



THE EFFECTIVENESS OF 3D ANATOMICAL MODELS IN TEACHING HUMAN
ANATOMY TO MEDICAL STUDENTS

Turgunova Dildora Ziyapovna
Andijan Branch of Kokand University, Uzbekistan
Email: turgunovakuaf@gmail.com
ORCID: 0049-3922-3944-2234



Abstract

Human anatomy is one of the fundamental subjects in medical education and requires students to understand complex three-dimensional relationships between organs, tissues, vessels, nerves, and anatomical regions. Traditional teaching methods based on textbooks, atlases, lectures, and cadaveric dissection remain important, but they may not always provide sufficient opportunities for repeated visualization and spatial learning. The aim of this study was to evaluate the educational effectiveness of three-dimensional anatomical models in teaching human anatomy to medical students. A literature-based analytical approach was used to examine the influence of physical and digital 3D models on anatomical knowledge, spatial understanding, student engagement, motivation, and long-term retention. The reviewed evidence indicates that 3D anatomical models can improve visualization of complex structures, facilitate understanding of anatomical relationships, and support active learning. Their greatest educational value is observed when they complement, rather than replace, conventional teaching methods. The integration of 3D technologies into anatomy education may therefore contribute to more effective, interactive, and clinically oriented medical training.

Keywords: human anatomy, medical education, 3D anatomical models, anatomy teaching, spatial learning, medical students, educational technology.

Introduction

Human anatomy forms the structural basis of medical knowledge and provides essential information required for understanding physiology, pathology, surgery, radiology, and clinical medicine. Medical students are expected not only to memorize anatomical terminology but also to understand the spatial relationships between structures and apply this knowledge in clinical situations.

Traditional anatomy education has historically relied on lectures, textbooks, anatomical atlases, cadaveric dissection, prosected specimens, and plastic models. Cadaver-based education remains particularly valuable because it exposes students to real anatomical variation and provides direct experience with human tissues. However, cadaveric teaching may be limited by availability, cost, ethical considerations, preservation requirements, laboratory time, and the difficulty of repeated independent practice.

Two-dimensional anatomical images are useful for presenting basic information, but they may be insufficient for students who have difficulty mentally reconstructing complex three-dimensional structures. Areas such as neuroanatomy, cardiovascular anatomy, pelvic anatomy, cranial anatomy, and musculoskeletal relationships frequently require advanced spatial reasoning.



URGANCH DAVLAT TIBBIYOT INSTITUTI JANUBIY OROLBO'YI TIBBIYOT JURNALI

2 - TOM, MAXSUS SON-3. 2026

14.00.00 - TIBBIYOT FANLARI ISSN: 3093-8740

The development of three-dimensional anatomical models has created new opportunities for teaching. These models may include physical replicas produced by conventional manufacturing or 3D printing, computer-generated interactive models, and digital applications that allow structures to be rotated, enlarged, isolated, or viewed from multiple perspectives.

The educational advantage of these technologies lies in their ability to convert abstract anatomical information into visually accessible spatial representations. Students can repeatedly explore structures and examine relationships between organs, vessels, nerves, bones, and muscles.

The aim of this study was to evaluate the effectiveness of 3D anatomical models in teaching human anatomy to medical students and to analyze their influence on knowledge acquisition, spatial understanding, motivation, and clinical learning.

Materials and Methods

This study was conducted as a qualitative analytical review of scientific literature concerning the use of three-dimensional anatomical models in undergraduate medical education.

Peer-reviewed studies and educational reviews examining physical 3D models, 3D-printed anatomical structures, virtual anatomical models, and interactive digital platforms were considered. Particular attention was given to studies comparing 3D-based teaching with traditional lectures, textbooks, two-dimensional illustrations, conventional plastic models, and cadaver-based methods.

The analysis focused on several educational outcomes, including students' anatomical knowledge, spatial comprehension, examination performance, learning motivation, engagement, satisfaction, and ability to apply anatomical information in clinically relevant situations.

Studies involving musculoskeletal anatomy, neuroanatomy, cardiovascular anatomy, abdominal anatomy, and other complex anatomical regions were considered because these areas frequently require strong three-dimensional visualization skills.

The collected information was analyzed to identify consistent advantages, limitations, and appropriate educational roles of 3D anatomical models in contemporary medical curricula.

Results

The reviewed literature indicates that 3D anatomical models can significantly support the acquisition of anatomical knowledge, particularly when students are required to understand complex spatial relationships.

One of the main educational advantages is improved visualization. Traditional textbooks present anatomical structures on flat surfaces, whereas 3D models allow students to observe anatomical relationships from several directions. Rotation and manipulation of a model make it possible to identify structures that may be difficult to understand in two-dimensional illustrations.

Students can also examine layers separately. For example, during musculoskeletal anatomy teaching, individual muscles can be removed or isolated to demonstrate their origin, insertion, innervation, and relationship with surrounding structures.

In cardiovascular anatomy, 3D models can demonstrate the spatial organization of cardiac chambers, valves, coronary vessels, and major arteries. In neuroanatomy, they may help students visualize complex structures such as the ventricular system, cranial nerves, cerebral pathways, and relationships within the brainstem.

Another important finding is increased student engagement. Interactive models encourage students to participate actively rather than passively receiving information during lectures. Students can explore structures independently, test their understanding, and repeat difficult topics.

Repeated access is a major advantage of digital 3D models. Unlike cadaveric specimens that may only be available during scheduled laboratory sessions, digital anatomical models can often be accessed through computers, tablets, or mobile devices.

This flexibility allows students to study at their own pace. Difficult anatomical areas can be revisited multiple times until adequate understanding is achieved.



URGANCH DAVLAT TIBBIYOT INSTITUTI JANUBIY OROLBO'YI TIBBIYOT JURNALI

2 - TOM, MAXSUS SON-3. 2026

14.00.00 - TIBBIYOT FANLARI ISSN: 3093-8740

Three-dimensional models may also support students with different learning styles. Visual and spatial learners may particularly benefit from interactive representations, while students who prefer practical manipulation may benefit from physical 3D-printed models.

Another educational benefit is the ability to present pathological or patient-specific anatomy. Three-dimensional printing technologies can create models based on computed tomography or magnetic resonance imaging data. Such models may demonstrate congenital abnormalities, tumors, vascular variations, fractures, and complex surgical anatomy.

This creates a connection between preclinical anatomy and clinical medicine.

Studies have also suggested that 3D models may improve short-term knowledge acquisition and examination performance in some anatomical topics. Their effect appears particularly strong when the anatomical region has complicated spatial relationships.

However, the evidence does not support the complete replacement of traditional anatomy teaching.

Cadaveric dissection provides information that models cannot fully reproduce. Real human specimens demonstrate tissue texture, natural variation, anatomical complexity, and spatial relationships within an actual body.

Similarly, textbooks and atlases remain useful because they provide standardized terminology, diagrams, descriptions, and systematic organization.

Therefore, the strongest educational approach appears to involve combining different methods.

Three-dimensional models can be used before dissection to prepare students for laboratory work, during practical classes to clarify difficult structures, and after laboratory sessions to reinforce previously learned information.

The effectiveness of 3D models also depends on their quality. Simplified or inaccurate models may create misconceptions. Models must therefore be anatomically correct and appropriately designed for the educational objective.

Digital technologies may also require suitable hardware, software, technical support, and instructor training.

Despite these limitations, the overall evidence indicates that 3D models provide a useful complementary tool in modern anatomy education.

Discussion

The findings of this review demonstrate that three-dimensional anatomical models can substantially improve the learning environment in medical anatomy education.

Anatomical learning requires both factual knowledge and spatial understanding. Students must recognize not only the names of anatomical structures but also their positions, directions, relationships, and clinical significance.

This requirement explains why 3D visualization can be particularly useful.

The educational effectiveness of 3D models can also be explained through active learning principles. When students manipulate a model, select structures, rotate organs, or explore anatomical layers, they interact directly with the learning material.

This active participation may improve attention and promote more meaningful learning compared with passive observation alone.

Another important factor is cognitive load.

Complex anatomical diagrams can contain large amounts of information. Students may experience difficulty mentally converting two-dimensional images into three-dimensional structures.

Interactive 3D models reduce some of this mental reconstruction requirement by presenting spatial relationships directly.



URGANCH DAVLAT TIBBIYOT INSTITUTI JANUBIY OROLBO'YI TIBBIYOT JURNALI

2 - TOM, MAXSUS SON-3. 2026

14.00.00 - TIBBIYOT FANLARI ISSN: 3093-8740

However, excessive visual information may also increase cognitive load. If a digital model simultaneously displays too many structures, labels, colors, or animations, students may become distracted.

Therefore, effective educational design is essential.

The role of teachers also remains important.

Three-dimensional technology does not automatically produce better learning. Instructors should guide students toward clinically important relationships, explain anatomical terminology, and integrate models with lectures, dissection, radiological images, and clinical cases.

One particularly valuable application is the integration of anatomy with medical imaging.

Students can compare a 3D anatomical model with CT, MRI, ultrasound, or radiographic images. This may improve their ability to translate basic anatomical knowledge into clinical interpretation.

Three-dimensional printing also has potential for individualized education. Patient-specific anatomical models may allow students to study real variations and pathological conditions.

This approach can be particularly useful in surgical anatomy, orthopedics, neurosurgery, cardiovascular medicine, and maxillofacial education.

Nevertheless, financial and technical limitations should be considered.

High-quality printers, software licenses, advanced visualization systems, and technical maintenance may be expensive. Less-resourced institutions may therefore need to introduce such technologies gradually.

Another challenge is curriculum integration.

If 3D models are used only as optional demonstrations without connection to learning objectives or assessment, their educational value may remain limited.

Their use should be linked to clearly defined competencies and practical tasks.

The available evidence therefore suggests that 3D anatomical models should be considered complementary teaching tools rather than replacements for established methods.

A blended educational model combining lectures, atlases, cadaveric material, physical models, digital visualization, clinical imaging, and case-based learning may provide the most comprehensive anatomy education.

Conclusion

Three-dimensional anatomical models represent an effective and increasingly valuable educational tool for teaching human anatomy to medical students.

Their main advantages include improved visualization of complex anatomical relationships, enhancement of spatial understanding, increased student engagement, repeated access to learning materials, and stronger integration between basic anatomy and clinical medicine.

Physical 3D-printed models and digital interactive systems can be particularly useful for teaching anatomically complex regions such as the brain, heart, pelvis, cranial structures, and musculoskeletal system.

However, 3D models should not completely replace cadaveric dissection, textbooks, anatomical atlases, or instructor-guided learning.

Their greatest educational effectiveness is achieved when they are integrated into a multimodal teaching strategy.

The successful implementation of 3D anatomy education requires accurate models, appropriate technology, trained instructors, clearly defined educational objectives, and integration with clinical applications.

Overall, combining 3D anatomical models with traditional teaching methods can contribute to a more interactive, understandable, clinically relevant, and student-centered approach to anatomy education.



URGANCH DAVLAT TIBBIYOT INSTITUTI JANUBIY OROLBO‘YI TIBBIYOT JURNALI

2 - TOM, MAXSUS SON-3. 2026

14.00.00 - TIBBIYOT FANLARI ISSN: 3093-8740

References

1. Azer SA, Azer S. 3D anatomy models and impact on learning: A review of the quality of the literature. *Health Professions Education*. 2016;2(2):80–98.
2. Yammine K, Violato C. A meta-analysis of the educational effectiveness of three-dimensional visualization technologies in teaching anatomy. *Anatomical Sciences Education*. 2015;8(6):525–538.
3. Hackett M, Proctor M. Three-dimensional display technologies for anatomical education: A literature review. *Journal of Science Education and Technology*. 2016;25:641–654.
4. Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 5th ed. Elsevier; 2023.
5. Estai M, Bunt S. Best teaching practices in anatomy education: A critical review. *Annals of Anatomy*. 2016;208:151–157.
6. Lim KHA, Loo ZY, Goldie SJ, Adams JW, McMenamin PG. Use of 3D printed models in medical education: A randomized control trial comparing 3D prints versus cadaveric materials for learning external cardiac anatomy. *Anatomical Sciences Education*. 2016;9(3):213–221.
7. McMenamin PG, Quayle MR, McHenry CR, Adams JW. The production of anatomical teaching resources using three-dimensional printing technology. *Anatomical Sciences Education*. 2014;7(6):479–486.
8. Triepels CPR, Smeets CFA, Notten KJB, et al. Does three-dimensional anatomy improve student understanding? *Clinical Anatomy*. 2020;33(1):25–33.
9. Ghosh SK. Cadaveric dissection as an educational tool for anatomical sciences in the 21st century. *Anatomical Sciences Education*. 2017;10(3):286–299.
10. Moro C, Štromberga Z, Raikos A, Stirling A. The effectiveness of virtual and augmented reality in health sciences and medical anatomy. *Anatomical Sciences Education*. 2017;10(6):549–559.