

CHAPTER 11

Web-Based Apps and Augmented/ Virtual Reality for Anatomy Learning

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Introduction

A thorough understanding of anatomy is crucial in medical education and is regarded as a fundamental subject for precisely acquiring clinical and surgical practices (Singal et al., 2020). The study of anatomy is included in the initial years of medical education to establish the fundamentals necessary for clinical training and application (Turney, 2007). Cadavers, combined with theoretical lectures, have been a traditional approach to developing anatomical knowledge among medical students over many centuries. Even today, the dissection or prosection of cadavers is still widely recognized as the most effective method for learning anatomy (McLachlan, 2004). However, the ongoing advancements in science and technology significantly alter the nature of the learning process (Kenski, 2003). As a result, there was a transition from conventional teaching methods to innovative and diverse teaching techniques (Boff et al., 2020). In addition, the global education, health, and economic sectors have been significantly impacted by the Covid-19 pandemic that emerged in recent times. Various countries have implemented social and physical distancing policies as a preventative measure to curtail the spread of the disease.

Consequently, many schools and universities have shut down, affecting over 91% of students worldwide and experiencing disrupted education (UNESCO, 2020). Furthermore, the closure of anatomy labs and classrooms due to the pandemic has discontinued theoretical and practical lessons involving cadavers and models. Thus, there was an increased urgency to explore new technological teaching methods as a substitute for cadaver dissection in anatomy instruction at medical schools. Therefore, several universities have resorted to distance education as a substitute. However, the anatomy course faced challenges adjusting to remote learning methods because its practical training was conventionally dependent on cadaver dissections (Santos et al., 2022). Hence, some of the supplementary technologies that have been developed are currently under investigation (Singal et al., 2020; Wish-Baratz et al., 2020). Besides the negative impacts of the Covid-19 outbreak and its aftermath, the literature suggests significant benefits and prospects for incorporating diverse technological methods in teaching anatomy (Longhurst et al., 2020; Smith & Pawlina, 2021). Furthermore, there has been a proliferation of technological tools for teaching and learning anatomy due to the strong preference of today's younger students for technology-driven approaches (Border, 2019; Clunie et al., 2018). Within this framework, students are more involved in generating novel approaches to learning (Farias et al., 2015). Consequently, there has

been a substantial rise in the utilization of digital resources for teaching anatomy in the past twenty years (Trelease, 2014; Trelease et al., 2020).

With technology constantly progressing rapidly, there are revolutionary methods to study anatomy (Uruthiralingam & Rea, 2020). The literature on anatomy teaching mentions several types of technological resources, which include (Santos et al., 2022):

- 3D printing
- Extended reality (XR)
 - Virtual reality (VR)
 - Augmented reality (AR)
 - Mixed reality (MR)
- Digital tools – Web-based applications
 - Social media; Youtube, Facebook, etc.
 - Audiovisual resources; Screencasts.
 - Digital platforms
- Other technological resources
 - Ultrasound
 - Quick response code (QR code)
 - Audience response system (ARS) – Kahoot! Etc.

Various technologies, techniques, and methodologies are employed in anatomical education, but augmented and virtual reality with web-based apps have gained significant attention and popularity (Barry et al., 2016; Uruthiralingam & Rea, 2020). These emerging technologies are increasingly gaining popularity, making them valuable alternative options for educators (Duarte et al., 2020).

Extended reality (XR)

(Virtual reality+Augmented reality+Mixed reality)

Extended reality (XR) refers to technologies that offer immersive experiences by merging the physical and virtual dimensions. This term encompasses human-machine interactions and computer-generated environments, from incorporating virtual objects into real-world settings to completely immersive digital experiences (Fast-Berglund et al., 2018). The term "XR" is used to describe a spatially immersive ecosystem that encompasses virtual reality (VR), augmented reality (AR), and mixed reality (MR) hardware collectively. The purpose of this ecosystem is to facilitate immersive learning experiences. The studies were grouped as XR when the visualization technologies created immersive 3D depictions of the human body, which enabled a direct comparison between these methods and traditional 2D teaching techniques (Moro et al., 2021).

Virtual Reality: The individual is completely immersed in a synthetic environment, which they experience through sensory stimulation such as sight, hearing, and movement. This stimulation imitates real-world properties and is facilitated by high-quality, continuously updating head-mounted displays, stereo headphones, and motion-

tracking systems (Moro et al., 2021).

Virtual reality is a sophisticated interface for interacting with users and an operating system facilitated by graphical resources and computer-based applications. This interaction is achieved through computational techniques and equipment designed to immerse individuals in three-dimensional (3D) environments, allowing them to interact with the virtual elements in real-time (Tori & da Silva Hounsell, 2020).

Augmented Reality: AR is a technology that incorporates digitally created virtual elements into the physical environment, and it is defined by the simultaneous existence and interaction of real and virtual objects (Azuma et al., 2001). AR involves projecting digital models onto the real world using a camera and screen, such as a smartphone or tablet. As a result, the user can engage with both the tangible and virtual components of their surrounding environment (Moro et al., 2021). The categorization of AR can be based on how the user perceives the mixed world:

When computer-generated virtual objects can be visualized directly by the human eye, either by merging them with real-world video or integrating them seamlessly into the environment, it is referred to as direct vision or immersive. Conversely, when real and virtual images are blended in a video and presented to the individual through a device like a monitor or a projector without precise alignment, the resulting reality is categorized as indirect or non-immersive (Santos et al., 2022).

While VR aims to provide a fully immersive experience where users are completely immersed in a simulated environment, AR does not necessarily offer the same level of immersion. AR allows for the overlay of virtual objects onto the real world, but it still maintains a connection to the user's physical surroundings. The user remains aware of the real world while interacting with virtual elements in AR, which sets it apart from the fully immersive nature of VR (Tori & da Silva Hounsell, 2020).

Mixed Reality: AR involves superimposing digital information onto real-life objects, whereas MR offers an added level of engagement. The MR technology projects holographic images anchored to real-world objects, allowing users to interact with them as physical objects (Moro et al., 2021).

Mixed reality combines features from both VR and AR, blending computer-generated 3D virtual objects with the real world. It enables users to interact in real time using technological devices. As a result, MR creates novel environments that merge virtual and physical elements, seamlessly integrating virtual components into reality or real-world elements into the virtual realm. These elements coexist and interact, enhancing the overall experience (Rodello et al., 2010).

Among the tools utilized for visualizing 3D models in anatomy through extended reality technology, some examples include:

- Virtual dissection table (Sh et al., 2019).
- Microsoft HoloLens (Weeks et al., 2021).
- Oculus Rift VR - MR equipment based on the head-mounted display system (Stepan et al., 2017).
- Magic mirrors screen-based systems: It enables users to investigate anatomical structures alongside medical images related to their own body using the Microsoft Kinect platform (Ma et al., 2016).

The absence of variance in learning outcomes among AR, VR, and traditional educational methods is a favorable finding that supports the potential use of these groundbreaking technologies in educational settings. Furthermore, incorporating AR and VR technologies into teaching may greatly benefit students' spatial awareness and comprehension of anatomical structures in 3D (Moro et al., 2021). Nevertheless, it is crucial to introduce assessment strategies that ensure fairness when implementing new learning tools. For example, some researchers have found that VR may be disadvantageous for students with poor visuospatial ability compared to traditional learning anatomy involving tangible objects (Wainman et al., 2021). The virtual dissection chart, such as Anatomage, can potentially enhance student performance (Rosa et al., 2020). However, producing individualized models for each anatomical unit can be expensive. As a result, due to the limited purchase of these tables, they are rarely utilized by groups of more than eight students and during brief periods (Fyfe et al., 2018).

In the present times, literature depicts the existence of alternative platforms that encompass not only anatomy videos and texts but also provide an augmented reality (AR) experience. Furthermore, these platforms possess a multifunctional capability that combines various internet-dependent technologies within user-friendly software, such as the Complete Anatomy platform (Motsinger, 2020). In addition, Sketchfab is another frequently utilized platform for hosting interactive 3D content (Erolin et al., 2019). These supplementary technologies offer straightforward usability and require minimal financial resources, making them suitable for integration into new medical curricula.

Infrastructure-intensive resources such as VR, AR, and MR require complex handling, additional physical equipment, and substantial financial investment. For instance, VR necessitates a head-mounted display system (Stepan et al., 2017), while MR technologies utilize equipment like Microsoft Kinect and 3D televisions (Messier et al., 2016).

While studies demonstrate some degree of learning effectiveness with these technologies, their accessibility is limited compared to straightforward computer platforms. Additionally, both VR and AR experiences were found to have similar learning efficacy. However, VR was associated with dizziness and nausea in several students (Ammanuel et al., 2019; Birbara et al., 2020). Consequently, teachers favored the utilization of AR due to these concerns.

Certain studies suggest that AR and VR do not significantly enhance students' learning effectiveness compared to traditional methods (Duncan-Vaidya & Stevenson, 2021; Moro et al., 2021). However, it is worth noting that the AR experience can still be efficacious even without complete immersion (Chytas et al., 2022). Nevertheless, perhaps the critical consideration lies not in efficacy alone but in understanding the requirements and potential for practical application.

Nowadays, efforts have been made to enhance the head-mounted display system of VR. For instance, introducing new equipment like the Oculus Quest 2 (Facebook Technologies) aimed to improve the VR experience. However, these attempts have proven unsuccessful, as the new head-mounted display system failed to address the issues of its predecessor and led to additional health complications (Machkovech, 2020; CPSC, 2021). Consequently, these facts highlight the limited accessibility of VR technologies, particularly in the context of developing countries, and their potential to cause health issues.

Digital tools – Web-based applications

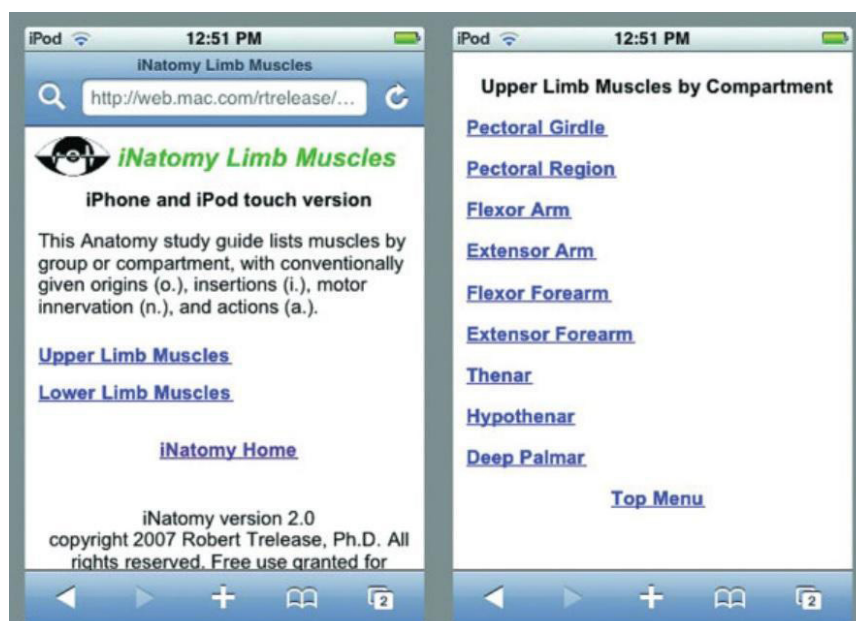
Digital tools revolve around technological resources that rely on internet connectivity for their operation, whether it involves downloads or continuous access. Similarly, they can be virtually accessed and viewed on various computer equipment, from laptops to smartphones and tablets. Moreover, most of these technologies incorporate audiovisual or interactive content (Santos et al., 2022).

Integrating new technologies into everyday use is a multifaceted process known as the Diffusion of Innovations (DOI) (Rogers, 2010). An excellent illustration of the diffusion in the mid-1990s, widely recognized among anatomists, is the gradual and widespread acceptance of the personal computer (PC), multimedia, and the World Wide Web for anatomical informatics and educational purposes. PCs have become indispensable tools in various fields, enabling learners to carry out their everyday academic tasks, from attending lectures and participating in laboratory work to engaging in distance learning. Over the past few years, portable or mobile personal computing devices have emerged as viable additions to using PCs in education (Trelease, 2008).

This project on Diffusion of Innovations (DOI) was a practical demonstration of applied anatomical informatics by showcasing how anatomical information in text, clinical imaging data, histological images, and educational videos could be conveniently transferred and utilized on the iPhone and iPod touch. These educational multimedia resources could be transferred to an iPhone directly from a PC using the standard iTunes software synchronization process or accessed through a wireless connection to web servers. An instance of this is the iNatomy limb muscles flashcard application, which can be accessed and run on an iPod touch using the Safari Web browser. In addition, it can be downloaded directly from a public website (Figure 1). The successful utilization of podcasting and smartphone technology relies on educational developers' proficiency and ability to seamlessly integrate these tools with other learning resources within targeted instructional programs (Trelease, 2008).

Figure 1

Screen Capture Images of the iNatomy Limb Muscles Flashcard Application Running on an iPod Touche (Trelease, 2008)

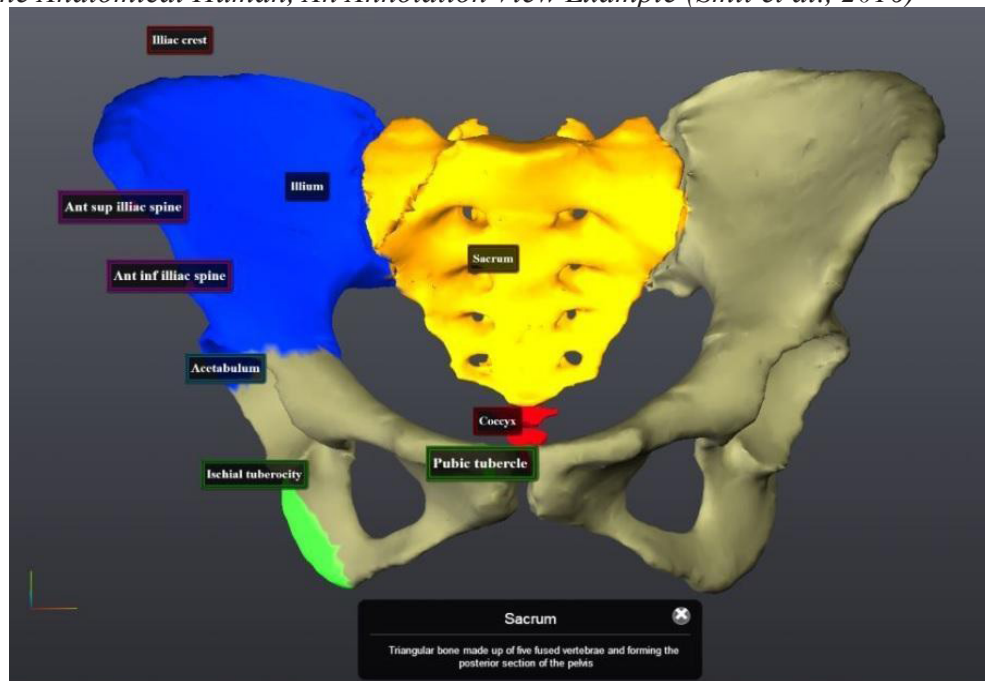


The Essential Skeleton 4, another web-based mobile application, offers a comprehensive 3D representation of the skeletal system. It enables users to zoom in and examine bones from various perspectives. By tapping on a particular bone, its name is displayed. Moreover, a related information box appears upon bone selection, providing additional details such as pronunciation and location. Furthermore, users can access specific bone structures and joint associations by selecting the information icon within the information box. The Essential Skeleton 4 app is free of charge and compatible with both Apple and Android devices. (Bice et al., 2016). Bice et al. (2016) found that incorporating mobile applications improved students' grades on skeletal exams. In addition, students expressed a positive reception towards using technology in their classes and appreciated the convenience of accessing the applications on different mobile devices.

The Online Anatomical Human (OAH) is a web-based application that utilizes authentic human anatomy and incorporates medical image data, offering linked 2D and 3D views that users can freely explore and interact with. This application stands out as the sole platform that supports real medical imaging data in both 2D and 3D perspectives. Its primary objective is to be an educational resource accessible to anyone with a modern web browser. In addition, users can annotate specific regions, add comments, and include hyperlinks to different media (Figure 2). The platform continually aims to expand its information and educational value by ensuring access to medical experts (Smit et al., 2016).

Figure 2

Online Anatomical Human, An Annotation View Example (Smit et al., 2016)



Another digital tool, social media platforms like YouTube (owned by Google LLC), serve as primary examples of this category, providing an online platform for sharing videos (Mustafa et al., 2020). Unfortunately, while a vast amount of human anatomy content is available on this platform, there is a scarcity of high-quality content or videos uploaded by professors. Typically, students can access the videos on the platform like any other user, or tutors can create and share customized materials directly. Consequently, the platform is an alternative to traditional in-person classes (Raikos & Waidyasekara, 2014).

Facebook can be utilized as a digital educational tool, offering various opportunities for communication, collaboration, and content sharing. Teachers and students can create groups or pages to facilitate discussions, share resources, and engage in online learning communities. Facebook Live can be used for live-streaming classes or presentations, allowing real-time student interaction. Additionally, Facebook Events can help organize educational activities, such as webinars or workshops. However, it's crucial to consider privacy and data security when using Facebook in an educational context (Jaffar, 2014).

The literature also mentions audiovisual resources, including screencasts. Screencasting is a teaching method that involves recording a computer's or mobile device's screen while providing a narration or commentary. Educators can create videos demonstrating various concepts, processes, or software applications. Screencasts can deliver lectures, explain complex topics, provide step-by-step tutorials, or showcase digital resources. This teaching method offers several benefits. Firstly, it allows for flexibility as educators can create screencasts at their convenience, and students can access them anytime, anywhere. It also provides a visual and auditory learning experience, making it easier for students to understand and retain information. Screencasts can be paused, rewound, and rewatched, allowing students to learn at their own pace. Additionally, screencasts can be easily shared and accessed repeatedly, serving as valuable reference materials (Ghilay & Ghilay, 2015).

The literature reports that replicating the drawing component of traditional anatomy lessons through screencasts has enhanced the student experience and knowledge retention, resulting in its growing popularity among students. Furthermore, the mobile nature of screencasts enables students to utilize this resource according to their preferred learning style at a time and location that is most suitable for them (Pickering, 2015).

Another term for digital tools is digital platforms. Digital platforms in education refer to online platforms or software applications designed to facilitate teaching and learning activities. These platforms provide a range of tools, resources, and features that support various aspects of education, including content delivery, interaction, collaboration, assessment, and administration. They also enhance access to educational resources, promote online collaboration, personalize learning experiences, and facilitate remote or blended learning environments. In addition, they offer convenience, flexibility, and diverse learning opportunities for students and educators alike (Alanzi & Alhalafawy, 2022). Some of them have been specifically designed to be accessed through smartphones, such as applications that provide 3D anatomical content or essential theoretical texts (Mansouri et al., 2020).

Jamboard, a collaborative digital whiteboard platform developed by Google, can be a valuable tool in medical education. For example, Jamboard can help study anatomy due to its interactive and visual features. Here are some specific ways Jamboard can be utilized for anatomy education:

1. **Labeling and Annotating:** Instructors or students can upload anatomical images or diagrams onto the Jamboard canvas and use the drawing tools to label different structures. This allows for a hands-on approach to learning anatomy, where students actively identify and label anatomical parts (Figure 3).

2. **Virtual Dissections:** Jamboard can simulate virtual dissections instead of traditional physical dissections. Instructors can upload high-resolution images or diagrams of anatomical structures and guide students through dissection by highlighting

and explaining different layers or structures. Students can collaborate and contribute their observations and questions in real time.

3. Conceptual Understanding: Anatomy involves understanding the spatial relationships between various anatomical structures. Jamboard's canvas provides a platform to create concept maps, mind maps, or flowcharts to illustrate and connect different anatomical concepts. This visual representation aids in conceptual understanding and retention.

4. Clinical Case Studies: Jamboard can be used to analyze and discuss clinical case studies with an anatomical focus. Instructors or students can upload relevant patient imaging (e.g., X-rays, CT scans, MRI) and annotate the images to highlight specific anatomical abnormalities or structures related to the case. Collaborative discussions can help students apply their anatomical knowledge to real-world scenarios.

5. Interactive Quizzes and Review Sessions: Jamboard allows instructors to create interactive quizzes or review sessions for anatomy topics. Instructors can present questions, diagrams, or images on the board, and students can use the drawing tools to indicate their answers or annotate the structures being discussed. This active participation enhances recall and reinforces learning.

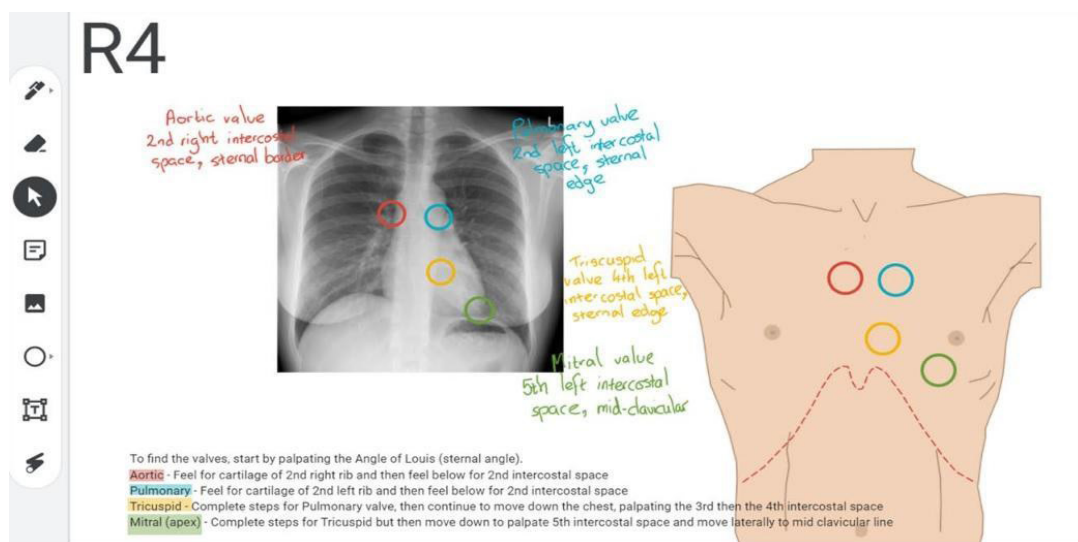
6. Group Projects and Presentations: Jamboard facilitates group projects and presentations on anatomy topics. Students can collaborate to research and compile information on a specific anatomical system or structure and then present their findings using the board's drawing tools, text boxes, and multimedia elements.

7. Remote Learning: Jamboard is especially beneficial for remote anatomy education. Instructors can share the board with students, allowing them to access and contribute to the material from their devices. In addition, distant learners can actively engage in discussions, labeling, and concept mapping, ensuring they have access to interactive learning experiences.

Jamboard, with other resources such as textbooks, interactive anatomy software, or physical models, provides a well-rounded anatomy learning experience (Sweeney et al., 2021).

Figure 3

An Example of Jamboard Slide (Sweeney et al., 2021)



Video conferencing digital platforms like Zoom, Microsoft Teams, or Google Meet are widely used for synchronous virtual classes, webinars, or remote meetings. They enable real-time communication, screen sharing, and participant collaboration. In most research studies on online teaching in medical education, it has been observed that online teaching is effective and beneficial for students. However, in contrast to these findings, most students preferred discontinuing online teaching after the lockdown period. This preference could be attributed to insufficient planning, the absence of well-developed teaching modules, and inadequate supporting infrastructure, including unreliable internet connections (Roy et al., 2020).

In a survey conducted among students to determine the approach they took when faced with challenges in learning anatomy, it was found that a significant majority (70%) relied on web-based platforms, such as search engines (62%) and social media sites (10%), to obtain information. On the other hand, 29% of students opted for suggested anatomy textbooks as their solution, whereas 5% mentioned their intention to contact their instructor for assistance. Consistent with earlier research findings, most students (78%) identified YouTube as their primary source for accessing anatomy-related videos. Medical websites were chosen by 8% of the respondents, while Facebook and other social media platforms (22%) were considered beneficial depending on the topic in question (Barry et al., 2016).

Conclusion

Studies indicate that emerging technologies do not negatively impact learning or assessment outcomes and can be effective alternatives to conventional teaching methods. Consequently, educators in medical sciences may consider integrating virtual or augmented reality as supplementary instructional tools.

In the wake of the pandemic, anatomy teachers need to repurpose and enhance internet-based resources and utilize platforms that incorporate AR and instructional videos.

Preferably, internet-based technologies should encompass versatile online platforms that offer a combination of AR capabilities and anatomy videos created by university instructors.

Simultaneously, these resources are both cost-effective and capable of delivering quality education. Consequently, they can be effectively incorporated into new medical curricula.

Furthermore, due to students' widespread acceptance of these innovative technologies, there will be an increase in the availability of well-crafted, multiplatform resources. Thus, students can easily access and acquire essential information in numerous fields, including anatomy, from any location at any time.

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