

Anatomy and Physiology Teaching After COVID-19

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Abstract

The COVID-19 pandemic prompted rapid changes in anatomy and physiology education and renewed discussion about how practical subjects can be taught remotely. This narrative review examines teaching approaches described in literature published during 2020–2023, including virtual and augmented reality, three-dimensional models, online learning, home laboratory activities, simulation and collaborative teaching. The literature illustrates how digital tools can support visualisation, flexible access and student participation while complementing practical instruction. Four tables summarise the teaching methods and tools described in the cited studies. Reported benefits vary across settings, technologies and learning outcomes; the review does not establish that any one approach is universally superior. The discussion considers how educators can combine digital resources with practical experience, select technologies for defined educational goals and support students during changes in delivery. These approaches offer lessons for course design following the emergency transition to remote teaching.

Keywords: Anatomy, physiology, virtual reality classes, post-COVID-19, dissection tools, online learning

Introduction

Anatomy and physiology provide a foundation for medical, nursing and allied health education. Their concepts recur in clinical training, simulation and professional assessment (Hillyer and Gordon 2020; Kagan et al. 2021; Saravanan et al. 2023). Students need to understand both the structure of the human body and the relationships between its parts. Cadaver dissection offers an opportunity to examine three-dimensional relationships and anatomical variation, and it introduces students to the responsibilities associated with handling human remains (Papa et al. 2022). Dissection also reveals the textures and distinctive characteristics of organs and tissues (Arráez-Aybar et al. 2023). This

understanding supports the interpretation of medical images and physical examination. Digital learning therefore needs to be considered in relation to these practical educational purposes, rather than simply as a change in the medium through which information is delivered.

Since the middle of the 20th century and throughout the 21st century, significant obstacles to instructing anatomy in medical institutions have been found (Papa et al. 2022). The COVID-19 pandemic created major obstacles during the period covered by this review, prompting unanticipated and quick modifications in anatomy teaching strategies and offering a chance for a significant redesign of the medical curriculum's explanation of human anatomy (Abid et al. 2021; Ghazi-Saidi et al. 2020; Papa et al. 2022). The transition from in-person to virtual instruction is evidence of how the previously mentioned challenge, along with technological advancements and increasing opportunities for internet-based instruction, have significantly raised the burden on anatomy education. The development of new digital technologies like augmented and virtual reality has made this pressure more noticeable in recent years (Krajčovič et al. 2022; Kumar et al. 2023). As a result, universities all around the world have implemented various teaching strategies. Online teaching offered continuity and opportunities for active learning, while limiting tactile experience available during face-to-face anatomy instruction (Papa et al. 2022). Medical schools consequently needed to incorporate online learning into their curricula at short notice. Medical schools all over the world were forced by the epidemic to be creative and embrace blended learning or online virtual classrooms. The COVID-19 crisis forced medical schools around the globe to swiftly migrate to online interactive classrooms, involving entirely digital dissection exercises in anatomy, or implement blended instruction. This gave the anatomical sciences, in particular, an intriguing push for creativity (Ward 2021).

With the use of virtual environments, augmented reality, and immersive 3D visualisation tools, learners can now examine the anatomical framework and physiological events in a secure, fascinating setting (Gloy et al. 2022; Mendez-Lopez et al. 2022). These technological developments have not only overcome physical boundaries but have also made flexibility possible on a level that was formerly unimaginable. The epidemic has also highlighted the value of adaptability and perseverance in schooling. To gauge learners' abilities and expertise, teachers are employing cutting-edge assessment techniques including online quizzes, simulations, and virtual dissections. These techniques have promoted critical thinking and problem-solving skills in addition to ensuring regular evaluation. In this changing environment, educators' responsibilities today include not only imparting knowledge but also encouraging digital literacy and independent study. It is encouraged for students to take charge of their education by participating in cooperative, peer-led learning groups and independently investigating resources. This narrative review aims to examine these paradigm shifts in post-COVID anatomy and physiology instruction, examining the diverse approaches, resources, and methodologies used by teachers to respond to the opportunities and challenges of this revolutionary period. By analysing these methods critically, we hope to inform discussion of medical education's

future and add to the conversation about pedagogical innovation in the post-pandemic era.

Virtual Reality and Three-Dimensional Representations

In recent years, a variety of innovative technologies have been harnessed to revolutionize anatomy education. VeLight is a technology that Yu et al. 2022 created so that students could learn the human body based on CT information employing a 3D Virtual Reality display (zSpace). VeLight empowers instructors to create instructional material leveraging their own materials and delivers straightforward, obvious interactions. Using virtual reality headsets, Fairén et al.'s VR4Health program enables learners to view 3D representations of various human body parts up close. The program is made to be used independently in an HMD gadget as a self-learning tool. It also feeds facts to teachers so they can monitor learners' activities and may focus their efforts on the specific needs of the students. An interactive three-dimensional (3D) graphic instructional object displaying an up-to-date understanding of the physiology and anatomy of sucking and swallowing in infants is created and updated by Puccini et al. in 2022. Innovation in medical and health education was achieved through a learning system that combines three-dimensional intelligent interactive models with audio, visual, and light elements with a software program. This system enabled learning about science branches including anatomy and histology (Taş and Bolatlı 2022).

Users were able to interact with an immersive virtual anatomy atlas to discover human anatomical structures (Gloy et al. 2022). Due to the immersive nature of the virtual reality environment and the ability to autonomously and dynamically navigate an accurate depiction of human anatomy, VR learning may support factual learning, especially when used to assist cadaver dissection courses. Mendez-Lopez et al. created an augmented reality app for mobile devices in 2022 to display anatomical and physiological data pertaining to the brain and carried out an educational endeavor utilizing 3D visualization techniques using the AR platform. An inexpensive auxiliary that nevertheless maintains educational benefits is anatomic modelling created using "desktop" three-dimensional (3D) printing (Clifton et al. 2020). Moro et al. 2021 evaluated the efficacy of instruction when a similar course was presented using augmented reality through either the Microsoft HoloLens or a portable tablet device. Applying a case-focused method with XR technology, Nakamatsu et al. (2022) sought to enhance student inquiry and involvement by explaining radiographic anatomy. Cadavers were scanned using an MRI machine and then assessed for radiological, pathological, and anatomical conditions before case presentations according to X-ray visualizations and student participation. The C3-7 spine was split into its own distinct facet and transverse regions, and replicas of the spine were 3D printed by Clifton et al. in 2021 as part of their investigation into an excellent clarity separation

and 3D printing technique.

Table 1: [Virtual reality](#) and 3D representation classes for anatomy and physiology education

Author(s)	Year	Teaching/Learning Method	Tools Used
Yu <i>et al.</i>	2022	Anatomy learning with VR using VeLight	3D Virtual Reality display (zSpace)
Fairén <i>et al.</i>	2020	Self-learning with VR4Health application	Virtual Reality systems (HMD device)
Puccini <i>et al.</i>	2022	3D graphic video for newborn anatomy	Dynamic 3D graphic video
Taş and Bolatlı	2022	Smart interactive models for science education	3D smart interactive models, application
Gloy <i>et al.</i>	2022	Interactive anatomy atlas with VR	VR for interactive anatomical exploration
Mendez-Lopez <i>et al.</i>	2022	Mobile AR application for brain visualization	Mobile AR application
Clifton <i>et al.</i>	2020	Anatomical simulation through 3D printing	“Desktop” 3D printing
Moro <i>et al.</i>	2021	Learning with augmented reality (HoloLens or tablet device)	Microsoft HoloLens or mobile tablet device
Nakamatsu <i>et al.</i>	2022	Case-based radiological anatomy using XR technology	MRI scanning, XR technology
Clifton <i>et al.</i>	2021	Educational model through high-resolution 3D printing	3D printing for vertebral models

Online Learning

Jaberzadeh and Mansouri (2021) developed two short-term research projects and detail how different elements of the aforementioned initiatives, such as instructions, trials, and evaluations, have been altered to ensure the necessary physical distancing in order to carry out home-based research concerning cognitive neuroscience at Monash University and accomplish the educational goals that typically take place in face-to-face practical sessions. For students in undergraduate programmes from several medical programmes in the KSA, Al-Neklawy and Ismail 2022 examined the Blackboard (Bb) collaborative platform for virtual team-based learning (TBL) events. Recent developments

regarding learning have shown that models and smartphone applications can be useful tools for nursing educators and that the Clinic Vitals mobile app can be a resource for supporting vital-sign instruction (Hester et al. 2021). H5P was employed as a framework to encourage independent and autonomous learning while providing an in-depth examination of the process of development involved in connecting tasks with instructional objectives. Because the H5P tasks were integrated with the internet-based educational administration platform, it was possible to monitor how often students accessed these assets (Sinnayah et al. 2021). By encouraging learners to learn for themselves via engaged involvement in small groups, METAPAD was an effective puzzle-based learning activity for comprehending the intricate nature of biochemical pathways. The METAPAD game puzzle is seen by students as a technique of teaching and learning that actively engages them and fosters their creativity, critical thinking and problem-solving skills (Surapaneni 2023). In a physiology course at Chile's Universidad Andrés Bello, serious games were employed in addition to concurrent online classrooms to maintain a regularity of instructional activities. Gamification, a popular learning technique for online instruction mandated by COVID-19, calls for the utilization of serious games as a tactic (Arias-Calderón et al. 2022).

To narrow the gap between live group discussion (GD) and virtual GD in the conventional manner (VGD), Kaur et al. 2021 created a new yet practical multistep technique for carrying out structured virtual group discussion (sVGD). It included prepping the learners and incorporating the successive sections of the Tuckman framework for group dynamics—forming, storming, norming, and performing into the virtual format. A preliminary 3-week online physiology course using Rain Classroom and the smartphone app WeChat was introduced by Feng et al. in 2022 and they assessed the results of the virtual education in physiology. For a 1-month web course, Federal University of Pampa students studying medical sciences participated in synchronous conferences twice a week and asynchronous pursuits involving scenarios, scholarly publications, and participatory digital resources (Alves et al. 2021). When used to revisit pre-clinical concepts throughout medical rotations, vertical integration (VI) is a compelling instructional method that produces knowledge acquisition and student satisfaction throughout the workshop (Fogarasi et al. 2022). Using e-books in nursing education's hybrid curriculum's anatomy and physiology courses helped students prepare for self-directed study (Govindan et al. 2023).

Table 2: Anatomy and physiology learning based on online educational tools

Author(s)	Year	Teaching/Learning Method	Tools Used
Jaberzadeh and Mansouri	2021	Home-based studies in cognitive neuroscience	Online platform (Zoom), short-term research projects

Al-Neklawy and Ismail	2022	Online team-based learning (TBL) with Blackboard platform	Blackboard Collaborate platform
Hester <i>et al.</i>	2021	Mobile application for vital signs instruction	Clinic Vitals mobile application
Sinnayah <i>et al.</i>	2021	Self-paced and self-directed learning with H5P	H5P platform, online learning management system
Surapaneni	2023	Puzzle-based innovation (METAPAD) for biochemical pathways	METAPAD gaming puzzle
Arias-Calderón <i>et al.</i>	2022	Serious games as complement to synchronous online classes	Serious games for gamification
Kaur <i>et al.</i>	2021	Structured virtual group discussion (sVGD)	Tuckman model of group dynamics, virtual format
Feng <i>et al.</i>	2022	Preliminary online physiology course with Rain Classroom	Rain Classroom, WeChat mobile application
Alves <i>et al.</i>	2021	Web course using online educational platforms	Online educational platforms, synchronous and asynchronous activities
Fogarasi <i>et al.</i>	2022	Vertical integration (VI) to refresh pre-clinical concepts	Educational workshop for clinical rotations
Govindan <i>et al.</i>	2023	Blended learning with e-books for anatomy courses	E-books for anatomy and physiology, blended learning

Technology for Practical Sessions

During the pandemic, a major concern for cadaveric dissection was the sourcing and availability of bodies that can be used for dissection. The International Federation of Associations of Anatomists (IFAA) acknowledges that body sourcing is usually challenging during pandemics such as Covid-19. The possibility of contracting diseases can exacerbate this problem during such outbreaks. The medical school's in person practical was substituted with online spirometry practicals via Zoom, in which the instructor displayed the medical school's practical while the students watched from their homes by electronically manipulating the instructor's laptop (Bhaskar et al. 2020) and an instructional strategy known as hybrid learning, in which learners were given permission to use internet-based educational resources and performed experimental tasks using readily available common household

supplies and smartphones while at home (Youssef et al. 2021; Dutta 2022). In an educational institution classroom, Flores and Marzullo 2021 created a straightforward procedure for making high-magnification glass and gelatin ball lenses. They also created an optimized system to facilitate smartphone focusing and photo-taking. To assist instructors in delivering their anatomy and physiology laboratory workshops online, Mayerhofer et al. 2022 created a cheap, adaptable technology package coupled with openly accessible instructional materials. Digital education, collaborative instruction, and virtual classrooms were all used in the nontraditional classroom (NTC) methodologies used for physiology laboratory classes (Meng et al. 2022). The use of gamification, interactive instruction, and flipped educational settings in gross anatomy practical sessions improved individual retention and made the best use of the restricted practical period (Gómez et al. 2023). Head-mounted display technology can be utilised to improve educational results and boost student enthusiasm via realistic virtual reality laboratory models (Tsirulnikov et al. 2023). Virtual dissection was incorporated into the gastrointestinal anatomy course by Emadzadeh et al. in 2023, and the academic experience that resulted from this improved student comprehension.

Table 3: Virtual technologies to assist practical session.

Author(s)	Year	Teaching/Learning Method	Tools Used
Bhaskar <i>et al.</i>	2020	Online spirometry practical through Zoom	Zoom platform, remote control of teacher's laptop
Youssef <i>et al.</i>	2021	Blended learning approach	Online instructional material, household materials, mobile applications
Dutta	2022	Laboratory exercises at home with household materials	Household materials, mobile applications
Flores and Marzullo	2021	DIY ball lenses for high magnification photography	Glass and gelatin ball lenses, smartphone
Mayerhofer <i>et al.</i>	2022	Remote physiology laboratory courses with hardware kit	Customizable hardware kit, teaching resources
Meng <i>et al.</i>	2022	Nontraditional classroom (NTC) physiology laboratory classes	E-learning, peer teaching, flipped classroom
Gómez <i>et al.</i>	2023	Blended learning with flipped classrooms and gamification in gross anatomy practicals	Flipped classrooms, collaborative learning, gamification

Tsirulnikov <i>et al.</i>	2023	Immersive virtual reality laboratory simulations	Head-mounted display technology, VR simulations
Emadzadeh <i>et al.</i>	2023	Virtual dissection table for gastrointestinal anatomy	Virtual dissection table (VDT)

Other Teaching Approaches

The favored instructional approach for the education of pupils was the “flipped classroom,” which appeared to increase academic results, especially among learners who were underperforming on challenging concepts (Bansal et al. 2020). Medical students in Oman were given the opportunity to make memes pertaining to their educational goals in renal physiology because memes sparked interest in the subject, enabled collaboration among classmates, spelt out complicated notions simply, enhanced comprehension of associated ideas, and promoted an enjoyable environment for learning (Subbiramaniyan et al. 2022). Li et al. 2021 trained an AI dialogue platform to instruct students in medicine anatomy using a freely available machine learning architecture that was further refined with a tailored database. [Chatbots powered by artificial intelligence](#) make it possible to educate medical sciences through active discourse. With the aid of freely accessible software, instructors can construct sophisticated educational environments by modifying conventional technologies.

According to Lima et al. 2020, learners who are studying human anatomy and physiology digitally tend to use the YouTube, Zoom, Mentimeter, and Lt platform as their go-to resources. The Federal University of Minas Gerais created an emergency remote learning (ERL) plan that aided learners in gaining possession of technology and a web connection and permitted the resumption of lessons in an online format (Gonçalves-Manso et al. 2022). The UTA program helped students in college and actively assisted teachers throughout ERL by utilizing various technologies in web pages and online communities like Microsoft Teams, YouTube animated video courses, and Instagram. The modules in the Understanding Your Physiology (Lt by ADInstruments) course feature video instances that highlight various sorts of Lt actions in order to convey the educational material in an engaging manner (Halpin 2022). Through the use of Google group technology for CBT, medical scholars were able to investigate outside of the educational setting the practical uses of their basic sciences courses as early as their first year of study. This helped them strengthen their autonomous instruction and teamwork skills. CBT is an effective technique to develop analytical abilities, examine a variety of assets, and conceptualize relevant aspects of basic science (Vedi and Dulloo 2021). The collaboration between professions, interaction, and comprehension of laryngeal anatomy and voice health by learners taking artistic endeavors and speech-language pathology courses can all be improved with

the help of Seeing Voices (Hersh et al. 2023). A multidisciplinary group used superior technology to broadcast laryngeal images onto huge screens while providing in-depth, actual-time discussion for Seeing Voices, which consisted of two 3-hour courses held in a roomy university lecture hall. In two experimental scenarios, the usage of displays mounted on the heads has an effect on the students' enthusiasm for learning and performance.

To comply with the anatomy teaching requirements for various fields at multiple phases, Zhang et al. 2021 create three-dimensional (3D) digital anatomical models with anatomically realistic content. They also create an adaptive instructional system for educators and learners centred around the fundamental aspects of anatomy. More than 6,000 3D digital structural simulations, 5000 anatomical annotations, 50 anatomical function videos, and 150 microanatomy illustrations have been created using this academic, comprehensive, and multifaceted system. The instructional resources include sectional anatomy, anatomy of motion, topographic anatomy, systematic anatomy, and a virtual anatomical operation table. Cadaveric examinations assist the teachers in fostering participatory conversation with the pupils, which improves interpersonal abilities among them (Patra et al. 2023).

At the undergraduate level, ultrasonography was a legitimate teaching tool that helped students understand anatomy more efficiently and gain hands-on knowledge with cutting-edge technology (Alexander et al. 2021). At the higher stages of biomedical science, virtual microscopy is an potentially useful visual aid for better instruction and comprehension of histology (Singh and Naicker 2023). Images from microscopes may now be broadcasted to the entire class while also saving money on the expense of purchasing a microscope for each student thanks to the integration of huge monitors, applications, and microscopes. If learners can effectively employ this technique, sketching on an iPad can be a helpful complement for studying anatomy on paper (Styn et al. 2023). A straightforward and cost-free teaching strategy was described by Moszkowicz et al. in 2020 as a way to make up for the loss of daily classes conducted in the surgical section utilizing the Google Hangouts app. The challenges with anatomical instruction at the college of medicine at Al-Balqa Applied University in Jordan were addressed by the didactic method that incorporated anatomical models and the Anatomage Table (Funjan et al. 2023).

The use of High-Fidelity Mannequin, Complete 3D Anatomy software, and Anatomage Table are a few examples of particular innovations and inventions that make teaching anatomy and associated basic medical sciences simpler and more efficient (Owolabi and Bekele 2021). This was made possible through the successful implementation of a system for learning management called Canvas, as well as internet access for connecting, teleconferencing, virtual meetings, and meticulously planned online evaluation. The Anatomage Table serves as an immersive online instructional tool, an excellent “complement for cadaveric skill lab” discussions, and a tool for functional anatomy demonstration, prosection, digital dissection, and virtual representations of certain activities (Owolabi et al. 2022).

Students were directed through an in-depth understanding of anatomy, radiographic placement, and pathology utilising a realistic three-dimensional (3D) virtual radiography simulation tool while x-raying a virtual simulated patient in the virtual reality (VR) suite utilizing HTC Vive Pro™ headgear and hand controllers (O'Connor et al. 2021). Medical learners became passionate about utilising technological advances through the stereoscopic 3D education of neurological anatomy that was shown on a big specialised screen utilising a dual video projector (Jacquesson et al. 2020). The Hackspace for Innovation and Visualisation in Education at the University of British Columbia, Faculty of Medicine, is made up of various teams of learners and teachers who have resolved pedagogical problems and are working to deploy new technology and tools for learning. The HIVE's heterogeneity enhances its efficacy by offering a variety of viewpoints and encouraging collaboration between universities and professions (Muñoz-Leija et al. 2021). To become technically proficient in laparoscopic suturing and knot tying in an instructional environment, entirely autonomous training via e-learning may be a workable training technique (Schmidt et al. 2020).

Table 4: Additional teaching approaches and educational tools

Author(s)	Year	Teaching/Learning Method	Tools Used
Lima <i>et al.</i>	2020	Online tools for human physiology learning during COVID	Lt platform, Zoom, Mentimeter, YouTube
Gonçalves-Manso <i>et al.</i>	2022	Emergency remote learning (ERL) plan	Online tools, equipment, internet network
Halpin	2022	Lt by ADInstruments for interactive course delivery	Lt platform, video case studies, social media platforms
Vedi and Dulloo	2021	Google group technology for CBT	Google groups, online resources, self-directed learning
Hersh <i>et al.</i>	2023	Interprofessional collaboration in laryngeal anatomy	Quality equipment, large screens, interprofessional team
Zhang <i>et al.</i>	2021	3D digital anatomical models and anatomy teaching system	3D digital anatomical models, teaching system
Patra <i>et al.</i>	2023	Cadaveric dissections for interactive communication	Cadaveric dissections for interactive communication
Bansal <i>et al.</i>	2020	Flipped classroom for student learning	Flipped classroom instructional approach

Subbiramaniyan <i>et al.</i>	2022	Learning through memes in renal physiology	Use of memes for learning outcomes
Li <i>et al.</i>	2021	AI dialogue system for teaching medical students' anatomy	Open-source machine learning architecture, AI dialogue system
Alexander <i>et al.</i>	2021	Ultrasound for anatomy education at the bachelor level	Ultrasound technology
Singh and Naicker	2023	Virtual microscopy for histology teaching and learning	Virtual microscopy, software, large monitors
Styn <i>et al.</i>	2023	Tablet-based learning for anatomy	Drawing on tablets, digital platforms
Moszkowicz <i>et al.</i>	2020	Google Hangouts and anatomical models for surgical education	Google Hangouts, anatomical models
Funjan <i>et al.</i>	2023	Anatmage Table and anatomical models for education	Anatmage Table, anatomical models
Owolabi, J. and Bekele, A.	2021	Anatmage Table, Complete 3D Anatomy software, High-Fidelity Mannequin	Anatmage Table, 3D Anatomy software, Mannequin
O'Connor <i>et al.</i>	2021	3D virtual radiography simulation with VR technology	VR technology (HTC Vive Pro™ headsets and hand controllers)
Jacquesson <i>et al.</i>	2020	Stereoscopic 3D teaching of neuroanatomy	3D technology, video projectors
Muñoz-Leija <i>et al.</i>	2021	Innovative educational tools at the Hackspace for Innovation	Various educational technologies
Schmidt <i>et al.</i>	2020	E-learning for laparoscopic suturing and knot tying training	E-learning platforms

Conclusion

The literature reviewed from 2020–2023 illustrates a substantial expansion in the ways anatomy and physiology can be taught. Virtual reality, three-dimensional models, simulation and online resources supported continuity of education when access to classrooms and laboratories was restricted. Collaborative activities, home experiments and flexible delivery also created opportunities for

participation and independent learning. These developments offer useful options for course design, but reported benefits depend on the learning task, available resources and the students involved. Digital visualisation and practical experience serve related educational purposes, and their combination should follow clearly defined learning goals. Educators can draw on these approaches while evaluating student understanding, access and engagement in their own settings. The review is a narrative synthesis of selected literature and should not be interpreted as an exhaustive scoping review or a comparative estimate of intervention effectiveness.

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