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ARTICLE

Virtual Simulation in Forensic Medicine Education in China

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Abstract

Virtual Simulation is an innovative interactive pedagogical strategy in higher education. This paper analyzes the virtual simulation teaching projects currently underway in forensic medicine education in China. It explores the characteristics, advantages, and limitations of virtual simulation teaching in forensic medicine in China. The first batch of 11 virtual simulation projects are all synthetic designing experiments of over 2 class hours, mainly targeting the undergraduate students in the second year and above. Most projects focus on forensic pathology education. They provide active immersive experiential learning with data-driven teaching and real-time assessment. Further efforts are needed to integrate advanced technologies, diversify teaching content, and promote collaboration and resource sharing.

Keywords: Virtual simulation; Forensic medicine; Education

1. Introduction

Virtual simulation technology has seen increasing integration into higher education in China, with the Chinese Ministry of Education initiating national virtual simulation experimental teaching center (iLAB-X: https://www.ilab-x.com) construction in 2013[1,2]. Currently, over 3,500 virtual simulation education projects are implemented in Chinese higher education institutions, covering 41 major categories such as mechanical engineering, chemistry, civil engineering, and medicine. Among them, there are 13 projects related to forensic medicine education. This paper aims to summarize and analyze the first batch of

11 projects (online in 2019), discussing the advantages and limitations of virtual simulation education in forensic medicine.

2. General information and characteristics

The first batch of virtual simulation experimental projects of forensic medicine in China were conducted by 11 colleges and universities, as shown in table1. Among them, there are 6 comprehensive universities, 3 political and legal institutions, and 2 medical institutions. Each institute provides more than 2 class hours for the projects, mainly targeting students in the second year and above. These students have a foundation in relevant basic disciplines, making them more receptive to forensic medicine experimental courses. Notably, not as in the curriculums in other medical discipline, of which 46.5% are basic practice experiments[1], all the curriculums of forensic medicine are synthetic designing experiments. These projects provide in-class exams, and more than 400 participants have completed the exam in each project with a passing rate over 45%.

Table1. General information of virtual simulation experimental projects of forensic medicine in China

Project	Institute	Discipline	Class hour	Student	In-class exam Participants	Passing rate
Virtual simulation experiment of forensic thoracic anatomy based on cases of sudden cardiac death	Jilin University	Forensic pathology	6	Fourth-year clinical medicine, fifth-year forensic science undergraduate and postgraduate	540	83.9
Virtual simulation experiment of forensic medicine at the scene of a traffic accident	Southern Medical University	Forensic pathology	2	Fourth-year forensic science undergraduate and postgraduate	569	40.9
Forensic training based on virtual simulation of homicide scenes investigation	Sun Yat-sen University	multiple	4	Third-year forensic science undergraduate	584	83.2
Virtual simulation experiment of cadaver surface examination	Fujian Police College	Forensic pathology	4	Third-year forensic science and technology undergraduate	2203	98
Virtual simulation experiment of forensic pathological brain anatomy	Huazhong University of Science and Technology	Forensic pathology	4	Fifth -year clinical medicine, fourth -year forensic science undergraduate and postgraduate	464	93.1
Virtual simulation experiment of on-site forensic examination of cadavers	Guangxi Police College	Forensic pathology	2	Second or third-year forensic science and technology undergraduate	1050	45.1
Virtual simulation experiments for the extraction, and preservation of forensic biological samples	Liaoning Police College	Forensic genetics	2	Second or third-year forensic science and technology undergraduate	1235	77.6
Virtual simulation experiment of post-mortem redistribution of ethanol	Shanxi Medical University	forensic toxicology	2	Fourth-year forensic science undergraduate	1334	88.8
Case-based comprehensive forensic capacity training program	Central South University	multiple	4	Fourth-year forensic science undergraduate	3752	92.0
Forensic identification of brain injury	Soochow University	multiple	4	Fourth and fifth-year forensic science undergraduate	1142	88.5
Virtual simulation teaching project for crime scene investigation	Sichuan University	multiple	2	Second, third or fourth-year, forensic science undergraduate and postgraduate	698	100

Forensic medicine comprises various sub-disciplines, including forensic pathology, forensic clinical medicine, forensic genetics, forensic toxicology, forensic psychiatry, and more. Among the first batch of projects, four cover multiple sub-disciplines, such as “Forensic training based on virtual simulation of homicide scenes investigation ” by Sun Yat-sen University (Fig.1), “Case-based comprehensive forensic capacity training program” by Central South University, “Forensic identification of brain injury” by Soochow University, and “Virtual simulation teaching project for crime scene investigation” by Sichuan University, covering forensic pathology, forensic genetics, forensic clinical medicine, and other sub-disciplines. While seven fifths of the remaining projects are focused on forensic pathology. This emphasis on forensic pathology may be attributed to the challenges posed by limited cadaver resources and the difficulty in conducting autopsy experiments, which virtual simulations can effectively address. Some projects, such as the one at Central South University, leverage the school’s expertise in forensic entomology to create virtual simulation experiments unique

to the school[3]. Others, like the project at Southern Medical University, capitalize on the strengths of their Forensic traffic accident appraisal research institute, combining their expertise in forensic medicine, traceology, biomechanics, and vehicle engineering[4]. In

Figure 1. The teacher from Sun Yat-sen University is giving instructions to the students who are taking the in-class exam.

terms of equipment, among these projects, 3 projects (from Southern Medical University, Guangxi Police College and Sichuan University) provide VR versions equipped with VR devices such as HTC VIVE, controllers, and VR goggles for experimental operations. The other 8 projects, except for projects conducted by Sun Yat-sen University and Huazhong University of Science and Technology, require the installation of specific plugins but can be accessed through a web browser. Regarding network requirements, these projects have low bandwidth requirements for client-to-server connections, with most systems deployed on public cloud servers requiring 5-10M bandwidth, which is generally suitable for broadband users. Systems deployed on local network servers typically require 10-100M bandwidth. These indicate that such projects reduce the requirements for equipment and network, facilitating the promotion and use of virtual simulation experimental projects in teaching plans and societal services. Notably, Sichuan University's project supports mobile devices, allowing users to access the project through smartphones or tablets. This can be considered as a trend for the exploration of virtual simulation projects in forensic medicine education in the future.

Most of these projects are integrated into professional teaching plans, with online operation for over 3 years, serving tens to thousands of students within their institutions. Additionally, some projects offer services to the community, benefiting forensic professionals and continuing education for personnel in public security bureaus, procuratorates, courts, and judicial appraisal institutions. For example, the project "Virtual simulation experiment of forensic thoracic anatomy based on cases of sudden cardiac death" is currently establishing a virtual anatomy laboratory in collaboration with the Second Hospital of Jilin University, Jilin

Judicial Identification Center, Jilin Provincial Public Security Department, and Changchun Municipal Public Security Bureau, providing free access to universities and society within five years. Another project, "Virtual simulation experiment of forensic medicine at the scene of a traffic accident", plans to integrate big data, artificial intelligence, human-computer interaction, sensors, virtual reality, augmented reality, and cloud computing technologies to optimize the project. It will be expanded to all medical and law students in the university, providing free teaching services to universities and society. The project "virtual simulation experiments for the extraction, and preservation of forensic biological samples" is expected to provide training and assessment services for public security police officers in the future.

In these projects, the system interface first presents the case, allowing students to understand the experimental purpose. In the subsequent interactive operations, students learn the principles, key points, and forensic significance of each operation. Each student's operation is recorded as backend data, which is then analyzed, summarized, and scored. The projects adopt a problem-based learning (PBL) approach, combining online virtual simulation teaching with offline group discussions and case analysis. Teachers can provide feedback on students' progress through the system backend. This online virtual simulation teaching model, predominantly based on problem-oriented learning, enhances students' interest in knowledge acquisition, inspire innovative thinking, and improve efficiency compared to traditional passive learning methods.

Most virtual simulation projects focus on forensic pathology education, where autopsy is a crucial component. However, due to the challenges posed by the limited availability of cadaver resources and the time constraints of real-world experiments, many schools face difficulties in conducting traditional forensic autopsy experiments[5]. The simulations familiarize students with operational procedures, and the cases are often based on real-life scenarios, providing practical experience within the school environment. For example, the project conducted by Guangxi Police College not only allows students to experience real dissection scenes but also provides an opportunity to practice forensic pathology skills and methods in an environment that simulates actual forensic scenes. This innovation in teaching methods breaks the time and space constraints of traditional experimental teaching methods, ensuring that students can learn relevant knowledge more efficiently and conveniently. Simultaneously, virtual simulation projects can save costs and resources compared to traditional experimental teaching methods, making them more economical and practical.

Unlike traditional experimental teaching limited to single subjects, many projects integrate multiple branches of forensic medicine, establishing comprehensive experimental plans centered around core content. This approach enhances teaching efficiency and students' comprehensive application skills, contributing to the cultivation of practical forensic medical professionals. The virtual simulation experimental teaching system can standardize the teaching content and process, ensuring that each student receives the same learning resources and opportunities. The system backend records each student's operation data, allowing teachers to evaluate and analyze students' mastery of specific knowledge, the effectiveness of their operations, and their overall performance. This data-driven teaching model helps identify students' weaknesses and strengths, allowing for targeted guidance and personalized teaching. Teachers can also use the system to conduct real-time assessments,

enhancing the timeliness and objectivity of the evaluation process. Additionally, the virtual simulation teaching model promotes active learning, enabling students to actively explore, think, and solve problems during the learning process. This enhances students' ability to apply theoretical knowledge to practice, cultivating comprehensive forensic talents with practical skills.

3. limitations and Challenges

Although virtual simulation experimental teaching in forensic medicine education has achieved significant progress in China, some challenges still need to be addressed.

While many projects have achieved remarkable results in applying virtual simulation technology to forensic medicine education, the integration of advanced technologies such as artificial intelligence, big data, augmented reality, and cloud computing is still insufficient. Some projects have proposed plans to integrate these technologies in the future, but the current situation is that the application of these cutting-edge technologies is not yet widespread in forensic medicine education. The full integration of these technologies could further enhance the authenticity, interactivity, and intelligence of virtual simulation projects, providing students with a more immersive and realistic learning experience[6,7].

The projects tend to have a single, programmatic focus, making them effective for initial practical exposure but less suitable for long-term training. Most virtual simulation projects in forensic medicine education currently focus on forensic pathology, and there is a lack of diversity in teaching content. While forensic pathology is a crucial sub-discipline, it is essential to expand the scope of virtual simulation projects to cover other sub-disciplines within forensic medicine, such as forensic psychiatry, forensic clinical medicine, forensic genetics, and forensic toxicology. Diversifying the teaching content can meet the needs of students with different interests and career goals within the field of forensic medicine. Some projects overly rely on memorization rather than understanding the underlying principles, potentially leading to the development of formulaic forensic professionals lacking adaptability to different situations.

Although some projects have started to collaborate with external institutions and organizations, more efforts are needed to promote collaboration and resource sharing in the field of virtual simulation experimental teaching in forensic medicine. Collaboration between universities, judicial identification centers, public security bureaus, and other relevant institutions can contribute to the sharing of resources, expertise, and case materials. This collaboration can lead to the development of more comprehensive and diverse virtual simulation projects, enriching the overall quality of forensic medicine education.

Another concern that is commonly expressed by teachers and students is relatively low interactivity and immersion. In comparison to real-world practice, virtual simulation projects currently lack the tangible experience gained from hands-on operations8. Students interact with the system primarily through mouse clicks and keyboard inputs, missing the nuanced feel of using instruments like scalpels or pipettes. The low interactivity level poses challenges for applied professions, especially for forensic medicine.

While various branches of forensic medicine are covered in existing projects, many are standalone initiatives or involve only one discipline within a single university. The

number of class hours allocated is often minimal (not exceeding six hours), and the duration of implementation is short (mostly under three years). Thus, their impact on teaching in higher education institutions is still limited.

4. Prospects

In conclusion, the application of virtual simulation technology in teaching provides unprecedented experiences for students and teachers, stimulating students' curiosity. While VR education resources based on typical cases offer cost-effective case-based learning, challenges related to low interactivity, weak immersion, and uncertain teaching quality persist. Continued efforts to integrate advanced technologies, diversify teaching content, and promote collaboration and resource sharing will contribute to the further development and enhancement of virtual simulation in forensic medicine education in China. More efforts are needed to direct toward augmented reality (AR), mixed reality (MR), and metaverse technologies in the future. The integration of these technologies into forensic medicine education has infinite potential as a new platform for cultivating forensic talents.

Note

Ren-Jie LI and Ling LUO contributed equally to this study.

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