 million. The combinative fists of “emergency policies plus long-term mechanisms” have nourished the transformation of online education, upgrading from supplementary measures to standard configurations.

(4) Deep kinetic energy: potential development resilience, and national confidence supported by the comprehensive national strength.

The explosive development of online education essentially embodies a concentrated reflection of national strength in technology and governmental capabilities. In contrast to the epidemic education response in 190 nations around the world, China has achieved 99.5% coverage of online learning for students by the advantage of digital infrastructure with 5.42 million 4G base stations (accounting for 60% of the world) and 1.4 billion mobile Internet users. However, in most

developing countries, the poor network coverage rate of less than 30% results in stagnation of teaching. Behind this gap, the economic confidence formed by China's GDP ranking second in the world for 10 consecutive years was reflected, as well as the clustering breakthroughs of technologies such as 5G, cloud computing, and big data under the strategy of "new infrastructure". As pointed out by a report from an academic research institution, "The prosperity of online education during the epidemic is not only a satisfaction of knowledge demands, but also a group choice from a nation to extend the inheritance of civilization through technology in crisis." This educational innovation on the foundations of national strength, is devoted to promoting the vigorous growth of learning methods and continuously achieving a historic leap from "dependence on physical classrooms" to "native digital learning".

1.3 Development Status of Online Education

With technological innovation and social evolution, many emerging technologies have gradually penetrated into various aspects of modern education, giving rise to innovative concepts, i.e., distance education, digital classrooms, virtual classrooms, and smart classrooms, to name a few. The online education systems are featured with distinct advantages and limitations in diverse teaching modes due to their cross-regional, convenient, and low-cost features. Online classroom teaching may integrate high-quality educational resources and overcome geographical limitations because of its ability to break through time and space barriers, which plays a crucial role in ensuring education for students.

From a global perspective, conventional education styles suffered from a lot of tensions worldwide when the COVID-19 epidemic was spreading. As reported by a survey from UNESCO, about 200 countries in the world have been forced to suspend traditional on-campus teaching. Developed countries such as the United States, the United Kingdom (UK), and Japan have continued to conduct remote teaching through diverse ways of online teaching. Taking the UK as an example. The Ministry of Education attaches great importance to teaching security during the epidemic period, and has standardized the online education system through a series of policies and multiple measures. To ensure educational equity, online education resources are open to all schools, while education platforms such as Oak National College and online learning Apps are advocated. Given the abundant online resources in the UK and the lack of a designated platform, most schools have picked appropriate online resources and familiar teaching modes to the requirements of teachers and students to ensure efficiency in knowledge acquisition. Besides, some schools provide learning materials and assignments to students via express delivery, while students submit feedback through text messages or emails to help teachers dynamically adjust their teaching plans.

However, in some developing countries, due to unfavorable factors such as equipment shortage and lack of funds, it is difficult to implement online education for the majority of students, and the activities of teaching have basically stagnated. In China, online education remains in the early stages of development. Under the background of the COVID-19 epidemic, Internet enterprises have accelerated the deployment of online education, while the participation of teachers and students in online teaching also exhibits significant improvements. Internet education is regarded as an important trend in future education development, which shows a certain impact on traditional educational institutions. For teachers and students, online education is both an exploration of new teaching models and an adaptive challenge—some groups quickly integrate into this transformation of education, while others still require some time to adapt to the transition of teaching scenarios from offline to online. It is clear that the deep fusion of online education and the modern education system still calls for long-term promotion.

Most notably, online schools and online teachers in the field of postgraduate entrance examination in China have become important communication forces in a variety of styles towards online education, relying on the promotion of both assessment and certification systems. In this context, 3D Modeling technology-related online classrooms have been progressively complementing traditional teaching methods, promoting the iterative upgrading and improvement of the education system in China by building an innovative educational ecosystem through integrating both virtual and real elements.

2 Analysis of the Necessity of 3D Modeling in Online Classrooms

Traditional classroom teaching depends on fixed campus locations as well as utilizing blackboard writing and paper textbooks to achieve face-to-face knowledge interaction among teachers and students. This teaching mode creates an immersive atmosphere through collective learning scenes in physical spaces, which facilitates the stimulation of interests from students in knowledge exploration, and enables them to master the content in an efficient manner through intuitive knowledge transmission. Teachers can also monitor the learning status of students via real-time observation of their classroom reactions, calibrate deviations in knowledge understanding or problematic issues on learning behavior on the spot; meanwhile, teaching strategies and progress are dynamically adjusted in accordance with feedback from students.

However, traditional teaching is vulnerably constrained by inherent educational thinking and overly relies on repetitive knowledge transmission, which may lead to the solidification of fixed patterns of thinking, and to some extent, restrict the innovative thinking development and knowledge expansion abilities of students (Shao & Hu, 2020). Especially during the pandemic, this teaching model that relies on offline gatherings has been forced to stagnate. On the other hand, the online classroom teaching promoted by the epidemic, has realized the connection of long-distance teaching in different places through Internet technology, hence, the education process may continue in public health emergencies — teachers and students keep on carrying out teaching activities with the help of multiple teaching software and education platforms; Students are even capable of consolidating their knowledge after class through massive online educational resources, which deepen their understanding and expansion of knowledge through multi-dimensional comparative learning, and thereby stimulate their interest in self-oriented learning.

Currently, the online teaching model also has quite a few drawbacks (Qi, 2020). For instance, many types of software came out with uneven functionality, most platforms appear with problems such as a single interaction mode and insufficient scene simulation, making it difficult to build an immersive classroom atmosphere. In addition, after the COVID-19 epidemic, traditional regulations of teaching have been gradually recovering, and online education is once again facing the dilemma of slow development due to factors such as inertia in use and imperfect evaluation systems. The keynote topic in contemporary education reform lies in how to scientifically allocate the proportion of offline and online teaching, and fully leverage their complementary advantages. The exploration of online classroom teaching on the basis of 3D Modeling technology represents an innovative practice in response to this trend.

3 Systematic Design of Online Classroom via 3D Modeling

The configuration of online classrooms via 3D Modeling is comprised of three core modules (Li et al., 2021):

classroom simulation, knowledge service and intriguing learning system. A brief introduction to these modules is presented below (Li et al., 2021).

3.1 Classroom Simulation Settings

As the platform for main control, the classroom simulation system consists of two parts: a 3D animated student model and a simulated animation classroom. The 3D animation student model generates a 1:1 mapping with intrinsic features of students via multimodal data collection. This model integrates the teaching interaction layer and information visualization layer to achieve the following functions: the interaction layer supports simulations on standardized teaching behavior such as attendance in class, real-time questions and answers as well as their online status display, while the visualization layer adopts a management mode of dual permission, for instance, information on individual privacy (which includes name, age, academic data, family contact information, etc.) can be proceeded via blockchain encryption technology and mutually verified with the official system, which is only accessible to oneself, his or her guardian, and the teachers for credit granting. Regarding information on teaching data (including analytical reports on homework, curves of subject performance, and accumulation trajectories for credits, etc.), the mechanism of hierarchical sharing should be established such that teachers and classmates are capable of obtaining it through secure authentication.

Meanwhile, these main functions of simulating an animation classroom and constructing a dual-perspective immersive space are presented as follows: the elements of the physical classroom environment should be fully replicated on the student terminal and equipped with devices for interactive teaching. The blackboard area integrates an intelligent live streaming entrance, supporting seamless redirection to live streams of teachers. The teacher terminal is equipped with a multi-dimensional data dashboard, which integrates real-time dynamic information such as the status of students' attendance, classroom participation, and feedback on quizzes. Accurate teaching decisions can be assisted through an engine for data visualization.

3.2 Knowledge Service System

As a knowledge service system recognized as the center of teaching assistance, a 3D knowledge graph engine has been constructed. It may systematically integrate the subject of Ontology library with real-time updated educational big data, providing a three-level service on knowledge retrieval: the basic layer supports keyword level literature retrieval, the advanced layer achieves interdisciplinary concept association analysis, and the intelligent layer uses technology of natural language processing (NLP) to analyze semantic meaning of questions from students and automatically generate visual knowledge context maps. A specially developed augmented reality (AR) assisted parsing module can convert complex formulas into 3D dynamic demonstrations. Mechanical principles courses also adopt physics engines to conduct virtual disassembly experiments. The system is equipped with an intelligent guidance module to provide recommendations on personalized learning paths in accordance with the cognitive maps of students, which is integrated with massive open online courses (MOOC) platforms to achieve precise delivery of high-quality course resources.

3.3 Intriguing Learning System

The intriguing learning system has created a gamified learning system, where its kernel music learning engine consists of three modules: the knowledge arena supports real-time matching of battles on subject knowledge, using the Elo rating system to ensure fairness in competition. The virtual laboratory transforms courses such as chemistry

experiments and geometric Modeling into sandbox games and simulates physical rules by a Unity engine. The design of the achievement system consists of growth incentive systems such as learning milestones and disciplinary medals.

Most notably, the introduction of an artificial intelligence (AI) storyline editor in the system allows teachers to customize their scripts on teaching and integrate boring concepts of grammar into storylines of an escape prison game, while historical events are reconstructed into games of strategic management. The built-in module on emotional recognition of learning in the system dynamically adjusts the difficulty level of games and a flexible reward mechanism through facial expression analysis and operational behavior data, ensuring a deep balance between entertainment and education. This system consists of two auxiliary systems and a platform of main control, which achieve data connectivity through a microservice architecture: the retrieval records of knowledge service system, the intelligent Question and Answer (Q&A) module which optimizes 3D models, the challenging data from the gamified learning system, and some feeding back analysis of weak points in the knowledge graph, and hence, a complete educational cycle of “teaching-evaluation-reinforcement” is ultimately structured.

4 System Implementation of Online Classroom via 3D Modeling

The key point of implementing an online classroom via 3D Modeling lies in the 3D student animation model (Deng, 2020) in the classroom simulation system and the construction of a simulated animation classroom. Its core technical implementation can be decomposed into the modular solutions as below (Deng, 2020).

4.1 Construction of 3D Character Animation System

In the process of character modeling, the strategy layered production is adopted as follows: the fundamental topology structure of the human body can be constructed through mainstream 3D Modeling tools, and then imported into high-precision carving software for optimization at the pore level. In the stage of production, Photoshop is jointly used for texture mapping, BodyPaint 3D is adopted for 3D material projection so as to construct a digitalized student model with realistic physical properties.

4.2 Development of Virtual Classroom Scenes

The spatial architecture performs implementation of a transformative mechanism from 2D to 3D as follows: Firstly, a planar layout of the classroom is generated with respect to Computer-Aided Design (CAD) drawings, and detection algorithms are applied using node topology to verify spatial rationality. The 3D framework is created via further parameterized Modeling. In the stage of scene refinement, physical attributes are assigned to elements such as tables, chairs, and teaching aids through the Physically-Based Rendering (PBR) material system. Finally, the scheme of global lighting rendering is exploited to achieve environmental light and shadow fusion as well as color correction.

4.3 Integration of Real-time Interactive System

Implementation of online teaching function is known in the following scenarios: in the module of live streaming, low latency audio and video transmission is ensured via dependence on Web Real-Time Communication (WebRTC) streaming media transmission protocol and distribution network combined with content delivery network (CDN). In

the interactive function, as constructed on the cloud service architecture of “Internet Plus”, the status synchronization between teachers and students is realized through a full-duplex communication protocol by WebSocket.

4.4 Intelligent Knowledge Management System

The mechanism of information retrieval should inherit an architecture on hierarchical processing described as below: the search engine receives natural language queries at the front-end, after NLP segmentation and semantic conversion of vectors, inverted index retrieval is executed in the Elasticsearch cluster, while the returned results are sorted and optimized using the Term Frequency-Inverse Document Frequency (TF-IDF) algorithm. A hybrid architecture of MySQL and MongoDB is adopted by the underlying database to achieve joint storage and management of structured data and unstructured content.

4.5 Engine of Educational Gamification

Development of an interactive teaching module is proposed as follows: WeiXin Markup Language (WXML) is utilized for declarative page layout on the basis of WeChat Mini Program technology stack to implement responsive style control through WeiXin Style Sheets (WXSS), process game logic and animation state machine with JavaScript, then achieve interactive knowledge Question and Answer scenes in combination with the engine of Canvas drawing.

In a nutshell, the proposed system may achieve full technological coverage from 3D production to online education functions through designing a modular architecture. While maintaining the completeness of that professional toolchain, a digitalized plan for teaching solutions is built up to meet the requirements of educational scenarios.

5 Conclusions

To sum up, the online classroom as constructed via 3D Modeling technology represents not only a major breakthrough in the field of educational technology but also a profound reformation in educational philosophy and teaching styles. This innovative educational practice shows dependency on advanced computer graphics processing capabilities, integration of virtual reality (VR) and augmented reality (AR) technologies, which thoroughly breaks limitations of traditional face-to-face teaching in physical space, as well as the weaknesses of conventional online education in immersion and interactivity, opening up a new path for the modernization and personalized development of education. In this mode, both teachers and students are no longer restricted by geographical separation, while engaging in real-time interaction in a highly simulated virtual environment instead.

Meanwhile, 3D Modeling technology enables unlimited expansion of teaching scenarios. All the abstract concepts can be transformed into intuitive and vivid visual experiences, from microscopic cellular structures to macroscopic cosmic galaxies, from restoration of historical relics to conception of future cities, which greatly enriches the level and depth of teaching content (Sun & Zhao, 2021). With the help of high-precision motion capture and real-time feedback systems, students may not only “see” and “touch” knowledge, but also deepen their understanding and mastery of knowledge via simulation tests, virtual operations and other methods, making the process of learning more active and efficient.

In addition, online classroom teaching via 3D Modeling also integrates techniques of artificial intelligence and big

data analysis, which intelligently adjust strategies of teaching and their difficulties with respect to learning behavior and effectiveness of students, achieving personalized teaching (Shang, 2020). The system is capable of offering real-time feedback on the learning status of students, helping their teachers accurately identify difficult points in their studies, adjust priorities of tutorials in a timely manner, and thereby structure an ecosystem of teaching with dynamic optimization and closed-loop feedback. This student-oriented teaching mode not only improves the efficiency of teaching but also shows promotion in the cultivation of critical thinking, innovation ability, and problem-solving ability towards students. In the long term, 3D online classrooms may represent not only a revolution in educational technology, but also a profound foresight for the prospective form of education. It prompts educators to re-examine the essence and purpose of education, then think about how to cultivate future citizens who have both solid knowledge foundations as well as innovative thinking and practical abilities in the seamless integration of virtual and reality (Zhao, 2020).

With the consistent progress on maturity of technology and deepening of its applications, 3D online classrooms will lead education into a more open, inclusive, and efficient new era, allowing high-quality educational resources to transcend geographical and economic boundaries, which may fairly benefit every learning soul with enthusiasm, truly achieve a deep fit between virtual teaching spaces and real educational needs, then open up a new chapter in educational equity and quality improvement (Wang et al., 2025).

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