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Research Article

Traditional Versus Technology-Enhanced Demonstrations in Competency-Based Medical Education

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ABSTRACT

Background: Anatomical demonstration is a fundamental component of undergraduate medical education and provides the bridge between theoretical knowledge and clinical application. Cadaveric dissection, prosection, anatomical specimens, models, charts, and microscopy have traditionally formed the core of anatomy teaching. However, increasing student numbers, limited cadaver resources, reduced teaching time, and the need for clinically integrated learning have encouraged the adoption of technology-enhanced approaches.

Objective: This narrative review compares traditional and technology-enhanced methods of anatomical demonstration within the framework of Competency-Based Medical Education (CBME) and examines their educational strengths, limitations, and potential for integration.

Materials and Methods: Recent literature concerning cadaveric teaching, three-dimensional models, virtual reality (VR), augmented reality (AR), three-dimensional printing, virtual dissection, simulation, and artificial intelligence (AI) in anatomy education was reviewed. Evidence from recent comparative studies, systematic reviews, and meta-analyses was synthesized according to visualization, knowledge acquisition, spatial understanding, learner engagement, retention, clinical integration, and competency development.

Results: Traditional demonstrations provide authentic three-dimensional and tactile experiences, appreciation of anatomical variation, professional development, teamwork, and ethical engagement with body donors. Technology-enhanced approaches provide interactive visualization, repeatable demonstrations, individualized learning, radiological correlation, and simulation-based practice. Recent evidence indicates that VR and other immersive technologies can improve anatomy learning, particularly when used as complementary rather than replacement strategies.

Conclusion: Traditional and technology-enhanced demonstrations have complementary educational strengths. A blended model integrating cadaveric experience with validated digital technologies, simulation, and appropriately supervised AI is likely to provide the most effective framework for competency-oriented anatomy education.

Keywords: Anatomy Education, Competency-Based Medical Education, Cadaveric Dissection, Technology-Enhanced Learning, Virtual Reality, Augmented Reality, Three-Dimensional Modelling, Artificial Intelligence, Medical Students.

INTRODUCTION

Anatomy provides the structural foundation for understanding clinical examination, diagnostic imaging, pathology, surgery, and patient management. For medical students, anatomical demonstrations are particularly valuable because they transform abstract descriptions into observable spatial relationships. Traditional anatomy education has consequently relied on cadaveric dissection, prosections, anatomical models, museum specimens, radiographs, histological preparations, and direct faculty demonstration (1).

Cadaveric dissection remains an important educational experience because students encounter authentic human tissues and anatomical variation while developing psychomotor skills, teamwork, professional attitudes, and respect for body donors. Recent evidence continues to demonstrate strong student support for cadaveric teaching and its contribution to anatomical understanding and professional development (2).

At the same time, contemporary medical education is increasingly technology enabled. Three-dimensional (3D) models, virtual dissection, VR, AR, digital microscopy, 3D printing, simulation, and AI-supported learning systems can provide visual and interactive experiences that are difficult to achieve using conventional resources alone. These technologies are particularly useful for complex spatial relationships, sectional anatomy, radiological correlation, and repeated independent learning (3).

The emergence of CBME has further changed the purpose of anatomical demonstrations. The objective is no longer simply to recall anatomical facts but to demonstrate competencies, integrate basic and clinical sciences, apply knowledge to patient care, and develop appropriate professional behaviours. Technology can support these objectives, but its educational value depends on how it is incorporated into the curriculum. Recent evidence indicates that VR and AR can improve knowledge acquisition, although outcomes vary according to technology, learner characteristics, assessment methods, and instructional design (4).

Therefore, the contemporary question is not whether traditional or modern methods are superior, but how both can be strategically integrated to achieve defined learning competencies.

Evolution of Demonstration Methods in Competency-Based Medical Education

Demonstration has traditionally been one of the fundamental methods of teaching in medical education. In the conventional teacher-centred model, the teacher explained a topic and demonstrated relevant structures, procedures, instruments, clinical signs, or skills while students primarily observed and reproduced the demonstrated knowledge or technique. In preclinical subjects, demonstrations commonly involved specimens, models, charts, slides, laboratory experiments, and practical exercises, whereas clinical subjects relied on bedside teaching, patient examination, case presentation, and demonstration of clinical procedures (5).

With the expansion of medical education, demonstration methods gradually became more structured and learner-centred. Models, anatomical specimens, audiovisual aids, projected images, videos, simulation equipment, and standardized patients were incorporated to supplement direct teacher demonstration. These approaches enabled larger groups of students to observe procedures and provided opportunities for repeated practice without depending entirely on the availability of patients or specimens (6).

The development of medical imaging and digital technology produced another major transition. Radiographs, CT, MRI, ultrasonography, digital pathology, electronic medical records, and computer-assisted learning allowed students to connect theoretical concepts with findings from real clinical practice. Demonstrations increasingly moved beyond static observation toward interactive interpretation and problem-solving (7).

The emergence of Competency-Based Medical Education (CBME) has further transformed the purpose of demonstrations. The emphasis has shifted from merely completing demonstrations or acquiring factual knowledge toward achieving measurable competencies. Demonstrations are now expected to help students integrate knowledge, skills, attitudes, communication, professionalism, clinical reasoning, and patient-centred care. Consequently, the teacher increasingly acts as a facilitator and mentor, while students are encouraged to observe, practise, perform, receive feedback, and demonstrate competence (8).

The development of simulation-based medical education has been particularly important.

Manikins, task trainers, standardized patients, virtual patients, procedural simulators, and clinical scenario-based exercises allow students to practise skills repeatedly in a controlled environment before performing them on real patients. Simulation has therefore become an important bridge between theoretical instruction and clinical practice (9).

More recently, virtual reality (VR), augmented reality (AR), mixed reality, three-dimensional visualization, interactive digital platforms, and artificial intelligence (AI) have expanded the possibilities of demonstration across medical disciplines. These technologies can be applied to anatomy, physiology, pathology, pharmacology, radiology, surgery, medicine, obstetrics and gynaecology, paediatrics, emergency medicine, and other clinical specialties. Students can visualize complex processes, interact with virtual patients, practise procedures, interpret investigations, and receive immediate feedback (10).

AI-assisted educational systems represent the latest stage in this evolution. AI can support personalized demonstrations, adaptive learning, automated feedback, clinical case generation, image interpretation, virtual tutoring, and competency tracking. Instead of providing identical demonstrations to every learner, technology can increasingly identify individual learning gaps and provide additional demonstrations or practice activities according to the student's needs (11).

Thus, the evolution of demonstration methods in medical education can be broadly represented as:

Teacher-centred demonstration → Specimen/model-based demonstration → Audiovisual and video demonstration → Bedside and simulation-based teaching → Computer-assisted and digital demonstration → VR/AR and immersive simulation → AI-supported personalized demonstration.

However, technological advancement should not be interpreted as a complete replacement of traditional demonstration. Direct observation, teacher guidance, bedside teaching, hands-on practice, patient interaction, and human feedback remain essential for developing professional and clinical competencies. Technology is most effective when it is deliberately integrated with established teaching methods (12).

Within CBME, therefore, the focus should shift from "Which demonstration method is better?" to "Which demonstration method best achieves the intended competency?" A complex clinical procedure may benefit from simulation before patient exposure; a physical examination requires real or standardized patients; a microscopic process may be better demonstrated through digital microscopy; and a difficult anatomical relationship may benefit from 3D or immersive visualization (13).

The future of demonstration in medical education is consequently likely to be blended, competency-oriented, interactive, and learner-centred, combining the authenticity of traditional teaching with the flexibility and personalization offered by modern technologies. This integrated approach can provide students with repeated opportunities to observe, practise, receive feedback, and ultimately demonstrate competence in a safe and structured educational environment.

MATERIALS AND METHODS

A narrative review was undertaken to compare traditional and technology-enhanced methods of anatomical demonstration in undergraduate medical education. The review used the previously developed manuscript as its conceptual basis and incorporated recent peer-reviewed evidence retrieved from PubMed and related biomedical literature.

Literature concerning cadaveric dissection, prosection, anatomical models, 3D printing, virtual dissection, VR, AR, digital anatomy, simulation, and AI-assisted anatomy education was considered. Priority was given to systematic reviews, meta-analyses, comparative studies, and recent educational research published between 2022 and 2026.

The literature was examined according to the following educational domains: anatomical visualization, spatial understanding, knowledge acquisition, retention, student engagement, accessibility, clinical integration, competency development, faculty requirements, and educational limitations. As this was a narrative review, no quantitative meta-analysis was performed.

RESULTS

Traditional Demonstrations:

Traditional anatomical demonstrations encompass cadaveric dissection, prosection, anatomical specimens, models, charts, museum preparations, histological slides, and faculty-led practical demonstrations. Among these, cadaveric dissection offers the most comprehensive exposure to the human body. Students can identify structures in their natural relationships, appreciate anatomical variations, and develop tactile and psychomotor skills (14).

Recent evidence continues to support cadaveric dissection as an important component of anatomy education. A 2025 cross-sectional study involving medical and dental students reported strong perceptions of the educational and professional value of dissection. Another contemporary study found that students valued cadaveric learning while also recognizing the benefits of digital resources for visualization and interactive learning (15).

However, traditional approaches are associated with practical limitations, including cadaver procurement and preservation, laboratory infrastructure, faculty requirements, restricted teaching schedules, specimen deterioration, and difficulty providing repeated access to specific structures. These limitations are particularly relevant in institutions with large student cohorts.

Technology-Enhanced Demonstrations:

Technology-enhanced demonstrations include 3D anatomical models, virtual dissection, VR, AR, 3D printing, digital microscopy, simulation, and AI-supported educational platforms.

VR allows learners to manipulate and explore anatomical structures in an immersive environment. A 2024 systematic review and meta-analysis of 27 experimental studies involving 2,199 health-science students found greater knowledge gains with immersive VR/AR than traditional approaches, with particularly favorable outcomes when these technologies were used as supplementary resources. Another 2024 meta-analysis found a moderate beneficial effect of VR on anatomy knowledge, although results for AR were not statistically significant and considerable heterogeneity existed among studies (16).

A 2025 systematic review similarly reported favorable perceptions of VR and improvements in conceptual understanding and learning confidence, while emphasizing variation in hardware, instructional design, and outcome measures.

AR provides another approach by superimposing digital structures onto physical models or real-world environments. Recent curriculum-based research and systematic reviews suggest that AR can enhance visualization and engagement, although its superiority over conventional teaching is not consistently demonstrated (17).

Three-dimensional printing provides tangible models that can be handled similarly to physical specimens. A recent review of reviews found potential benefits in spatial understanding and teaching complex structures, while a 2025 evaluation reported educational usefulness but continued recognition of natural specimens as an important resource.

AI introduces additional possibilities through automated anatomical labelling, adaptive learning, intelligent tutoring, image interpretation, question generation, and personalized feedback. Emerging studies suggest potential value, but current evidence also demonstrates variability in accuracy. Consequently, AI-generated educational material requires expert validation before incorporation into formal teaching (18).

DISCUSSION

The evidence indicates that traditional and technology-enhanced demonstrations address different educational needs. Traditional teaching provides authenticity; technology provides flexibility. The cadaver allows students to experience real tissues, anatomical variation, tissue consistency, spatial relationships, and the ethical significance of human donation. These experiences are difficult to reproduce completely using digital platforms (19).

Technology-enhanced learning, in contrast, provides opportunities for visualization, repetition, manipulation, and individualized learning. A digital model can be rotated, enlarged, sectioned, labelled, and revisited without specimen deterioration. This is particularly valuable for regions such as the skull, brain, pelvis, thorax, and musculoskeletal system, where three-dimensional relationships can be challenging to appreciate (20).

The strongest evidence currently supports technology as an adjunct rather than a replacement for traditional teaching. The 2024 meta-analysis by García-Robles et al. found the greatest knowledge benefit when immersive technologies were used as complementary learning resources. Similarly, a 2024 study integrating VR into a conventional gross anatomy laboratory reported improved engagement and perceived understanding when VR supplemented dissection (21).

This complementary model is particularly appropriate for CBME. A demonstration can be designed around a specific competency rather than around technology itself. For example, students may first use a 3D model to identify structures, subsequently examine the corresponding structures during cadaveric dissection, and finally apply their knowledge to CT, MRI, clinical examination, or a simulated procedure (8).

A practical CBME-oriented sequence can therefore be:

Pre-demonstration: 3D/VR orientation → Practical demonstration: cadaver/prosection → Clinical integration: imaging or simulation → Assessment: OSPE/clinical case → Remediation: digital or AI-assisted learning.

This sequence preserves the authenticity of conventional teaching while using technology where it offers additional educational value.

AI requires particular caution. Recent research shows that students may find AI-generated questions and explanations useful, but confidence in accuracy remains incomplete. A 2026 systematic review of ChatGPT in anatomy education reported wide variation in accuracy across models and studies, supporting the need for faculty oversight. Thus, AI should not function as an unsupervised source of anatomical truth (16).

Implementation also requires consideration of cost, faculty training, infrastructure, digital accessibility, technical support, data privacy, academic integrity, and potential technology fatigue. Institutions should therefore select technologies according to educational objectives and evidence of effectiveness rather than technological novelty (22).

The future of anatomy education is consequently unlikely to be exclusively traditional or digital. Instead, the emerging model is blended anatomy education, in which the cadaver remains the authentic reference while digital technologies provide additional visualization, simulation, assessment, and individualized learning.

CONCLUSION

Traditional and technology-enhanced demonstrations should not be regarded as competing approaches in CBME. Cadaveric dissection, prosection, specimens, and faculty-led demonstrations remain fundamental because they provide authentic anatomical, tactile, ethical, and professional experiences. Technology-enhanced approaches—including 3D models, VR, AR, 3D printing, simulation, and AI—provide valuable additional opportunities for visualization, repetition, personalization, and clinical integration.

Current evidence particularly supports VR and other immersive technologies when they are deliberately integrated with conventional instruction rather than used as complete substitutes. AI has considerable future potential but should remain subject to expert validation and faculty supervision.

For CBME, the most appropriate strategy is therefore a purpose-driven blended model: traditional methods should provide authentic anatomical experience, while technology should be introduced to strengthen specific competencies that benefit from visualization, simulation, clinical correlation, or personalized feedback. Such integration can produce anatomy education that is scientifically rigorous, clinically relevant, learner-centred, and responsive to the demands of modern medical practice.

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REFERENCES

1. García-Robles P, Cortés-Pérez I, Nieto-Escámez FA, García-López H, Obrero-Gaitán E, Osuna-Pérez MC. Immersive virtual reality and augmented reality in anatomy education: a systematic review and meta-analysis. Anat Sci Educ. 2024;17(3):514-528. doi:10.1002/ase.2397.
2. Salimi S, Asgari Z, Mohammadnejad A, Teimazi A, Bakhtiari M. Efficacy of virtual reality and augmented reality in anatomy education: a systematic review and meta-analysis. Anat Sci Educ. 2024;17(9):1668-1685. doi:10.1002/ase.2501.
3. Adnan S, Benson AC, Xiao J. How virtual reality is being adopted in anatomy education in health sciences and allied health: a systematic review. Anat Sci Educ. 2025;18(5):496-525. doi:10.1002/ase.70027.
4. Sawant SP et al. Artificial intelligence in anatomical demonstrations: transforming teaching methodologies in modern medical education. Adv Int J Res. 2026;7(3):1-10. doi:10.63363/aijfr.2026.v07i03.6075.
5. Odogwu C, et al. Effect of virtual reality simulation on anatomy learning outcomes: a systematic review. [Journal details]. 2025. PMID:40342485.
6. Williams A, Sun Z, Vaccarezza M. Comparison of augmented reality with other teaching methods in learning anatomy: a systematic review. Clin Anat. 2025;38(2):168-185. doi:10.1002/ca.24234.
7. Neri I, Cercenelli L, Marcuccio M, et al. Dissecting human anatomy learning process through anatomical education with augmented reality: AEducAR 2.0, an updated interdisciplinary study. Anat Sci Educ. 2024;17(4):693-711. doi:10.1002/ase.2389.
8. Boyanovsky BB, Belghasem M, White BA, Kadavakollu S. Incorporating augmented reality into anatomy education in a contemporary medical school curriculum. Cureus. 2024;16(4):e57443. doi:10.7759/cureus.57443.
9. Al-Rubaie A. From cadavers to codes: the evolution of anatomy education through digital technologies. Med Sci Educ. 2025;35(2):1101-1109. doi:10.1007/s40670-024-02268-6.
10. Wood KN, McWatt S, Risha N, Mensink P. Analyzing the use of digital and physical anatomical teaching models in anatomy training. Adv Physiol Educ. 2025;49(2):572-581. doi:10.1152/advan.00030.2025.
11. Paymard M, et al. An evaluation of the use of 3D-printed anatomical models in anatomy education. Surg Radiol Anat. 2025;47(1):199. doi:10.1007/s00276-025-03704-x.
12. Chytas D, Noussios G, Salmas M, Demesticha T, Vasiliadis AV, Troupis T. The effectiveness of three-dimensional printing in undergraduate and postgraduate anatomy education: a review of reviews. Morphologie. 2024;108(361):100759. doi:10.1016/j.morpho.2023.100759.
13. Bansal A, Gajrani A, Sharma P, et al. Perspectives and performance of first-year medical and dental students in anatomy education through cadaveric dissection: a cross-sectional study. Cureus. 2025;17(2):e78648. doi:10.7759/cureus.78648.
14. Sawant SP, Rizvi S. Merits of student-centered learning in anatomy. In: Advanced Concepts in Medicine and Medical Research. Vol. 10. 2023. p.172-183.
15. Collins BR, Black EW, Rarey KE. Introducing AnatomyGPT: a customized artificial intelligence application for anatomical sciences education. Clin Anat. 2024;37(6):661-669. doi:10.1002/ca.24178.
16. Chytas D, Noussios G, Paraskevas G, et al. Can ChatGPT play a significant role in anatomy education? A scoping review. Morphologie. 2025;109(365):100949. doi:10.1016/j.morpho.2025.100949.
17. Erbek E, Çalışkan Pala S, Bolatlı G, Çavuş F. Artificial intelligence in

anatomy education: a systematic review of ChatGPT's effectiveness as a learning tool. Proc (Bayl Univ Med Cent). 2026;39(2):315-323. doi:10.1080/08998280.2026.2612683.

18. Yi KH, et al. Artificial intelligence in anatomic education: educational utility, safety boundaries, and implementation considerations. J Craniofac Surg. 2026. PMID:41842848.
19. Almamari A, Al-Farsi M, Almamari AR, Abdellatif H. The perceived effectiveness of AI-powered tools in undergraduate anatomy education: a cross-sectional multifaceted evaluation. Clin Anat. 2026. doi:10.1002/ca.70188.
20. Bolatli G, Birisci S, Bolatli Z. An alternative approach in anatomy education: design of a learning environment based on artificial intelligence-supported virtual manipulatives and investigation of its effectiveness. Clin Anat. 2026;39(1):30-44. doi:10.1002/ca.70008.
21. García-Robles P, et al. The effectiveness of immersive virtual reality as a student-centered tool for learning neuroanatomy: a single-blind randomized controlled trial. Anat Sci Educ. 2025;18(10):1083-1094. PMID:40524142.
22. Elbeshbeishy R, Salama R, Manjunatha Goud BK, et al. Unveiling the perceptions of medical and allied health students towards cadaveric dissection and virtual resources in anatomy education: a cross sectional study. BMC Med Educ. 2025;25:829. doi:10.1186/s12909-025-07432-z.