Ma, J., Jin, Y, Zhao, D. & Chen, L. (2023). The Research on The Application of Educational Metaverse in Experimental Teaching of Medical Physiology. *International Journal of Technology in Teaching and Learning, 19(1*), 69-85.

The Research on The Application of Educational Metaverse in Experimental Teaching of Medical Physiology

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The arrival of the metaverse, as a new generation of information technology, will bring great changes to people's production, life, and learning. The educational metaverse is regarded as a new form of educational development, which will bring a transformative impact on educational teaching activities. In this context, this study has developed a general architecture of educational metaverse system, which includes the physical layer, software layer, data layer, and application layer, based on the technical, theoretical, and architectural support and its digital ecology of educational metaverse system construction. The study has tried to construct a physiology virtual experimental teaching system and taken the rabbit's exercise of respiration regulation experiment as an example to start the research on the educational metaverse in physiology experimental teaching. Participants of the study were 120 students from the 2019 clinical medicine class at School A. By analyzing the learning outcome of students in the virtual experiment course of the educational metaverse, it is concluded that educational metaverse can promote both teaching and learning in the process of experimental teaching; this research has explored the path for the new form of Internet education, which is of great significance for promoting the efficient construction of new education infrastructure and the innovative development of education modernization.

Keywords: educational metaverse, experimental teaching, application effect, medical physiology

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DOI: https://doi.org/10.37120/ijttl.2023.19.1.04

INTRODUCTION

The metaverse is defined as a multi-dimensional virtual network space composed of virtual reality, artificial intelligence, big data, cloud computing, blockchain, and other digital information technologies, which is parallel to the objective physical world. (Jeon et al., 2021; Lan et al., 2021). As a renaissance topic for 2021, the metaverse has shown long-term continuity and its related technologies are maturing for the foreseeable future (Lee et al., 2021). The combination of metaverse and education is called the "Educational Metaverse", which will bring new educational thinking, solve previously unsolvable problems, and provide new possibilities for the transformation of educational concepts and modes (Mascitti et al., 2011; Reyes, 2020; Qian et al., 2022). During this period, we are supposed to take advantage of the role of the metaverse in the teaching system to improve the learning environment, optimize the teaching process, enhance the on-site effect, and cultivate innovative talents. (Schroeder, 2022; Hu &Yu, 2022).

The metaverse has great potential to revolutionize human education and has a wide range of applications in healthcare and medical education (Wiederhold, 2022). The physiology laboratory course is a compulsory course for clinical medicine majors. It has contributed to students' understanding of abstract concepts, promoted students' interest in professional learning, and laid a solid foundation for other courses (Dohn et al., 2016; Griff, 2016). However, there were still some unavoidable problems in the process of physiology experimental teaching. Physiology laboratory has been difficult to construct the entire knowledge structure system alone, and it was likely to ignore the theory and practice, abstract and figurative, microscopic and macroscopic, the whole and the local intrinsic logical relationships (Varty, 2016). For example, the teacher in the theoretical class could not show the experimental content to the students in three-dimensional form, which led to the difficulty for some students to establish a complete experimental cognitive model (Helyer & Dickens, 2016). Therefore, we should focus on the application of educational metaverse in the experimental teaching of medical physiology.

At present, the metaverse is still in the early stage of conceptual clarification and framework construction, and studies on the construction of the educational metaverse and its teaching applications were relatively limited (Inceoglu & Ciloglugil, 2022). Based on the fundamental characteristics and development status of the educational metaverse at the present stage, this study aims to construct an educational metaverse system and take the rabbit exercise respiratory regulation experiment as an example to analyze the application effect of educational metaverse system in physiology experimental teaching. The research will enhance the quality of medical experiment teaching from the aspects of improving teaching methods, changing teaching modes, and increasing the content of virtual simulation experiment teaching.

LITERATURE REVIEW

To better construct a primary educational metaverse system and design a virtual experimental teaching system, this study has reviewed the exploration and application of educational metaverse and the current status of physiology experimental teaching.

THE EXPLORATION AND APPLICATION OF THE METAVERSE IN EDUCATION

Metaverse is a technology that transforming the world in a variety of ways, ranging from economics, engineering, and education (Akour et al., 2022). With the basis of the ecological composition and future development trend of the Metaverse, this study intends to explore the application of the Educational Metaverse from three aspects, including teaching, scientific research, and practical training.

In terms of teaching, as a three-dimensional virtual cyberspace parallel to the objective physical world, the significant advantages of the metaverse in combination with teaching and learning include: first, it has satisfied the sense of immersion and obtainment for teachers and students. The virtual and real worlds of the educational metaverse is updated in real-time, making it a highly simulated and perceptible teaching place (Nevelsteen, 2018). Zhang (2020/2021) revealed that embedding Virtual Reality in the curriculum helped to improve self-expression and higher-order thinking skills. Through the brain-computer interface, students are allowed to enter the educational metaverse classroom to observe the functions of the human body, analyze the structure of chemical molecules, deduce the physical formulas, and so on. For example, allowing students to gain embodied knowledge of the universe from the perspective of an astronaut; Secondly, it has created an educational field in which the virtual and the real coexist. Interactivity enables communication and interaction between the incarnations of teachers and students at any time, and anywhere. For example, the University of Glasgow, UK, created a mock courtroom environment in the educational metaverse by combining legal knowledge with the metaverse (Maharg, 2007). Several South Korean universities adopted the educational metaverse model to carry out online teaching activities in a variety of scenarios such as entrance ceremonies, medical education, campus tours, graduation ceremonies, etc., which were highly effective (Hu &Yu, 2022).

In terms of scientific research, the creation of various virtual laboratories within the educational metaverse has furnished boundless virtual simulation opportunities for disciplinary studies. First, it saves the cost of research. Due to the limitations of equipment, space, funds, and other external conditions, many research projects cannot be promoted in time. Through the educational metaverse, researchers could do all kinds of scientific research experiments without leaving their homes, obtaining the same data as in real scientific research, and saving huge costs under the premise of guaranteeing scientific research results. For example, Siyaev and Jo (2021a) designed the educational metaverse scenario for Boeing 737 aircraft maintenance training. The library of Brandeis University in the United States used virtual reality, augmented reality, and other equipment so that learners outside the school could also experience the same feeling as the on-campus laboratory through virtual simulation (Brandeis University, 2021). Second, to avoid risk. In the process of carrying out scientific research, the reality of experimental operations brought a certain degree of risk, but in the educational metaverse laboratory which carries out virtual experimental research, high-risk scenarios can be simulated safely, and difficult training can be practiced repeatedly (Lee et al., 2022). For example, virtual radioactivity physics experiments could avoid accidental radioactive injuries to students' bodies due to improper handling. Thirdly, it has broken the limitation of time and space. Scientific research in the metaverse laboratory can break the time and space barriers, for some experiments need a few months or even a few years to complete, in the educational metaverse laboratory through the time of a class is able to show the experimental process panoramic to the students (Locurcio, 2022). For example, in reality, it took several months for students of agricultural colleges to observe the growth of crops, while in the virtual laboratory, the whole life cycle of crops was presented in one lesson.

In terms of practical training, according to the functional characteristics of the metaverse, we have established a virtual training base that meets the practical requirements of students. The educational metaverse creates an immersive and interactive experience in which students can perceive changes in the parameters of a virtual simulation system, thus gradually recognizing things, summarizing laws, and mastering skills (Leon, 2023). First, to improve the real training environment. Virtual environments simulated the operating room environment at different stages of surgery in dental education (Locurcio, 2022). Students could step into the virtual training base without leaving home, human anatomy, experimental simulation, and other operations, to prevent interference caused by other factors in the real environment, but also to avoid the unnecessary management risks caused by the students out of the practical training. Secondly, to improve the efficiency of practical training teaching. Teachers have set up according to the content of practical training in the corresponding scene and technical parameters, each student can be alone at the same time in the virtual scene repeatedly practiced, and constantly self-improved. When students were proficient in practical skills, they could directly enter the real scene to carry out the work, shorten the process from theory to practical application, and save a lot of humans, material, and financial costs (Locurcio, 2022). For example, in the virtual aircraft driving training system, students could achieve the goal of mastering driving skills through repeated training in various weather conditions. A medical training course held in South Korea illustrated the prospects of metaverse applications in the field of medicine, using lung cancer surgery as an example, which was important for improving students' knowledge and learning efficiency (Koo, 2021).

CURRENT SITUATION OF PHYSIOLOGY EXPERIMENT TEACHING

The predominant approach to teaching in physiology laboratories has historically centered around theoretical courses, supplemented by specific experiments aimed at facilitating students' comprehension and retention of theoretical knowledge. The primary objectives have been to enhance students' practical skills and establish a groundwork for advanced professional courses, such as surgery. In traditional physiology experimental teaching, observation of internal organs could only be carried out through models, while the nervous system, cardiovascular system, and lymphatic system could not be fully studied, and observed (Mayerhofer et al., 2021). In addition, due to the limited experimental space, and experimental resources, the number of experimental groups in a laboratory was numerous, which greatly increased the workload of the teaching staff, and it was difficult for the teachers to take care of each trainee in the experiments (Fitzgibbon&Wallis, 2014). The continuous application and maturity of metaverse technology in education, healthcare, and other industry scenarios could gradually solve teaching problems such as monotonous traditional teaching content, inability to mobilize students' motivation, and difficulty in evaluating the effectiveness of learning (Kye, 2021). Consequently, this study employs digital information technology to establish a virtual teaching environment within the educational metaverse, aiming to enhance the effectiveness of physiology experimental courses.

In the process of promoting the development of experimental teaching, different experts and scholars adopted diverse approaches to carry out certain exploration attempts. Bui and his colleagues used 3D visualization technology to assist medical education, and the teaching effect was significantly better than traditional slide presentations or plastic models (Bui et al., 2021). Another research introduced utilized virtual reality and augmented reality for routine cardiopulmonary resuscitation (CPR) training, which allowed trainees to learn a variety of CPR skills effectively (Lee et al., 2021). Liu and colleagues introduced information technology, and artificial intelligence technology into medical experimental training teaching, constructed a basic clinical integration experimental training curriculum system of "early clinical, multi-clinical, repeated clinical", and created an experimental training learning space that was highly integrated with information technology, intelligence, and medical education, which strengthened students' clinical thinking and clinical practical ability training(Liu et al., 2020). Zammit and his colleagues adopted augmented reality technology for anatomy teaching, it was found that AR technology could significantly help students understand key anatomical structures, which could improve the utilization of experimental specimens by developing personalized experimental teaching content (Zammit et al.,2022). The immersive and interactive nature of virtual environments has been utilized to reduce the anxiety and pain associated with traditional rehabilitation, enabling more personalized and effective treatment (Seron, 2021). Referencing VR, and AR technology, students could simulate surgeries, and identify anatomical structures during physical exams (Bhugaonkar, 2022).

Based on the inherent characteristics of the educational metaverse, this study has constructed a comprehensive architecture of the educational metaverse system, including the physical layer, software layer, data layer, and application layer. Determining appropriate remote experimental teaching methods for physiology is particularly challenging compared to other disciplines in human biology (Smit, 2019). Collaborating with the Henan Provincial Medical Virtual Reality Engineering Research Center, we have developed a primary educational metaverse virtual experimental teaching system. This initiative, using the rabbit exercise respiratory regulation experiment as an illustrative example, integrates metaverse experimental teaching into the course, which fully incorporates the latest associated technologies within the metaverse, and designs a virtual experimental teaching system including a theoretical teaching scene and practical operation scene. The purpose of this study is to construct a primary educational metaverse system and test the application effect of the system in physiology experimental teaching in order to improve students' learning outcomes.

THE CONSTRUCTION OF EDUCATIONAL METAVERSE SYSTEM

The educational metaverse has expanded the time and space of teaching and learning for real-world teachers, students, administrators, and other educational entities. At this stage, it is crucial to focus on clearly establishing the foundational structure of the educational metaverse. The educational metaverse construction includes technology support, theory support, and architecture support.

TECHNOLOGY SUPPORT OF THE CONSTRUCTION

The progress and development of technology have laid a solid foundation for the construction of the educational metaverse (Sweeney, 2019). This study summarizes the seven technical pillars supporting the metaverse by synthesizing the industry's various expositions and analyses of the metaverse technical system: ① Communication technology 5G. Virtual and real devices need to have a higher resolution and frame rate to provide users with a real sense of immersion. The innovation of metaverse application in the field of education cannot be separated from the support of 5G communication technology, which has the characteristics of low latency, low energy consumption, high speed, and large-scale device connection. ② Extended Reality (XR), including Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR). Among them, VR provides an immersive experience, and realizes the input and output of information in the metaverse through human vision, hearing, touch, and motion capture; AR superimposes a layer of virtual information on a realistic scene; MR enables partial retention and free switching between virtual and reality by projecting a light field to the retina. ③ Blockchain technology. Blockchain technology can effectively create a decentralized content creation model for the metaverse, such as a distributed clearing platform, and value transfer mechanism, which allows safeguards the attribution and flow of value, and realizes the stable operation of the metaverse economic system; it can also be used for the creation of a continuous, and serialized encrypted information complex with the unique identity of the learner to safeguard the security of the data. ④ Artificial Intelligence (AI) technology. AI technology refers to theories and techniques that enable machines to learn from experience and perform various tasks. The use of AI technology is ubiquitous in the metaverse, such as voice semantic recognition of avatars, AI recommendation of social relationships, and AI construction of various virtual scenes. ⑤ Digital twin technology. With the help of simulation, sensation, and a mirror world, digital twin technology connects physical reality, and virtual reality, the metaverse needs digital twin technology to create a high-fidelity mirror world. ⑥Computer vision technology. Computer vision plays a crucial role in processing, analyzing, and understanding digital images or videos, to make meaningful decisions and act. The use of XR devices for recognizing visual information about user activities, and their physical environments helps to build more reliable and accurate virtual, and augmented environments. ⑦Edge computing technology. Edge computing is a new computing model with cloud computing as its core, modern communication networks as its pathway, and massive smart terminals as its frontier, integrating cloud, network, end, and intelligence. Edge computing technology can provide a high-quality interactive experience for all devices, thus increasing people's experience in the metaverse, and escorting the computing power to support the metaverse.

THEORY SUPPORT OF THE CONSTRUCTION

While acknowledging the significance of technology, it is imperative to delve into the educational theory associated with the educational metaverse. Distributed cognition theory, flow theory, information processing theory, and embodied cognition theory was the theoretical foundation of the educational metaverse (Chuah et al., 1999; Csikszentmihalyi et al., 2004). Building upon this groundwork, Fang et al. (2022) introduced the theory of human-computer collaborative education. The theory of authentic learning environment and the theory of experiential learning had been proposed to play a theoretical orientation for the construction, and experience of learning environment in the educational metaverse (Herrington et al., 2014). In addition, the research results of behaviorism, cognitivism, constructivism, connectionism, and other learning theories should be widely absorbed to try to construct the theory system of embodied space innovation teaching in the educational metaverse (Banan et al., 2020; Liu et al., 2021). At present, the theoretical framework of the educational metaverse in China is weak, and research methods are scarce. Therefore, alongside the development of new infrastructures, there is a heightened need to advance the innovation of teaching theories and research methods, specifically tailored to Chinese characteristics, and construct a robust theoretical framework for the educational metaverse (Qian et al., 2022).

ARCHITECTURE SUPPORT OF THE CONSTRUCTION

Consensus on the architectural composition of the metaverse is yet to be achieved in both industrial and academic circles globally. Despite this, various levels of architectural support for constructing educational metaverse have been proposed. For instance, Lim et al. (2022) introduced a metaverse architecture consisting of two components: the first encompassing both virtual and physical realms, and the second being the metaverse engine; Duan et al (2021) formulated a metaverse framework by drawing two vertical circles and overlapping them into three layers, including infrastructure (bottom), interaction (middle), and virtual ecosystem (top); Smart et al (2008) pointed out the metaverse roadmap and categorized the metaverse into four types: augmented reality, lifelogging, mirror worlds, and virtual worlds; Radoff et al (2022) proposed a seven-layered metaverse architecture, including infrastructure, human-computer interaction, decentralization, spatial computation, creator economy, discovery, and experience layers; The researchers designed a three-end, six-layered architecture for the education metaverse that included technology end, application end, analysis end, and physical layer, software layer, rule layer, application layer, data layer, and analysis layer (Hua et al., 2022).

THE OVERALL ARCHITECTURE OF EDUCATIONAL METAVERSE SYSTEM

According to the existing research on the construction of the metaverse, this study summarizes that the digital ecology of the educational metaverse comprises four layers: the digital technology layer, system platform layer, hardware device layer, and scene application layer. The digital technology layer primarily offers technological support for system R&D, as well as hardware development, including technologies such as communication, cloud storage, artificial intelligence, etc.; the system platform layer includes application, content design, content distribution, middleware, utility software, game engine, operating system, etc., which mainly builds the system integration platform for specific scene applications; the hardware equipment layer includes VR/AR headsets, brain-computer interfaces, somatosensory devices, language recognition, cameras, cell phones, personal computers, etc., facilitating the connection for scene applications; the functions of the scene application layer mainly offers support for the carrying out of scenes such as education, medical care, socialization, tourism, exhibition, live broadcasting, concerts and so on.

Building on the technical, theoretical, and architectural support of educational metaverse system construction, this study divides the educational metaverse system into four-layer architecture physical layer, software layer, data layer, and application layer, as shown in Figure 1. While the physical layer, software layer, and data layer architectures remain similar across systems with different themes (e.g., education teaching system, tourism experience system, museum display system), the distinguishing factor lies in the software ecological composition of the application layer. For example, the software ecosystem of the education system consists of functional software segments such as science education, skill training, professional education, and teaching quality assessment.

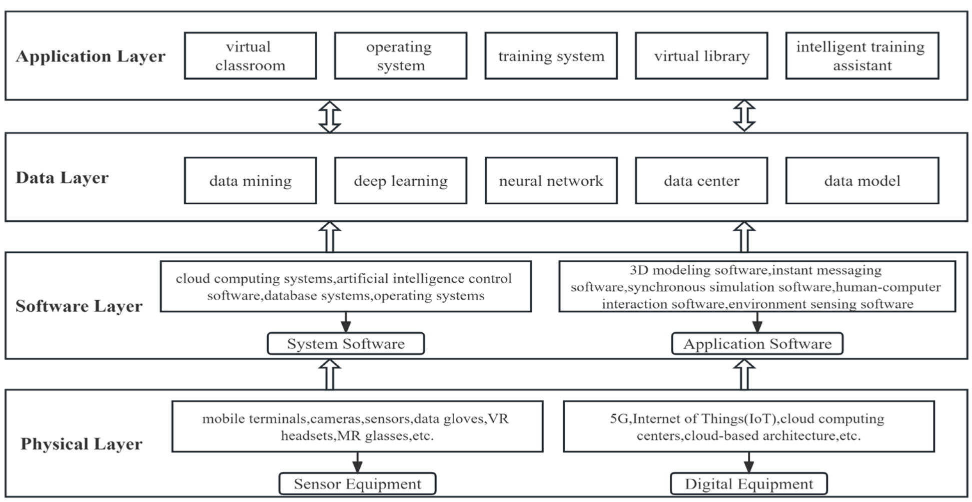

Figure 1**.** *Basic architecture of educational metaverse system*

The physical layer is the foundation of the whole educational metaverse system, the carrier for generating data, storing data, analyzing data, and applying data, which contains two major categories of sensing equipment, and digital facilities. Among them, sensing equipment utilized mobile terminals, cameras, sensors, data gloves, VR helmets, MR glasses, etc. to recognize various types of food in the educational teaching environment, and collect basic data for building the educational metaverse. Digital facilities include 5G, IoT, cloud computing centers, and cloud-based architectures to provide transmission, interconnection, and arithmetic support for the educational metaverse.

The software layer is primarily responsible for processing, analyzing, and managing the data obtained from the physical layer. It constructs the educational metaverse infrastructure based on the physical layer and facilitates the creation of the virtual environment. This layer comprises two components: the system software, and the application software. System software is used to control and coordinate the development and operation of hardware equipment and application software of the educational metaverse, and application software is used to realize specific functions, which is the key to link the physical layer, and the real application scene.

The data layer incorporates modules such as data mining, deep learning, neural networks, data centers, and digital models, focusing on data interconnection and interoperability. Its primary objectives are data management, storage, transmission, and integration, providing the necessary data support for the operation of the education metaverse system architecture.

The application layer is supported by big data, virtual reality, artificial intelligence, blockchain, and other technologies, which are deeply integrated with the education metaverse to provide users with a variety of specific application functions. By sensing the operation status of the systems in the education metaverse as well as the user status, it provides users with an instant virtual interaction experience in multi-dimensional time and space, and through the analysis of massive data, it realizes the purpose of accurately pushing learning resources to the users and implements personalized teaching.

Figure 2. *The overall diagram of the educational metaverse virtual experimental system*

The educational metaverse virtual experimental teaching system is divided into two parts: theoretical teaching and experimental operation. Theoretical teaching utilizing the virtual simulation experimental teaching platform, the generated three-dimensional virtual experimental theory course for the metaverse is integrated into the database. This course production is primarily grounded in traditional experimental theory teaching content, incorporating metaverse-related technologies such as network framework technology, three-dimensional engine technology, modeling technology, interaction design technology, and data service technology. The experimental operation scenario is based on the laboratory rabbit exercise respiratory regulation experiment as a reference, aiming to create a three-dimensional virtual network experimental space parallel to the physical experimental space. Students enter this space using a headset device, engaging in a metaverse virtual rabbit locomotor respiratory conditioning experiment that mimics the effects of the physical laboratory scenario. The overall diagram of the educational metaverse virtual experimental system is shown in Figure 2.

METHODOLOGY

RESEARCH QUESTIONS

This research aims to explore the potential enhancement of medical physiology experimental teaching through the utilization of an educational metaverse. The primary research question focuses on whether the implementation of an educational metaverse experimental teaching system can elevate the proficiency of medical students in both experimental theory and practical operations. We seek answers to the following two research questions:

1. Are the proportions of merit, good, passing, and failing rates the same for test group and control group?
2. How satisfied are students in test group with the educational metaverse experimental teaching model and how well did they master the experimental skills of rabbit motor respiratory regulation?

PARTICIPANTS

We chose 120 students from the 2019 clinical medicine class at School A as participants, with 60 assigned to the test group and the remaining 60 to the control group. Out of the total, 104 (86.7%) were women and 16 men (13.3%). The course instructor is consistent across both groups, and the evaluation method remains unchanged.

PROCEDURES

We divided the clinical medicine students into a control group and a test group, each group of students attends theory and laboratory course. Students in the test group studied the theory course and experimental operation of the experiments on the regulation of rabbits locomotor respiration in the educational metaverse, and did offline laboratory experiments on the regulation of rabbit locomotor respiration. Students in the control group studied the theoretical course of rabbit locomotor respiratory regulation experiment in the offline laboratory by the teacher through PPT and did offline laboratory experiments on the regulation of rabbit locomotor respiration.

The rabbit exercise respiratory regulation experiment is categorized into two components: the experimental theory course (1 credit hour) and the experimental operation course (1.5 credit hours). In the theory course, the instructor primarily imparted knowledge on the experimental purpose, principle, method, process, and precautions as outlined in the syllabus. During the practical experimental operations, students worked in groups of two under the guidance of the instructor, adhering to the requirements outlined in the theoretical course. The comparison of experimental teaching of the rabbits regulation of locomotor respiration is outlined in Table 1.

Table1. *Comparison of Experimental Teaching of Rabbits Motor Respiratory Regulation in Metaverse with Traditional Experimental Teaching*

Groups	Object of Study	Number of People	Class Hour	Teaching Model	Learning Content
Test Group	Clinical Medicine Students	60	4	Online and offline mixed teaching mode: online	Education metaverse virtual rabbit exercises respiratory regulation

				laboratory theory course (1 credit hour), online virtual laboratory operation (1.5 credit hours), offline laboratory rabbit locomotor respiratory regulation experiment (1.5 credit hours)	experiment theory course learning. Educational metaverse virtual rabbit locomotion and respiration regulation experiment operation practice. Rabbit locomotor respiratory regulation experiment in offline laboratory
Control Group	Clinical Medicine Students	60	2.5	Traditional teaching mode: classroom theoretical course teaching (1 credit hour), laboratory experiments on the regulation of locomotor respiration in rabbits (1.5 credit hours)	The offline instructor explains the theory course of rabbit locomotor respiratory regulation experiment through PPT. Rabbit locomotor respiratory regulation experiment in the offline laboratory

Refer to Figure 3 for a detailed depiction of the virtual training within the educational metaverse.

Figure 3. *Metaverse virtual rabbit exercise respiratory regulation practical training scene*

This experiment lasted for sixteen weeks and students were assessed at the end of the course. The theoretical course assessment involved a weekend closed-book examination, while the experimental course was evaluated based on the experimental report grades. To further understand the students' satisfaction with the educational metaverse virtual experimental teaching mode as well as the mastery of the experimental skills of rabbit locomotor respiratory regulation, the researchers conducted a questionnaire on the students of the test group after the end of the metaverse physiology experimental teaching course. Students were informed about the objective of the study and the informed consent was obtained. Participants completed both questionnaires either on paper or online, and were provided with contact information for the researchers in case of queries or clarifications. Confidentiality of participants' data and anonymity of their responses were assured throughout the study.

MEASUREMENTS

Project outcome score. After the experiment on the regulation of exercise respiration in rabbits carried out in the experimental, the theoretical and experimental course grades of the students in the test group and the control group were counted and analyzed. The full grade for both theory and lab was 100 points. Achieving more than 60 points in the theory course and experimental course was considered passing, 80-90 points was considered good, and more than 90 points was considered excellent. The overall distribution, passing rate, good rate, and merit rate of the examination results of the two groups of students were compared.

Survey. A survey was conducted for the students in the experimental group to find out the degree of satisfaction with the experimental teaching mode of metaverse as well as the degree of mastery of rabbit locomotor respiratory regulation. The questionnaire consisted of two parts. The response of the satisfaction questionnaire ranged from satisfied, more satisfied, mostly satisfied to dissatisfied. The response of the mastery questionnaire ranged from proficient, more proficient, mostly proficient to no proficient.

DATA ANALYSIS AND RESULTS

To answer the research question, data was analyzed using descriptive statistics, and chi-square test. All analyses were used by IBM SPSS 21. We showed the results of the study based on the research question.

ANALYSIS AND RESULTS FOR RESEARCH QUESTION 1

Theoretical and experimental scores of the experimental course on the regulation of locomotor respiration in rabbits were statistically analyzed separately for the two groups of students. The specific results are shown in Table 2.

Table 2. *Comparison of Experimental Teaching of Rabbits Motor Respiratory Regulation in Metaverse with Traditional Experimental Teaching*

Course	Group	Distribution of scores/person					Merit rate /%	Good rate /%	Pass rate /%	Failure rate /%
		＜60	60≤~＜70	70≤~＜80	80≤~＜90	90≤~＜100				
Theoretical Course	Test Group	0	7	16	25	12	20.00%	41.67%	100.00%	0%
	Control Group	4	20	24	10	2	3.33%	16.67%	93.33%	6.67%
Laboratory Course	Test Group	0	7	15	24	14	23.33%	40.00%	100.00%	0%
	Control Group	3	11	25	14	7	11.67%	23.33%	95.00%	5%

Compared with the control group, the merit rate, the good rate, and the pass rate of the theoretical course scores of the test group were increased by 16.67 percentage points, 25 percentage points, and 6.67 percentage points respectively. It indicates that the educational metaverse virtual experimental theory teaching can better enable students to understand the theoretical knowledge of the experimental course. Compared with the control group, the merit rate, good rate, and pass rate of the experimental course grades of the test group were increased by 11.66 percentage points, 16.67 percentage points, and 5 percentage points respectively. It demonstrates that the educational metaverse virtual experimental teaching system contributes to an improvement in students' practical skills in offline laboratory settings.

Table 3. *Relationship Between Groups and Theory Grades*

Variable	Test	Control	Chi-square	P-value
Merit	25(41.7%)	2(3.3%)	30.357	0.000
Good	12(20%)	10(16.7%)		
Pass	23(38.3%)	44(73.3%)		
Failure	0(0%)	4(6.7%)		

Table 4. *Relationship Between Groups and Laboratory Grades*

Variable	Test	Control	Chi-square	P-value
Merit	14(23.3%)	7(11.7%)	11.344	0.010
Good	24(40%)	14(23.3%)		
Pass	22(36.7%)	36(60%)		
Failure	0(0%)	3(5%)		

From the data, it shows the proportions of merit, good, passing, and failing rates for different groups are different. Table 3 and Table 4 shows that the test group has the highest number of distinctions, and the control group has the highest number of failures. It shows the relationship between groups and grades. Different groups showed significant differences in their performance in both theory and laboratory courses. There was a statistically significant association between groups and theory grades (chi-square = 30.357, p = 0.000). There was a statistically significant association between groups and laboratory grades (chi-square=11.344, p=0.010). The results indicates that the educational metaverse experimental teaching system can elevate the proficiency of medical students in both experimental theory and practical operations.

ANALYSIS AND RESULTS OF RESEARCH QUESTION 2

To further understand the students' satisfaction with the educational metaverse virtual experimental teaching mode as well as the mastery of the experimental skills of rabbit locomotor respiratory regulation, the researchers conducted a questionnaire on the students of the experimental group after the end of the metaverse physiology experimental teaching course, and a total of 60 questionnaires were distributed, 60 valid questionnaires were recovered, with an effective rate of 100%. The specific results are shown in Table 5.

Table 5. *Questionnaire Content and Results*

Content of the investigation	Result	Proportion
Satisfaction with the educational metaverse virtual experimental teaching model	satisfied	78.33%
	more satisfied	16.67%
	mostly satisfied	3.33%
	dissatisfied	1.67%
Acquisition of experimental methods and skills in the regulation of locomotor respiration in rabbits	proficient	66.67%
	more proficient	21.67%
	mostly proficient	9.99%
	no proficient	1.67%

After calculation, it found that 95% of students express satisfaction or higher with the metaverse virtual experiment teaching mode, with only 1.67% registering dissatisfaction. It shows that students are satisfied with the educational metaverse virtual experimental system as a whole. During the learning process, students could more intuitively observe, and learn the whole process of simulation experimental operations such as rabbit ear intravenous anesthesia, neck surgery, and thoracic surgery, which enhances the clarity of logical relationships between experimental steps, deepening students' understanding of theoretical knowledge and bolstering their interest in experimental courses.

Following the analysis, it revealed that 88.34% of students proficiently or relatively proficiently mastered the experimental methods and skills related to rabbit locomotor respiratory regulation, with only 1.67% indicating a lack of mastery. It shows that the metaverse virtual experimental operation greatly mobilizes the enthusiasm of students to master the experimental skills. It also indicates that the metaverse scenario teaching has a greater application prospect in the future education and teaching process.

CONCLUSION AND FURTHER STUDY

The application of the metaverse in the field of education has still been an emerging topic, and exploring the educational metaverse is of great significance. This study established the overall architecture of the education metaverse system, encompassing physical, software, data, and application layers. The primary physiology virtual experimental teaching system was jointly developed by the Henan Provincial Medical Virtual Reality Engineering Research Center, which initially explored the practical application of the education metaverse.

As a hotspot in today's science and technology industry, metaverse is currently in the primary period of development and needs many kinds of technology iteration and upgrading before metaverse can be realized and is confronted with many challenges such as technological risk, addiction risk, infringement risk, and ethical risk, etc. (Ali et al., 2023; Inceoglu & Ciloglugil, 2022; Bibri & Allam, 2022; Lan et al., 2021). Challenges include the immaturity of educational metaverse technology, insufficient strength in the technology base, suboptimal performance of hardware equipment, and the absence of a well-established curriculum production system. Moreover, the immersive sensory experience in virtual environments strengthens algorithmic training, leading learners to potentially become dependent on and addicted to the homogenized information provided by the metaverse, thereby affecting their mental well-being (Ning, 2018). In addition, the complexity of virtual and real identities, and the plurality of teaching and learning arenas in the educational metaverse may pose infringement risks, making it difficult to safeguard digital property rights, and privacy security (Falchuk et al., 2018; Inceoglu & Ciloglugil, 2022). Addressing these challenges necessitates continuous iteration and upgrading of the relevant technology to support the practical application of the educational metaverse. (Rokhsaritalemi et al., 2022). The relevant departments should strengthen the top-level design of the educational metaverse, optimize the path of anti-addiction, create a co-creative, and share educational ecology, to make better use of human subjectivity, and the value of education (Kye et al., 2022).

Despite these challenges, the potential impact on education is significant, prompting the need for strengthening top-level design, optimizing anti-addiction measures, and fostering a co-creative and shared educational ecology. The metaverse rabbit exercise respiratory regulation experimental teaching system developed in this study, based on virtual simulation technology, integrates artificial intelligence, knowledge graph, computer vision, and Internet of Things perception. While still in a primary form, the research results suggest that the metaverse can play a crucial role in the future of education and teaching.

It is acknowledged that this study was conducted in a relatively short period of time, with a limited sample size and some inherent flaws. Future research endeavors should focus on expanding the scope of study and exploring the application of the metaverse in the educational domain.

ACKNOWLEDGEMENT

This study was funded by 2022 Philosophy and Social Science Planning Project of Henan Province "Research on the Promotion Mechanism of Personalized Learning Based on Multimodal Data Evidence" (2022BJY034); 2023 Key Research and Development Project of Henan Province "Research on the Training Mechanism of Scientific and Technological Innovation Talents in Colleges and Universities under the Background of Digital Transformation Strategy" (232400411020)；2022 Research and Practice of Teaching Reform in Zhengzhou University "Research on the improvement mechanism of college students' online academic performance under the background of epidemic normalization " (2022ZZUJG133)；2022 Research and Practice of Teaching Reform in Zhengzhou University "Design and research of dual line integrated teaching for electrical experimental courses under the background of normal epidemic prevention on campus" (2022ZZUJG196).

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