



Research on Ethical Dilemmas and Coping Strategies in Medical Education under Metaverse Technology

Feifei Chu¹, Fan Wang¹, Xiangyu Feng¹, Jing Wang², Yongkang Cao³, Jinting Shang³, Xiji Shu^{1*}

¹Student Affairs Department, School of Medicine, Jiangnan University, Wuhan, 430056, China

²Hubei Land Resources Vocational College, Wuhan, 430090, China

³Hubei Key Laboratory of Cognitive and Affective Disorders, Jiangnan University, Wuhan, 430056, China

*Corresponding author: xijishu@jnhun.edu.cn

Abstract. Virtual world technology is reshaping medical education, but its adoption has raised unresolved ethical obligations. We proposed a Technology-teaching-ethics-Outcomes framework and integrated the evidence through a review from 2019 to 2025 and two illustrative cases to map out the benefits, risks and remedies. The case studies of HoloAnatomy mixed-reality program and virtual reality basic life support modules offer learning outcomes comparable to traditional teaching, while revealing governance gaps in telemetry, consent, and equity. We have combined three recurring predicaments: data privacy and security, algorithmic bias and interpretability, as well as technical dependencies that may erode professional judgment. In response, we recommend taking feasible safeguard measures: purpose-limited data flow, minimized and time-limited retention, role-based access, clear and revocation non-punitive opt-out consent, design-based security architecture, and capacity building that combines digitalization with the humanistic qualities of teachers and learners. The TPEO framework clarifies how moral guardrails affect teaching efficiency and institutional trust, providing a practical roadmap for compliant and scalable deployment. Our conclusion is that metaverse tools can expand access, accelerate mastery and support elastic delivery, but lasting value depends on embedding design ethics and strong data governance from the very beginning.

Keywords: Metaverse, Medical Education, Ethical Dilemmas.

1 Introduction

With the rapid development of science and technology, metaverse technology has become the focus of academic and industrial circles. In recent years, Chinese government attaches great importance to the development of metaverse technology. Policy documents such as the "Three-Year Action Plan for the Innovative Development of the Metaverse Industry (2023-2025)" are strong evidence. These policies clearly put forward that educational scenes such as virtual classrooms and virtual laboratories should

be constructed by using metaverse technology, and at the same time, the application of digital twin technology in clinical research should be promoted, and the cooperation between metaverse enterprises and medical institutions should be promoted.

In this context, the application of metaverse technology in the field of medical education has attracted increasing attention. On the one hand, metaverse technology can assist doctors in diagnosis, treatment and scientific research, thus improving the quality and efficiency of medical services. On the other hand, it can provide immersive and interactive learning experience for medical students and promote their all-round development. However, the integration of the two also brings new ethical dilemmas, such as data privacy protection, algorithm bias and over-reliance on technology.

Therefore, it is of great academic value and practical significance to study the ethical challenges and mitigation strategies in meta-cosmic medical education. By constructing an innovative analysis framework of medical education model, this study expands the relevant theories in the field of educational technology and ethics, explores the impact of metaverse technology on medical education, and provides a new perspective for academic research. At the same time, targeted strategies are put forward for ethical challenges, providing valuable reference for medical education practice and promoting the healthy development of medical education.

2 Methods

We adopted a mixed-methods design combining a systematic literature analysis, two explanatory case studies, and a structured comparative analysis. The literature corpus was scoped to 2019–2025 and searched in Web of Science, Scopus, PubMed, IEEE Xplore, and CNKI using Boolean strings that combined “metaverse / VR / AR / XR” with “medical education / health professions education” and “ethic / privacy / bias / governance”. Inclusion criteria were: (1) peer-reviewed outlet; (2) explicit educational use-cases; and (3) sufficient methodological detail to extract outcomes and ethical considerations.

3 Research Status and Existing Problems

Current research mainly focuses on the application of the metaverse in education, medical education, and interdisciplinary integration. The research topics involved include teaching method innovation and practice, innovative applications and challenges in the medical and health field, as well as interdisciplinary convergence, etc.

Firstly, relevant research focuses on the application of the metaverse in the field of education, aiming to address issues related to teaching method innovation and practical implementation. Roy et al. (2023) proposed that introducing the “metaverse”, an expansive virtual space, can create a more interactive learning environment. This approach not only promotes the development of synchronous communication and supports multi-user sharing of diverse experiences, but also, through the research framework it proposes, makes up for the deficiencies in the exploration of metaverse applications in education, thereby having a positive impact on the learning outcomes of both

students and educators^[1]. Chen et al. (2023) pointed out that since 2019, the research on educational metauniverse has received extensive attention. Several core themes have been extracted from the research, which have deepened people's understanding of the application of metauniverse in education and promoted the innovative development of teaching practice^[2].

Secondly, in order to meet the needs of interdisciplinary integration, the application of metauniverse in medical education has been paid attention to. Zaidi et al. (2024) believe that integrating the Metauniverse into medical education can improve the quality of medical training by providing an immersive and situational learning experience. This is particularly important for alleviating the resource shortage in low-and middle-income countries, and can significantly improve the educational achievements^[3]. Shadad et al. (2025) proposed that with the rapid development of Internet of Things (IoT), blockchain and other technologies, the metauniverse, as the ultimate form of the Internet, has attracted wide attention. By connecting the physical world with the virtual world, the virtual world can not only provide a high-quality user experience, but also apply artificial intelligence (AI) and blockchain technology to the fields of medical health and education, so as to improve the health outcomes and the quality of patient care, and further promote the development of medical innovation and education^[4].

Thirdly, focusing on "Meta-Universe Empowering Medical Education" aims to solve the challenges in the field of medical personnel training. Chen et al. (2023) proposed to integrate all kinds of technical equipment with other related elements to construct the theoretical framework of medical education meta-universe. This framework effectively solves the problems of insufficient practice opportunities and uneven distribution of resources in traditional medical education, and provides guidance for subsequent application practice^[5]. Liu et al. (2023) believe that the rise of educational metauniverse makes online teaching a driving force for innovation. By exploring the virtual immersion teaching space, their research provides a new research direction for the construction of virtual immersion teaching mode in the field of traditional Chinese medicine (TCM), and then helps the international exchange and cooperation of Chinese medicine culture^[6].

A comprehensive review of global research shows that the application of the metaverse in the fields of education and healthcare has made remarkable progress, especially in areas such as teaching method innovation, healthcare applications and related challenges, interdisciplinary integration, and medical education reform. However, the following key issues still need to be addressed urgently: Insufficient depth of exploration in educational applications: Current research has not yet delved deeply into the construction logic and evaluation mechanism of interactive teaching environments, and there are also research gaps in the sustainability analysis and effectiveness evaluation of learning experiences^[7]. Challenges in the medical and health sector remain unovercome: In research related to the medical metaverse, core problems include how to address the uneven distribution of medical resources, ensure user privacy and security, achieve technical compatibility and adaptation, and promote the full integration of metaverse technology into the entire medical service process. Cross-Disciplinary Integration Difficulties: How to achieve seamless convergence of the three major fields of

education, medical and health care, and information technology, and ensure the simultaneous improvement of educational quality and medical service efficiency during the integration process, remains a key issue that has not yet been broken through [8].

4 Case Studies in Metaverse-Enabled Medical Education

To ground the proposed framework in practice, we synthesize evidence from two representative implementations of metaverse-enabled medical education. The HoloAnatomy mixed-reality program at Case Western Reserve University employs Microsoft HoloLens to deliver musculoskeletal anatomy; randomized and controlled comparisons reported knowledge outcomes comparable to cadaveric dissection, with a separate study demonstrating substantially reduced time to mastery, and emergency remote delivery during campus closures confirming feasibility and favorable learner experience [9–11]. A virtual-reality basic life support (BLS) module was used to train protocol adherence and psychomotor quality; a randomized trial found mixed short-term effects but comparable effectiveness at three months relative to conventional manikin training, and a feasibility study identified usability, realism, and real-time feedback as key design drivers alongside barriers to address before scale-up [12,13]. Across both cases, platform telemetry constitutes personal data; governance therefore requires purpose limitation, data minimization, time-bound retention, role-based access, informed consent, and non-penalizing opt-out options. Collectively, these findings illustrate how technological affordances, pedagogical design, and ethical safeguards jointly operationalize the Technology-Pedagogy-Ethics-Outcomes pathway in preclinical anatomy and clinical skills training.

5 Innovation in Medical Education under Metaverse Technology

This study is grounded in the theoretical frameworks of educational technology and ethics, aiming to provide theoretical support for addressing ethical dilemmas in metaverse-enhanced medical education and for formulating corresponding response strategies.

The theory of educational technology is one of the core supporting theories of this research. The development of this theory can be traced back to the early 20th century, having gone through an evolution from audio-visual education, computer-assisted instruction to intelligent education in recent years. Throughout its entire development process, educational technology has always taken "optimizing the teaching process and enhancing educational effectiveness with the aid of technological tools" as its core orientation. In the context of medical education, this theory emphasizes the catalytic role of technology in educational practice [14]. For example, the application of technologies such as distance education and virtual reality (VR) has introduced brand-new teaching modes and methods for medical education. However, there are still limitations in the application of the current educational technology theory in medical education, which

are manifested in insufficient attention to the ethical connotation of technology and insufficient evaluation of its long-term impact^[15]. In this study, the theory of educational technology is applied to the field of medical education with meta-universe empowerment, aiming at exploring how to solve the inherent ethical problems in the field of medical education through technical tools.

Ethical theory provides the necessary moral judgment basis and value orientation for this study. Ethics, as a discipline to study moral norms and behavior norms, is of vital significance in the field of medical education. Medical ethics emphasizes the importance of professional ethics in clinical practice and requires educators to adhere to ethical principles in order to cultivate medical professionals with moral responsibility. However, with the rise of metaverse technology, ethical issues in medical education have become more and more complex, involving multiple challenges such as data privacy protection, algorithm bias, and over-reliance on technology. This study integrates ethical theory into medical education, aiming at constructing an ethical framework that can solve these emerging ethical dilemmas.

Under the background of metaverse technology, educational innovation is first embodied in the macro-policy level. The government should formulate relevant policies to clarify the role and orientation of metaverse in the field of education, so as to provide institutional support for medical education. For example, through the promulgation of "Metauniverse Education Development Plan", the application scenarios, technical standards and ethical guidelines for the integration of Metauniverse into the education field are clarified, and medical institutions are encouraged to actively explore their application potential in teaching. In practice, medical educators should make full use of metaverse technology to build an immersive and interactive learning environment, so as to improve students' participation and learning enthusiasm^[16]. This requires educators to have solid technical literacy and be proficient in using meta-cosmic tools for curriculum design, implementation and evaluation.

The impact of metaverse technology on medical education is mainly reflected in the analysis and evolution of teaching mechanisms. Firstly, metaverse technology promotes the integration and sharing of medical education resources, breaks the limitation of geographic space, and makes high-quality educational resources easier to obtain. Secondly, metaverse technology promoted the reform of education mode, from the traditional "teacher-centered" knowledge transfer mode to the "student-centered, teacher-guided" interactive learning mode. For example, virtual reality (VR) technology can support students to simulate clinical scenarios and improve their practical skills. Augmented Reality (AR) technology can enable students to obtain medical knowledge in real time and enrich their learning experience.

Technology provides rich case resources for medical education and helps students to combine theoretical knowledge with practical experience. Through the Metauniverse platform, students can participate in virtual experiments, remote consultations and other practical activities to exercise their clinical thinking and problem-solving skills^[17]. In addition, this technology can promote cooperation and communication among students and cultivate a dynamic learning community. For example, students can set up study groups through the meta-universe platform to solve medical problems together and

share their views and opinions. Meta-cosmic technology has given revolutionary potential to medical education by redefining resource allocation mode, teaching interaction form and experiential learning scene ^[18]. However, to realize the continuous integration of metaverse technology and medical education, it is necessary to carry out strict ethical review, establish a sound policy framework, and constantly optimize teaching practice ^[19]. Through the systematic exploration of these dimensions, this study provides a new perspective for academic dialogue in related fields, and also provides an action path for building a medical education system that meets the requirements of ethical norms and advanced technology.

6 Limitations and Future Directions of Medical Education under Metaverse Technology

The potential limitations of metaverse technology in the theoretical application of medical education are mainly reflected in the following dimensions: Technical constraints: In the process of technology implementation, there may be challenges such as immature technology and high cost of equipment, which may limit the equitable distribution of medical education resources ^[20]. Over-reliance on technology: Over-reliance on technical means may lead to the neglect of the cultivation of medical students' humanistic quality, thus hindering their all-round development ^[21]. Information integrity and security: In the meta-environment, how to ensure the authenticity and security of medical information, especially to reduce the risks of data leakage and privacy invasion, is still an unresolved key issue ^[22].

In view of the above limitations, this study puts forward the following theoretical supplements and method innovation paths: Technology optimization and upgrading: On the technical level, we will focus on the development of generative artificial intelligence and metaverse technology suitable for medical education. Specific measures include reducing equipment costs and improving technology accessibility to promote the fair distribution of educational resources. Integration of humanistic education: at the teaching level, pay attention to the cultivation of medical students' humanistic ability. Through the harmonious combination of technical assistance and moral care, medical professionals with social responsibility can be trained ^[23]. Improve the information security framework: at the information management level, establish a sound security system to ensure the authenticity and confidentiality of medical data and ensure compliance with relevant privacy protection regulations.

7 Conclusion

In this study, by deeply exploring the ethical dilemma given to medical education by the meta-universe and its mitigation strategies, the analytical framework of a new educational model is constructed, the applicability of classical educational theories in medical teaching is verified, and the teaching innovation path under the meta-universe par-

adigm is explored. The research results highlight the dual effects of metaverse technology: it not only brings unprecedented opportunities to medical education, but also causes ethical challenges such as data privacy risks, algorithm bias and technology dependence. This study lays a foundation for the healthy development of medical education relying on technology through theoretical exploration of the meta-cosmic integration medical education model. The results of this study are conducive to cultivating innovative educational models, cultivating interdisciplinary medical talents with global competitiveness, and promoting the deep integration of medical education with science and technology and humanities. Future research should focus on three core directions: optimizing the implementation path of technology, improving the humanistic quality of medical students, and improving the information security management system in line with international standards.

Acknowledgements

This research was graciously supported by the Ministry of Education's Industry-University Collaboration and Co-Education Program in Batch of 2023 (230805635302844, 230802458312216, 230831402007228).

References

1. Roy, R., Babakerkhell, M. D., Mukherjee, S., Pal, D., & Funilkul, S. (2023). Development of a framework for metaverse in education: A systematic literature review approach. *IEEE Access*, 11, 57717–57734.
2. Chen, X. L., Zou, D., Xie, H. R., & Wang, F. L. (2023). Metaverse in education: Contributors, cooperations, and research themes. *IEEE Transactions on Learning Technologies*, 16(6), 1111–1129.
3. Zaidi, S. S. B., Adnan, U., Lewis, K. O., & Fatima, S. S. (2024). Metaverse-powered basic sciences medical education: Bridging the gaps for lower middle-income countries. *Annals of Medicine*, 56(1).
4. Chaddad, A., & Jiang, Y. C. (2025). Integrating technologies in the metaverse for enhanced healthcare and medical education. *IEEE Transactions on Learning Technologies*, 18, 216–229.
5. Chen, S. H., & Wu, J. J. (2023). Theoretical construction of medical education metaverse. *China Medical Education Technology*, 37(4), 390–396. (in Chinese)
6. Liu, C. T., Ma, Y., Yan, Y., & Zuo, Y. Y. (2023). Exploring the application of metaverse in international education of traditional Chinese medicine. *China Medical Education Technology*, 37(3), 292–297. (in Chinese)
7. Shao, L. J., Tang, W., Zhang, Z. Q., & Chen, X. R. (2023). Medical metaverse: Technologies, applications, challenges and future. *Journal of Mechanics in Medicine and Biology*, 23(2).
8. Musamih, A., Yaqoob, I., Salah, K., Jayaraman, R., Al-Hammadi, Y., Omar, M., & El-lahham, S. (2023). Metaverse in healthcare: Applications, challenges, and future directions. *IEEE Consumer Electronics Magazine*, 12(4), 33–46.

9. Stojanovska, M., Tingle, G., Tan, L., & Ruthberg, J. S. (2020). Mixed reality anatomy using Microsoft HoloLens and cadaveric dissection: A comparative effectiveness study. *Medical Science Educator*, 30, 173–178.
10. Ruthberg, J. S., Tingle, G., Tan, L., & Stojanovska, M. (2020). Mixed reality as a time-efficient alternative to cadaveric dissection. *Medical Teacher*, 42(8), 896–901.
11. Wish-Baratz, S., Crofton, A. R., Gutierrez, J., Henninger, E., & Griswold, M. A. (2020). Assessment of mixed-reality technology use in remote online anatomy education. *JAMA Network Open*, 3(9), e2016271.
12. Leszczyński, P. K., Jędral, K. W., Malm, M., Malm, S., Rasmus, A., & Smereka, J. (2025). Effectiveness of teaching basic life support resuscitation using virtual reality: A randomized controlled trial. *BMC Medical Education*, 25, 1260.
13. Wiltvank, I. L., Besselaar, L. M., van Goor, H., & Tan, E. C. T. H. (2024). Redesign of a virtual reality basic life support module for medical training: A feasibility study. *BMC Emergency Medicine*, 24, 176.
14. Iwanaga, J., Muo, E. C., Tabira, Y., Watanabe, K., Tubbs, S. J., D'Antoni, A., Rajaram-Gilkes, M., Loukas, M., Khalil, M. K., & Tubbs, R. S. (2023). Who really needs a metaverse in anatomy education? A review with preliminary survey results. *Clinical Anatomy*, 36(1), 77–82.
15. Bernardes, A., Gardim, L., Araujo, A. A. C., Jensen, R., Motta, R. A., de Almeida, D. M., de Lima, R. R., & Peres, H. H. C. (2024). Exploring the metaverse in the education of healthcare students: A scoping review. *Revista Latino-Americana de Enfermagem*, 32.
16. Pyae, A., Ravyse, W., Luimula, M., Pizarro-Lucas, E., Sanchez, P. L., Dorado-Díaz, I. P., & Thaw, A. K. (2023). Exploring user experience and usability in a metaverse learning environment for students: A usability study of the artificial intelligence, innovation, and society (AIIS). *Electronics*, 12(20).
17. Jeong, W. J., Oh, G. S., Oh, S. H., & Whangbo, T. K. (2022). Establishment of production standards for web-based metaverse content: Focusing on accessibility and HCI. *Journal of Web Engineering*, 21(8), 2231–2256.
18. Kim, S., Jung, T. M. Y., Sohn, D. K., Suh, M., & Chang, Y. J. (2024). Factors associated with continuous use of a cancer education metaverse platform: Mixed methods study. *Journal of Medical Internet Research*, 26.
19. Yang, Z. K. (2022). Metaverse-driven comprehensive digital transformation in education. *Educational Research*, 43(12), 23–26. (in Chinese)
20. Wang, Q. F., & Liu, Y. (2024). Digital empowerment of medical education: Applications, challenges, and pathways. *Medicine and Philosophy*, 45(10), 65–68. (in Chinese)
21. Wang, R. J., & Wang, D. (2024). Ethical risks and coping strategies of ChatGPT intervention in medical education. *Medicine and Philosophy*, 45(2), 76–81. (in Chinese)
22. Mei, S., & Wang, X. L. (2022). Research on medical application scenarios of metaverse. *China Digital Medicine*, 17(11), 45–48. (in Chinese)
23. Jiang, J. B., & Wang, Q. F. (2024). Intrinsic mechanisms and practical pathways of digital empowerment in medical education. *Journal of Medical Informatics*, 45(2), 98–101. (in Chinese)

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

