

Artificial Intelligence Empowered Teaching Reform of Anatomy Courses Under Medical-Engineering Integration: Practice, Evaluation, and Reflection

WANG Yan, SUI Li, CAI Yusi

University of Shanghai for Science and Technology, Shanghai, China

CHEN Changle*

Shanghai Qigong Research Institute, Shanghai, China

With the rapid advancement of artificial intelligence (AI), medical education is undergoing profound transformation, particularly within the context of medical-engineering integration. Traditional lecture-based anatomy teaching is increasingly insufficient to meet the demands of interdisciplinary talent cultivation. This study explores the reform of an undergraduate anatomy course for biomedical engineering students through the integration of AI-assisted teaching tools and pedagogical innovation. A cohort of approximately 190 students participated in a 48-hour anatomy course in which the curriculum design, teaching content, instructional methods, and evaluation strategies were systematically restructured. AI-supported platforms, virtual simulation technologies, and case-based learning approaches were introduced through an incremental integration model. It was demonstrated that the reform was associated with significant improvements in student engagement, spatial understanding of anatomical structures, and higher-order learning outcomes in application-oriented tasks. Meanwhile, teaching management was facilitated and data-driven feedback was enabled through AI technologies, although increased demands were placed on teachers' digital competence. Overall, the integration of AI into anatomy teaching is feasible and shows positive effects. However, further refinement in curriculum design, evaluation systems, and teacher training is necessary to ensure sustainable implementation. This study may provide useful references for teaching reform in basic medical courses under the background of medical-engineering integration.

Keywords: artificial intelligence, medical-engineering integration, anatomy course, teaching reform, medical education

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WANG Yan, Ph.D., Lecturer, Institute of Orthopedic Biomedical and Device Innovation Research, School of Health Science and Engineering, University of Shanghai for Science and Technology, Shanghai, China.

SUI Li, Ph.D., Professor, School of Health Science and Engineering, University of Shanghai for Science and Technology, Shanghai, China.

CAI Yu-Si, School of Health Science and Engineering, University of Shanghai for Science and Technology, Shanghai, China.

CHEN Chang-Le* (corresponding author), Ph.D., Chief Physician, Shanghai Qigong Research Institute, Shanghai, China.

Introduction

The integration of artificial intelligence (AI) into higher education has accelerated rapidly in recent years, reshaping traditional pedagogical paradigms across disciplines (Francis, Jones, & Smith, 2025). In medical education, particularly in foundational courses such as anatomy, AI technologies offer new opportunities to overcome long-standing challenges related to knowledge complexity, spatial cognition, and student engagement (Li & Qin, 2023).

Simultaneously, the growing trend of medical-engineering integration has raised new expectations for undergraduate education. Biomedical engineering students are required not only to master basic anatomical knowledge but also to develop the ability to apply such knowledge in engineering contexts, including medical imaging, device design, and digital modeling. However, conventional anatomy teaching—characterized by didactic lectures and rote memorization—often fails to meet these interdisciplinary demands (Abdellatif et al., 2022).

Under the current circumstances, the present study aims to explore how AI technologies can be effectively embedded into anatomy teaching to improve learning outcomes and better align with the goals of medical-engineering integration (Binvignat et al., 2025). Through systematic teaching reform and empirical evaluation, this research seeks to provide a feasible framework for AI-assisted curriculum innovation.

Impact of AI on Anatomy Education Under Medical-Engineering Integration

Transformation and Challenges of Traditional Teaching Models

With the continuous integration of AI technologies into the field of education, teaching models in medical courses are undergoing a transition from knowledge-oriented instruction to competency-based learning. In traditional anatomy education, teaching primarily relies on instructor-led lectures and atlas-based memorization, where students tend to adopt passive learning approaches with limited classroom interaction (Ji, Zhu, Shen, & Zhu, 2023).

With the support of AI technologies, however, students now have access to more diverse learning resources and flexible learning pathways. As a result, individual differences in learning pace have become increasingly evident. While such flexibility enhances personalized learning, it also weakens the uniformity of traditional classroom instruction and poses new challenges for teaching organization (El Naggar & Gaad, 2024).

In teaching practice, it is observed that some students actively utilize digital resources for extended learning, whereas those with weaker academic foundations tend to repeatedly review core content. Although this stratified learning pattern improves accessibility and adaptability, it also makes it more difficult for instructors to maintain a consistent teaching rhythm in the classroom.

Moreover, in topics involving spatial structure comprehension—such as anatomical relationships—traditional two-dimensional images are often insufficient to support deep understanding. The introduction of three-dimensional visualization tools and dynamic simulations has significantly improved students' comprehension. However, this shift also increases the workload of instructors during the course preparation stage, as it requires additional effort in selecting, organizing, and integrating digital teaching resources.

Furthermore, the application of AI technologies is also transforming the role of teachers. Instructors are no longer merely transmitters of knowledge but are increasingly expected to act as facilitators of learning and integrators of educational resources. This shift requires teachers not only to possess solid medical knowledge but also to acquire a certain level of proficiency in digital tools and AI-assisted teaching methods.

Therefore, while AI brings new opportunities to anatomy education, it simultaneously imposes higher demands on teachers in terms of instructional design, technological competence, and adaptive teaching strategies.

Feasibility and Implementation Pathways of AI-Assisted Anatomy Teaching

Within the context of medical-engineering integration, anatomy courses are no longer limited to the transmission of basic structural knowledge but are increasingly expected to connect with engineering applications. At present, technologies such as medical image reconstruction, three-dimensional modeling, and virtual simulation have been widely applied in the medical field, providing a practical foundation for teaching reform.

Teaching practice indicates that when course content focuses solely on structural memorization, students' learning interest tends to be limited. In contrast, the introduction of clinical or engineering-related cases can significantly enhance classroom engagement. For instance, by presenting simplified three-dimensional reconstructions of computed tomography (CT) images, students are better able to understand the spatial relationships between organs. Such visual and application-oriented approaches help bridge the gap between theoretical knowledge and real-world scenarios, thereby improving learning motivation. These observations suggest that incorporating technological elements within a reasonable scope can enhance the practical relevance of anatomy education.

In terms of implementation pathways, it is advisable to begin with relatively accessible and moderately complex components. For example, integrating virtual anatomy software, introducing case-based discussions, and utilizing online teaching platforms for process management are practical entry points. These approaches require limited changes to the existing curriculum structure and are therefore easier to adopt in routine teaching. Meanwhile, digital platforms can support resource distribution, learning tracking, and feedback collection, contributing to a more continuous and structured teaching process.

However, several practical issues should also be considered. Differences in teachers' familiarity with digital tools and the uneven quality of teaching resources may affect the overall effectiveness of implementation. Therefore, it is important to strengthen faculty training and promote resource sharing to ensure consistency in teaching quality.

Overall, the application of AI technologies in anatomy courses demonstrates a considerable degree of feasibility. Nevertheless, its effectiveness largely depends on context-specific implementation and requires ongoing refinement through teaching practice.

Teaching Reform and Practice

AI-Driven Reform Design

Based on the teaching practice of the anatomy course for biomedical engineering majors (approximately 190 undergraduate students, 48 teaching hours in the 2025 academic year), this study introduces AI-related technologies and instructional tools into the teaching process. Rather than conducting a comprehensive overhaul of the existing curriculum, the reform follows a principle of "incremental embedding", aiming to gradually optimize the course structure without significantly increasing students' academic burden.

At the level of syllabus design, the course is restructured around an integrated training objective that combines foundational medical knowledge, engineering application awareness, and spatial cognition ability. While maintaining the classical framework of systematic anatomy, selected content related to medical imaging, three-dimensional modeling, and digital human reconstruction is incorporated. This adjustment is intended to

better align the course with the needs of medical-engineering integration. In addition, the course objectives are gradually shifted from a sole emphasis on knowledge acquisition toward a dual focus on structural understanding and application awareness. More specifically, greater attention is placed on students' ability to comprehend spatial relationships among anatomical structures and to establish preliminary connections between anatomical knowledge and real-world application scenarios.

In terms of content organization, differentiated teaching strategies are adopted according to students' disciplinary orientations, with an emphasis on linking structure and function, as well as theory and application. For students in rehabilitation engineering, the musculoskeletal system is taught in conjunction with examples such as prosthetic design and rehabilitation training, enabling a functional interpretation of bones and muscles. For those in medical imaging-related fields, basic imaging data are introduced during the instruction on the nervous system to illustrate nerve distribution and imaging characteristics. In the section on visceral systems, simple image interpretation cases are incorporated to help students establish correspondences between anatomical structures and clinical imaging. This context-based integration of content enhances both comprehension and learning engagement.

With regard to teaching methods, the traditional lecture-centered approach is gradually transformed into a hybrid model characterized by AI assistance and interactive learning. Supported by the virtual digital anatomy system available at the institution, three-dimensional visualization and simulated operations are integrated into classroom teaching to make abstract spatial relationships more intuitive. Meanwhile, short case analyses and in-class discussions are introduced to encourage student participation in the process of knowledge construction. In selected topics, AI-assisted tools are used to generate tiered questions and guiding prompts, which are then curated by instructors for real-time classroom interaction, thereby improving teaching flexibility and responsiveness.

In terms of assessment, the course aligns with the institution's ongoing reform toward process-oriented evaluation initiated in 2025. A comprehensive assessment model combining continuous assessment and final examination is adopted, including components such as classroom participation, assignment completion, and online learning records. These indicators provide a more comprehensive reflection of students' ongoing learning performance and help reduce the randomness associated with single summative assessments.

Overall, this AI-assisted, incrementally implemented reform improves the intuitiveness and interactivity of teaching without substantially increasing the course load. It also contributes to enhancing students' understanding and preliminary application of anatomical knowledge, thereby laying a foundation for subsequent professional courses.

Multidimensional Evaluation of Teaching Outcomes

To systematically assess the effectiveness of the AI-empowered reform in the anatomy course, a multidimensional evaluation was conducted, including analyses of academic performance, student feedback, teacher perspectives, and teaching supervision.

From the perspective of academic performance, students' overall scores showed a steady improvement compared with those prior to the reform. In particular, performance in structure identification and integrative application questions demonstrated noticeable enhancement. This suggests that students' understanding of anatomical structures has gradually shifted from rote memorization toward spatial comprehension and applied analysis. For example, in imaging interpretation tasks and structure localization questions, students were more

capable of making judgments based on three-dimensional structural relationships, and the error rate decreased accordingly. In addition, the distribution of scores became more balanced, with improvement observed among students with weaker academic foundations. This indicates that differentiated learning support and diversified instructional resources played a positive role. Results from formative assessments also revealed that students' ability to integrate knowledge across different systems improved, especially in modules related to the musculoskeletal and nervous systems.

In terms of student feedback, data collected through questionnaires and classroom interviews indicate that most students hold a positive attitude toward AI-assisted teaching. Students generally reported that three-dimensional anatomical models and virtual simulation resources significantly enhanced their understanding of complex structural relationships. This was particularly evident in topics involving spatially intricate regions such as the heart, brain, and pelvic cavity, where traditional two-dimensional explanations are often insufficient. Furthermore, the integration of imaging materials and clinical scenarios helped students establish connections between anatomical structures and their practical applications. Some students majoring in rehabilitation engineering noted that incorporating functional analysis into the study of the musculoskeletal system facilitated their transition to subsequent professional courses. However, it is worth noting that a number of students reported initial difficulties in operating virtual platforms, suggesting that a certain adaptation period is required. This highlights the importance of providing adequate guidance and technical support during the early stages of implementation.

From the perspective of teachers, instructors involved in the course generally agreed that the application of AI technologies improved both teaching efficiency and presentation quality. For instance, the use of virtual anatomy tools for structural demonstration reduced the time spent on traditional board drawing, allowing instructors to focus more on key concepts and explanations. In addition, learning data generated by the teaching platform provided valuable insights into students' progress, enabling teachers to make targeted adjustments during instruction. Nevertheless, some challenges were also identified. The selection and integration of appropriate teaching resources require additional time and effort, and the use of advanced tools, such as imaging data and three-dimensional models, places higher demands on teachers' digital literacy. Continuous learning and practice are therefore necessary for instructors to effectively implement such teaching approaches.

Feedback from teaching supervision further supports the effectiveness of the reform. Supervisors generally acknowledged that the course demonstrated improvements in classroom interactivity and visualization, and that it reflected a meaningful attempt to align anatomy teaching with the needs of medical-engineering integration. At the same time, they emphasized the importance of maintaining a balance between technological application and foundational knowledge instruction. In particular, they suggested that overreliance on technological tools should be avoided, and that the systematic structure of fundamental knowledge should remain a core component of the curriculum.

Overall, the introduction of AI technologies into the anatomy course has, to some extent, addressed the limitations of traditional teaching approaches that emphasize memorization over understanding. Students have developed a more intuitive grasp of structural relationships, which also provides support for subsequent professional learning. However, it should be recognized that this reform remains in an exploratory stage. Further efforts are needed in areas such as resource integration, refinement of evaluation criteria, and enhancement of teachers' competencies. Continuous improvement in these aspects will be essential to ensure the sustainability and broader applicability of this teaching model.

Discussion

Based on the teaching practice presented in this study, the integration of AI technologies into the anatomy course has, to a certain extent, improved both instructional efficiency and classroom delivery. First, in terms of teaching efficiency, the use of intelligent teaching platforms for resource integration and learning data management helps reduce repetitive tasks such as assignment grading and progress tracking, thereby allowing instructors to devote more effort to key content explanation and the design of interactive activities. Second, at the level of classroom interaction, the combination of virtual simulation and case-based instruction enhances student engagement. In particular, for topics involving complex spatial structures, three-dimensional visualization provides a more intuitive learning experience and compensates for the limitations of traditional two-dimensional diagrams. In addition, data-driven feedback mechanisms offer opportunities for implementing differentiated instruction and a certain degree of personalized guidance.

These findings are consistent with previous studies demonstrating that AI-supported and virtual simulation-based teaching approaches can significantly enhance student engagement (Thüs, Malone, & Brinken, 2024) and learning effectiveness in medical education (Lee, 2024). Moreover, compared with prior research that primarily focuses on single technological interventions, the present study integrates multiple AI-assisted strategies within a unified instructional framework, thereby providing a more comprehensive approach to anatomy teaching reform.

Despite these advantages, several challenges were identified during implementation. On the one hand, the introduction of AI tools increases the preparatory workload for instructors, particularly for those without a strong background in engineering or information technology, who need to invest additional time in learning and adapting to new tools. On the other hand, some students experience difficulties in adjusting to the new learning model during the initial stage, which may manifest as overreliance on digital platforms or insufficient self-directed learning ability. Furthermore, without proper guidance, excessive dependence on technological tools may negatively affect the consolidation of foundational knowledge.

This observation is in line with earlier research indicating that the effectiveness of digital learning environments depends not only on technological availability but also on appropriate pedagogical design and learner support (Yousefi et al., 2026).

To address these issues, several improvement strategies can be considered. First, faculty development should be strengthened through institutional training programs and interdisciplinary collaboration, thereby enhancing instructors' digital teaching competencies. Second, the course structure should be continuously optimized to ensure that fundamental anatomical knowledge remains systematic and coherent, while appropriately incorporating elements related to medical-engineering integration. Third, the evaluation system should be further refined by improving the design of formative assessment indicators, making them more practical, transparent, and consistent. Through these gradual adjustments, a more balanced integration of AI technology and course instruction can be achieved (Xu et al., 2024).

Conclusion

In summary, this study uses an anatomy course for biomedical engineering students as a case to examine the integration of AI technologies within the context of medical-engineering integration. Systematic reforms were implemented in syllabus design, content restructuring, instructional approaches, and assessment strategies, followed by a comprehensive evaluation based on teaching feedback. The findings suggest that, when

implemented with appropriate pacing and scope, AI integration can effectively enhance classroom performance, deepen students' understanding of the relationship between anatomical structures and practical applications, and promote more active and application-oriented learning approaches.

Nevertheless, this study remains exploratory in nature, and the generalizability of the proposed strategies across different teaching contexts requires further validation. Future research should focus on large-scale and longitudinal investigations to examine sustained teaching outcomes and to optimize instructional design in accordance with disciplinary characteristics. At the same time, maintaining an appropriate balance between technological application and fundamental educational objectives remains essential to avoid excessive reliance on tools at the expense of core knowledge development.

Overall, AI offers significant potential for advancing the reform of basic medical education. In the context of deepening medical-engineering integration, its thoughtful and context-sensitive application in teaching practice represents a promising pathway for improving the quality of interdisciplinary talent cultivation and provides a valuable reference for future educational research.

References

- Abdellatif, H., Al Mushaiqri, M., Albalushi, H., Al-Zaabi, A. A., Roychoudhury, S., & Das, S. (2022). Teaching, learning and assessing anatomy with artificial intelligence: The road to a better future. *Int J Environ Res Public Health*, *19*(21), 14209.
- Binvignat, P., Valette, S., Hara, A. T., Lahoud, P., Jacobs, R., Chaurasia, A., ... Richert, R. (2025). AI in learning anatomy and restoring central incisors: A comparative study. *J Dent Res*, *104*(13), 1479-1486.
- El Naggar, A., & Gaad, E. (2024). Inocencio SAM. Enhancing inclusive education in the UAE: Integrating AI for diverse learning needs. *Res Dev Disabil*, *147*, 104685.
- Francis, N. J., Jones, S., & Smith, D. P. (2025). Generative AI in higher education: Balancing innovation and integrity. *Br J Biomed Sci*, *81*(9), 14048.
- Ji, H., Zhu, K., Shen, Z., & Zhu, H. (2023). Research on the application and effect of flipped classroom combined with TBL teaching model in WeChat-platform-based biochemical teaching under the trend of COVID-19. *BMC Medical Education*, *23*(1), 679.
- Lee, H. (2024). The rise of ChatGPT: Exploring its potential in medical education. *Anatomical Sciences Education*, *17*(5), 926-931.
- Li, Q., & Qin, Y. (2023). AI in medical education: medical student perception, curriculum recommendations and design suggestions. *BMC Med Educ*, *23*(1), 852.
- Thüs, D., Malone, S., & Brünken, R. (2024). Exploring generative AI in higher education: A RAG system to enhance student engagement with scientific literature. *Frontiers in Psychology*, *15*, 1474892.
- Xu, W., Wu, Z., Zhang, C., Zhu, C., & Duan, H. (2024). PepCARES: A comprehensive advanced refinement and evaluation system for peptide design and affinity screening. *ACS Omega*, *9*(46), 46429-46438.
- Yousefi, F., Dehnavieh, R., Laberge, M., Haghdoost, A., Sasseville, M., Hekmat, S. N., ... Nadali, M. (2026). Integrating artificial intelligence (AI) in primary health care (PHC) systems: A framework-guided comparative qualitative study. *Healthcare*, *14*(2), 145.