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VIEWPOINT COMMENTARY

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Utilizing the metaverse in anatomy and physiology

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Abstract

Of the many disruptive technologies being introduced within modern curricula, the metaverse, is of particular interest for its ability to transform the environment in which students learn. The modern metaverse refers to a computer-generated world which is networked, immersive, and allows users to interact with others by engaging a number of senses (including eyesight, hearing, kinesthesia, and proprioception). This multisensory involvement allows the learner to feel part of the virtual environment, in a way that somewhat resembles real-world experiences. Socially, it allows learners to interact with others in real-time regardless of where on earth they are located. This article outlines 20 use-cases where the metaverse could be employed within a health sciences, medicine, anatomy, and physiology disciplines, considering the benefits for learning and engagement, as well as the potential risks.

KEYWORDS
computer simulation, exergaming, medical education, mixed reality, science education, technology-enhanced learning, virtual reality, virtual worlds

INTRODUCTION

The modern metaverse is presented through a computer-generated environment. In this immersive and networked virtual world, users interact with others by engaging a range of senses (including eyesight, hearing, kinesthesia, and proprioception). Although exact definitions vary, in general, the multisensory input allows users to feel part of the virtual environment in a closely similar way to how one would feel in the real world. Socially, it allows users to interact virtually, in real-time, with any other person no matter where on earth they are located. With its ability to provide a higher degree of freedom to create and share,[1] and a space for new social communication,[2] the metaverse may present an ideal mode with which to present educational content.

The concept of the metaverse extends beyond the current practice of using virtual and augmented reality, which is usually performed in-class to enhance learning and engagement.[3] Instead, with multiple people connected, the user's geographical location is largely irrelevant, and all learners can engage in real-time within the virtual environment,[4] interacting through realistic graphics and visualizations.[5] Anatomy and physiology have a strong focus on the positioning of the human body and the three-dimensional (3D) interrelationships between organs and features.[6] How the body is structured, and how these structures might adjust position during movement, aging, or disease is important for understanding the system as a whole. As such, the opportunity to present content within an entirely virtual world, viewed through stereoscopic 3D (as presented in the metaverse), presents a potential benefit to learners, and an exciting concept for educators.[7]

Work from home requirements during the COVID-19 pandemic accelerated the use of technology to facilitate connections that would have otherwise been face-to-face. However, there was still a feeling of disconnect, with sentiments of social isolation common.[8] After the pandemic, the use of technology in teaching classes such as anatomy has seen a rise in popularity, with educators increasingly embedding social media, online resources and 3D printing to supplement traditional teaching methods.[9] However, the benefits of these technologies have not always replaced the authentic learning achieved from realistic hands-on activities, such as cadaveric dissections.[9] Although a number of metaverse platforms have been available throughout this time, when surveyed internationally, more than 30% of anatomy educators had never heard the term "metaverse" before.[10] However, this seems likely to change. Some concepts in anatomy are now taught using the metaverse at Seoul National University College of Medicine in Korea,[11] and it is becoming increasingly used within medical practice.[12] There has also been success with anatomy teaching through the software Second Life. This metaverse-like virtual world has enabled team-based anatomical learning,[13] multiuser virtual environments for learning gross anatomy,[14] and competition between students to enhance enjoyment of presented concepts.[15] In all cases, learners appeared to appreciate the unique use of technology, showing that virtual worlds can present potentially highly engaging and motivating platforms for learning.

Services which enable access to the metaverse will continually expand in upcoming years. Multiple companies are developing their own versions of the metaverse. Meta, a technology company (Meta Platforms Inc., Menlo Park, CA) formerly named Facebook Inc., has spent billions of dollars building a Metaverse digital space that exists beyond the real world to connect people together, while the Microsoft Corporation is creating Microsoft Mesh (Microsoft Corp., Redmond, WA), based on the Microsoft Teams video chat and collaboration software. This follows a lead by the gaming industry, which has presented the metaverse through a range of platforms.[16] Epic Games Company adapted open-world virtual concepts into its virtual world, Fortnite (Epic Games, Inc., Cary, NC), to hold music concerts and open-world player experiences. Open and connected world concepts have enabled virtual elections to be held in Animal Crossing, a social simulation video game (Nintendo EPD, Kyoto, Japan). Roblox online game platform (Roblox Corp., San Mateo, CA), a virtual world that offers a way to tell stories and freely engage with others in an entertaining environment, is now played by more than half of the children in the United States.[17]

There has been an increasing number of globally networked metaverse platforms introduced recently, that can enable educators to engage with their students in a virtual space. This article provides insights into which features of the metaverse may be of particular interest to medical and health science educators and provides suggestions for how educators may be able to harness this upcoming advancement in technology.

TWENTY USE-CASES FOR THE METAVERSE IN ANATOMY AND PHYSIOLOGY

To explain the metaverse and frame the potentials within the context of anatomical sciences education, 20 use-cases regarding how this technology might be used to enhance anatomy and physiology workshops, laboratories, and hands-on sessions are outlined below. Each of the 20 examples listed in this document are currently possible using today's virtual and augmented reality devices. However, the metaverse expands upon the current use, with increased connectivity, accessibility, and interactivity, making it more accessible and simpler to use for both educators and learners. Proposed use-cases are presented with a potential activity, alongside additional considerations in the paragraph underneath, with risks and concerns of potential interventions presented after.

In-the-field authentic learning

Activity: Anatomy of the leg bones could be taught at the base of a virtual mountain, as part of a simulated case presenting a rock climber who has fallen and suffered a fracture.

In a health professional program, there is value in placing the student in authentic environments. Whether the activity is best suited to a hospital, on the roadside, or at a sports field, the educator can place the students in the desired location, timeframe, or activity. This "simulated workplace" gives an element of realism and can go a long way towards assisting students to become exposed in an authentic way to their potential future workplaces.[18] It may also prepare students for the future healthcare environment, where at least some consultations, training practices, and medical communication are predicted to be undertaken.[19]

Virtual dissections

Activity: Students perform a complete full-body dissection using an entirely virtual model.

Virtual models are becoming more lifelike than ever. Imaging and medical scans can be imported into 3D software to create a realistic model of the human body. Although virtual dissections are currently possible, the metaverse expands the benefits of this. The position of the student's hands is detected by motion controllers, providing precise control over the scalpel. The digital laboratory environment will feel increasingly real[2] as students can interact with the models, as well as students and staff around them. Collaborative virtual dissections, with and without a teacher-directed instruction, might also present a effective form of early training, exposing students to lab activities prior to engaging with cadavers or wet specimens, allowing for mistakes to be made and providing an avenue for practice. Fine movements can also be tracked. For example, positioning of the hands can be observed, even with current motion capture handsets available, which can help educators monitor student activity during anatomical dissections or when teaching surgical techniques.[20] As the underlying technology and virtual environments building the metaverse expands, it will present a more realistic, collaborative and accessible experience compared to what is currently possible within virtual reality, augmented reality, or digital dissection tables.

Viewing real-time teaching practices with a front-row seat

Activity: While a live autopsy is taking part in the real-world, students attend virtually, and can ask and answer questions by interacting with the educator.

In this scenario, there is a real-world activity taking place, and the metaverse facilitates the student's attendance in a much more realistic and engaging way compared to streaming through video platforms. While the professional is completing the autopsy, students attend virtually in avatar form in a way that feels, to them and the educator, like they are present. This means that every student attending virtually is given access to a front-row seat. With the correct video and 3D capture setup, and appropriate consent obtained, real-life specimens can be embedded in a way that allows complete, panoramic viewing, where students can navigate to the point of interest at any time, communicate with each other and the educator, and even interact by pointing or motioning towards structures. This blending of both real and virtual, as well as the mix of different technologies, may provide a great benefit to the overall learning experience.

Kinesthetics and body movements

Activity: One student's avatar presents as a skeleton and jogs around the laboratory, while other students observe the movements of the skeletal system.

Students cannot run around during a busy teaching laboratory. They could, however, virtually experience movement within the metaverse. Software could present virtual hands-on instructions across disciplines that could benefit from showcasing movements, such as biomechanics and muscle physiology, and depict the anatomical changes as certain structures contract, or interact with others during movements.[21] The user could follow a skeleton running, and add muscle layers to see how they facilitate this process. Students can interact, chosing which organs to view from the inside out.

Fully engage with specialist instructors from anywhere in the world

Activity: A specialist guest lecturer from California provides hands-on instructions to medical students in Australia.

Within a health science or medical program, students normally receive most of their instruction from academics living near, or around the university campus. The introduction of formal instruction via the metaverse would enable educators to join the students in virtual full-body form, to provide a lesson. They could point to joints on their body, show movements of the muscles and arms, and teach a variety of concepts just like if they were in the room with the students. The educator can also identify and respond to student interactions in real-time, which is important for effective online learning.[22] This opens the door to a more personal experience during remote instruction, more than what would be possible from video conferencing or through currenlly-available virtual and augmented reality devices.[23,24] This option to have access to specialist educators from anywhere in the world can enhance opportunities for universities to engage, and educate students in different ways.[25]

Serious games and gamification

Activity: Students are locked in a virtual escape room and must use their content knowledge to crack the code and find the exit.

The metaverse can be fun! Students can take off and fly around the room, race each other to certain points, or complete in activities. There is a growing amount of evidence that introducing serious games can be of great benefit to the student learning experience in disciplines such as anatomy and physiology.[26] This practice involves creating activities, experiences and entertaining games where the primary purpose is learning. The ease at which all participants, up to hundreds of people, can be connected together in the metaverse provides educators with a great potential to create engaging games, fun activities and enhanced learning experiences.[4] The collaborative environment can also facilitate activities currently employed in classes. For example, students can work together to connect sections of the brachial plexus,[27] or can race other groups to accomplish objectives in a fun and interactive way.

Virtual instructors

Activity: An entirely virtual artificial intelligence entity asks students questions about course content and answers student queries.

Artificial intelligence (AI) is already in use within a number of medical and health science programs. However, in many cases it remains focused around developing ways to process patient data, decipher radiographs, or expose students to the future potential of healthcare.[28,29] However, even beyond data processing and management, artificial intelligence is developing to a point where it can provide instructions to students from an entirely virtual entity. Students may be able to receive entire lectures from an AI or communicate with an AI-based virtual patient. Although possible, at the moment there are a range of issues from the software side to work through in order to fully utilize AI instructors in medical education, but this technology will continue to develop and improve in the near future.[30] However, even rudimentary AI may find a use as a revision resource, where after students have learnt in a structured and thorough way, can revise through two-way communication with a virtual instructor.

Virtual patients

Activity: Students fully communicate and interact with an entirely virtual patient, applying their anatomical sciences knowledge to clinical cases.

Students can practice communication strategies and soft skills in a realistic simulated environment alongside virtual patients. The metaverse would provide a much more authentic experience than what is possible through using a two-dimensional (2D) computer program or tablet-based applications. With complete avatars, advanced emotions and cues can be incorporated.[31] Even the distance between the student and the patient can be assessed and monitored. Virtual patient data can also be produced as part of the consultation (in some cases with the use of AI), providing health information for students to assess and identify suspected issues.[32] Artificial patients may also present an effective bridge to practice communication and clinical skills before meeting with real patients. This may have some benefit in reducing anxiety associated with newly learned content. As no physical or simulated patient is involved, the student can practice this at any time, in any place, for any number of repetitions.

Showcasing variation

Activity: A student can scan through 1000 different, yet realistic, heart 3D models to find the one which they would like to use in their studies for that day.

The limitation of plastic models and cadavers is that they are constrained in their ability to showcase variation. Virtual models do not have this issue. The virtual environment can present any disease or disorder, at any time, at any stage, and in any form the educator desires. This empowers educators with resources far beyond what is commonly available in even the most well-stocked teaching or cadaveric laboratories. Anatomical variation is one particular area of teaching largely omitted from many health professional programs.[33] However, being entirely virtual, the metaverse can allow for the instantaneous viewing of endless variation, with little extra effort from the educator if models are available. This can also present and animate the natural progression of diseases and disorders, and allow side-by-side comparisons between healthy and diseased tissues. For example, students can watch a lesion forming in multiple sclerosis, or a heart slowly developing fat deposits. Of particular benefit with a connected metaverse, would be for students to watch these processes occurring in a collaborative virtual environment.

Linking between disciplines

Activity: A person's avatar has trouble breathing (physiology), starts to have an asthma attack (pathology), and students administer an asthma puffer (pharmacology) to act on the trachea (anatomy) and alleviate the dysfunction (pathophysiology).

With a completely virtual, connected environment, the metaverse can allow interdisciplinary connections like never before.[12] To fully understand diseases, medical and scientific disciplines such as anatomy, physiology, pathology, pharmacology, and more all need to be integrated and applied to the clinical scenario. The virtual world presented in the metaverse can facilitate this in a meaningful way and enable students to make connections between academic disciplines.

Facilitating communication

Activity: A student from Australia can shake hands with a student from the United States of America and discuss course content over a virtual model.

With every student connected in the same place and at the same time, regardless of their physical location, means that learners can ask and answer questions at any time. They can communicate with each other, raise their hands, or motion to the educators or other students they would like attention. They can also communicate in real-time with anyone around the world, with their reactions observed in real-time. More than simply responding to text questions during an online lesson, the metaverse can allow educators to observe if students seem “lost” or confused through either their personal stance or expressions, or the presentations of emojis or virtual cues. This way, even in a large group of attendees at a lesson, individualized attention can be offered to students when required. In avatar form, students can even be trained in non-verbal communication strategies, showing emotion, reinforcing or contradicting verbal comments,[31] or using gestures to emphasize with a patient or classmate.[34]

Stations-based teaching

Activity: In the middle of a teaching session, in a class with hundreds of learners, each student is placed into a small group for a 5-minute hands-on activity before rejoining the class.

Students can be placed at virtual “stations” or moved into small or large groups to discuss concepts. No longer constrained by the physical size of the room, educators can separate groups widely, or keep them close together to facilitate discussions between stations. There has been some success with using metaverse elements for virtual stations-based approaches. The online game, Second Life, has been used for medical education, where students were able to collaborate between, and compete against, other students while learning radiology,[15] or where students were engaged with virtual team-based learning in an anatomy course.[13]

Safety

Activity: Multiple students dissect different parts of a virtual cadaver at the same time, with no risk of any scalpel injuries or accidents.

Dissection apparatus, social distancing, heavy furniture, and more can all pose risks when there are large numbers of students in a hands-on laboratory. In the metaverse, none of these considerations matter. There is no physical risk to having hundreds of students taking part in any activity. However, although there is no physical risk, there is the potential for the metaverse to affect mental health, or to impact the personal security of users.[35]

Student-created content

Activity: Students create a fun small hands-on activity where they need to attach virtual labels to a skeleton, which is later shared with others in the cohort.

The content housed in the metaverse does not need to be created or managed by the educators. Students can create, embed, and engage with content. Students can also take part in near-peer remote teaching, which has shown promise in anatomy lessons.[36] This practice is occurring across many health science and medical programs, but the metaverse will make it much easier to connect learning together in a meaningful way.

Save and share

Activity: A small group of students have a discussion that is saved and shared with a student who was not able to attend class.

Everything that is done in the metaverse can be saved for later recall or shared with other groups.[2] If something happens in the first laboratory, but not the second, the latter can use recordings of snippets of information from the former for revision or preparation. Recording lessons in complete 3D within the virtual environment extends far beyond the capabilities of video capture technologies used in current teaching practices. Not only could students repeat a session in its entirety, but pause and digitally navigate through the space or 3D models in their own time. This allows for recording of some experiences, rather than just content, and allows exploration within the revision material to accommodate some degree of interactive self-directed learning.

Assessment for spatial and 3D interrelationships

Activity: Part of the assessment in a medical program's anatomy course involves placing a student in the metaverse and asking them to identify features of the musculoskeletal system.

Unless a student is present, it is very challenging to assess their ability to comprehend the 3D relationships between organs. However, this knowledge is vital if, for example, the student aims for a future career in pursuits such as surgery. Although learning is often now augmented with technology-enhanced teaching practices, assessment processes remain largely 2D and lag behind in innovation.[3] With either paper-based, or the new format of computer-based assessments, it can be challenging to assess student knowledge of 3D interrelationships.[6] This is further exacerbated where traditional modes of assessments, such as face-to-face spotter examinations, are slowly being phased out due to the requirement for online learning, or staff burnout.[37] The metaverse may have the potential to reinvigorate examinations so that students can present, describe, discuss, and be assessed on concepts in a realistic way from anywhere in the world.[38] The use of the metaverse could also bring back real-time formats of spotter examinations, where the students are immersed and assessed within a true 3D environment. To assist staff, student work can be viewed from any place, at any time, and recordings can be made of the whole session to alleviate the stresses when having to assess students live and, in real-time.

Blended attendance

Activity: Some students can attend a class in-person, while others attend virtually, with both able to complete the same activities.

Wearing mixed-reality headsets (currently available now, such as the Microsoft HoloLens), each student is able to communicate and interact with each other in real-time. This starts to allow student interactions in a way that is nearly as effective as face-to-face, but in a hybrid environment. By closing the gap between students attending face-to-face and those attending virtually, educators can create experiences that equally accommodate class attendees, regardless of their location. In addition, physical resources, previously available only to on-campus attendees, can find new use. For example, students attending remotely could ask students to hold up physical models available in the lab and use them to form a discussion about organs or features, blending the real and virtual worlds during collaborative student-led discussions.

Asynchronous teaching

Activity: A student asks a question about last week's autopsy, and the environment changes to instantly place the group back into the exact scenario at last week's timepoint and view it all again in real-time.

Instantly, a previously run lesson, lecture, laboratory, or experience can be incorporated into the class. Sessions, experiences, gamified concepts, discussions, and more can be revisited and replayed at any time. This return to the content can assist to facilitate revision and knowledge consolidation after lessons have concluded.

Stand in someone else's shoes

Activity: Acting as a virtual avatar, students "become" a paramedic, and walk through an accident scene from their perspective.

The metaverse allows students to embody the avatar of other people and view their world from a first-person perspective. The environment appears real. This experience could be a doctor doing a hospital ward round, or a pathologist assessing a specimen in a clinic.

This provides the potential for broad and authentic experiences beyond the direct scope of their enrolled study pathway. Of interest may be in exposing students to various workplace roles, in particular during the later years of their programs. Learners could act as a pathologist and asses a provided sample, perform the duties of a ward nurse during patient assessments, undergo a home medicine review as a pharmacist. This provides authentic learning which may help to provide context to the learning material or help students to develop workplace-ready skills.

Equal accessibility

Activity: A student formerly bound to a wheelchair will now have the same viewpoints and high viewing angles over cadavers in a dissection laboratory. Students with anxiety surrounding the use of cadavers can now observe from the comfortable environment of their own home.

There are various reasons why students may be disadvantaged in a physical class. Students may not like being physically crammed around a single specimen or may not feel comfortable being in a large group (for example, during social isolation restrictions). Although some disabilities, such as sight, may be exacerbated in a virtual environment, in other cases, the virtual world will remove many restrictions, such as those from a range of physical disabilities. In addition, students with hesitations about using human models and specimens, or anxiety about meeting with a patient for the first time, may have fewer concerns within a virtual environment, providing a much more equal learning opportunity in some cases.

DISCUSSION

Although there are platforms for the metaverse available now, there has been a relatively limited use among anatomical sciences educators to date.[10] However, as the developing and available metaverses become better equipped to handle medical and science curricula (i.e., incorporation of high-resolution realistic models), there is the potential for a rapid uptake of the technologies, potentially disrupting the ways in which content is taught. An initial hurdle will be for educators to come to terms with this new mode of learning and teaching, but also with the embedding of a virtual environment into the learning experience. The first steps will be to engage with the elements that make up the metaverse: virtual reality; augmented reality; online communications; avatars; and online environments. Some of these steps have already taken place, with many university educators embracing remote delivery of their classes in recent years. Whether this was through video-conferencing, streamed lectures, or even voice-over-PowerPoint, educators have already taken the first steps towards virtual delivery. The next steps to a metaverse-enabled environment will require additional thought in how collaboration, communication and networking between students and staff is undertaken.

Risks of using the metaverse for the presented examples

Although there are exciting prospects for using the metaverse in learning and teaching, educators will also need to consider the risks of embedding the technologies within their classes. For example, some students may find learning through a head-mounted display distracting. In a few cases, students may become cybersick during sessions, or may simply not enjoy learning in a virtual environment.[39] The risk of students being allowed to be anonymous also needs to be taken into account (i.e., is it *actually* the person named on the screen?). Visual impairment or hard-of-hearing students may be disadvantaged. There is a cost associated with the devices, and in general, some educators may be hesitant to adopt a new technology that disrupts the normal way in which they teach, limiting faculty-wide rollouts. Connectivity is also key, and if connections drop out, the lesson may not be able to continue as planned. This may also adversely affect those with poor internet or limited access to technology, and the less technology-savvy learners may struggle to keep up. Intellectual property issues are also of note, if students create content, or educators upload content into the virtual software suite, it is unclear who owns this data, or what restrictions may be placed on its use.

Protection of privacy and data security is an additional concern for educators wishing to engage students with the metaverse.[40] Biometrics, behaviors, and personal information can all be collected by large corporations. There is usually no way around this, as the provision of personal information by users is often a core component of the agreements signed prior to being authorized to login. Surveillance of virtual worlds may not be possible, leading to issues monitoring and censoring interactions, removing inappropriate chat, or monitoring for illegal activities, posing additional risks for users, especially if non-enrolled users are allowed to join the class learning environments.[41] Virtual currencies utilized within the metaverse environments may not be secure and lack the protection that centralized currencies hold within regulated financial systems.[42] This poses a risk if learners are expected, or able to, pay money to acquire lesson content, add-ons or additional licenses to access certain information behind paid services. There is also a limiting factor regarding the time it will take to train staff, in order for all members of a teaching team to provide a similar level of quality instruction. Lastly, if students are expected to revise or study from home using the metaverse, it may disadvantage any who are unable to afford the headsets, computers, or data download plans required, as well as those living in areas with lower-quality internet connections.

Limitation of the study

Without formal evaluations, this article does not provide any measure of success for the presented interventions. Future projects should assess and evaluate use of the metaverse in anatomical sciences education, to provide evidence-based recommendations and insights into the benefits and risks of this technology-enhanced approach to learning. Finally, acting on any of the presented 20 interventions listed may require educators to provide a formal assessment of their own prior to being fully embedded within the broader Faculty. To accomplish this, frameworks such as the Universal Design for Learning[43] could be utilized to provide insights into whether specific interventions would be of benefit. Lastly, this article has outlined opportunities for the use of the metaverse in anatomical sciences education, although has not unpacked how the new platforms would actually perform these lessons better than what is currently available (e.g., standalone virtual reality programs, videos, websites).

CONCLUSIONS

The metaverse will enable a range of novel and unique ways to teach and learn. In many cases, it will extend upon current practices, such as the use of live video for remote teaching, virtual dissections, or gamification, although may present some risks that need to be considered. However, the metaverse's increased accessibility, connectivity, authenticity, and immersion means that educators in the anatomical sciences may find appeal in considering converting at least some of their curricula into this virtual environment.

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REFERENCES

1. Tan TF, Li Y, Lim JS, Gunasekeran DV, Teo ZL, Ng WY, et al. Metaverse and virtual health care in ophthalmology: opportunities and challenges. *Asia Pac J Ophthalmol*. 2022;*11*:237–46.
2. Kye B, Han N, Kim E, Park Y, Jo S. Educational applications of metaverse: possibilities and limitations. *J Educ Eval Health Prof*. 2021;*18*:32.
3. Moro C, Birt J, Stromberga Z, Phelps C, Clark J, Glasziou P, et al. Virtual and augmented reality enhancements to medical and science student physiology and anatomy test performance: a systematic review and meta-analysis. *Anat Sci Educ*. 2021;*14*:368–76.
4. Wiederhold BK. Metaverse games: game changer for healthcare? *Cyberpsychol Behav Soc Netw*. 2022;*25*:267–9.
5. Zhao YH, Jiang JJ, Chen Y, Liu RC, Yang YL, Xue XY, et al. Metaverse: perspectives from graphics, interactions and visualization. *Vis Inform*. 2022;*6*:56–67.
6. Chytas D, Salmas M, Demesticha T, Troupis TG. The important role of interaction when virtual reality is used for anatomy education. *Anat Sci Educ*. 2022;*15*:636–7.
7. Itoh Y, Chen Y, Iida K, Shiiki M, Mitsubuchi K. Experiment of metaverse learning method using anatomical 3D object. In: Spencer SN, editor. *Proceedings of the 8th international conference on Virtual Reality Continuum and its Applications in Industry (VRCAI'09); Yokohama, Japan, 2009 December 14–15*. New York, NY: Association for Computing Machinery; 2009. p. 289–94.
8. Galanti T, Guidetti G, Mazzei E, Zappalà S, Toscano F. Work from home during the Covid-19 outbreak: the impact on employees' remote work productivity, engagement, and stress. *J Occup Environ Med*. 2021;*63*:e426–32.
9. Iwanaga J, Loukas M, Dumont AS, Tubbs RS. A review of anatomy education during and after the COVID-19 pandemic: revisiting traditional and modern methods to achieve future innovation. *Clin Anat*. 2021;*34*:108–14.
10. Iwanaga J, Muo EC, Tabira Y, Watanabe K, Tubbs SJ, D'Antoni AV, et al. Who really needs a metaverse in anatomy education? A review with preliminary survey results. *Clin Anat*. 2023;*36*:77–82.
11. Jeon JH. A study on education utilizing metaverse for effective communication in a convergence subject. *Int J Internet Broadcast Comm*. 2021;*13*:129–34.
12. Werner H, Ribeiro G, Arcoverde V, Lopes J, Velho L. The use of metaverse in fetal medicine and gynecology. *Eur J Radiol*. 2022;*150*:110241.
13. Gazave CM, Hatcher AR. Evaluating the use of second life™ for virtual team-based learning in an online undergraduate anatomy course. *Med Sci Educ*. 2017;*27*:217–27.
14. Richardson A, Hazzard M, Challman SD, Morgenstein AM, Brueckner JK. A "second life" for gross anatomy: applications for multiuser virtual environments in teaching the anatomical sciences. *Anat Sci Educ*. 2011;*4*:39–43.
15. Rudolphi-Solero T, Jimenez-Zayas A, Lorenzo-Alvarez R, Domínguez-Pinos D, Ruiz-Gomez MJ, Sendra-Portero F. A team-based competition for undergraduate medical students to learn radiology within the virtual world second life. *Insights Imaging*. 2021;*12*:89.
16. Sandrone S. Medical education in the metaverse. *Nat Med*. 2022;*28*:2456–7.
17. Jeon JH. A study on the principle of metaverse composition with a focus on Roblox. *Video Cult*. 2021;*38*:257–79.
18. Wu Q, Wang Y, Lu L, Chen Y, Long H, Wang J. Virtual simulation in undergraduate medical education: a scoping review of recent practice. *Front Med (Lausanne)*. 2022;*9*:855403.
19. McWilliam A, Scarfe P. The metaverse and oncology. *Clin Oncol (R Coll Radiol)*. 2022;*35*:12–4.
20. Ebina K, Abe T, Higuchi M, Furumido J, Iwahara N, Kon M, et al. Motion analysis for better understanding of psychomotor skills in laparoscopy: objective assessment-based simulation training using animal organs. *Surg Endosc*. 2021;*35*:4399–416.
21. Brooks SV. Current topics for teaching skeletal muscle physiology. *Adv Physiol Educ*. 2003;*27*:171–82.
22. Mishall PL, Meguid EM, Khalil MK, Lee LM. Transition to effective online anatomical sciences teaching and assessments in the pandemic era of Covid-19 should be evidence-based. *Med Sci Educ*. 2022;*32*:247–54.
23. Lee H, Woo D, Yu S. Virtual reality metaverse system supplementing remote education methods: based on aircraft maintenance simulation. *Appl Sci*. 2022;*12*:2667.
24. Park CS, Park NJ. Adapting to cutocracy: a survival strategy for prospective health professions educators in the era of the metaverse. *J Prof Nurs*. 2022;*41*:A1–4.
25. Wilcha RJ. Effectiveness of virtual medical teaching during the Covid-19 crisis: systematic review. *JMIR Med Educ*. 2020;*6*:e20963.
26. Moro C, Phelps C, Birt J. Improving serious games by crowdsourcing feedback from the STEAM online gaming community. *Internet High Educ*. 2022;*55*:100874.
27. Lefroy H, Burdon-Bailey V, Bhangu A, Abrahams P. A novel technique for teaching the brachial plexus. *Clin Teach*. 2011;*8*:196–9.
28. Kundu S. How will artificial intelligence change medical training? *Commun Med (Lond)*. 2021;*1*:8.
29. Paranjape K, Schinkel M, Nannan Panday R, Car J, Nanayakkara P. Introducing artificial intelligence training in medical education. *JMIR Med Educ*. 2019;*5*:e16048.

30. Combs CD, Combs PF. Emerging roles of virtual patients in the age of AI. *AMA J Ethics*. 2019;*21*:E153–9.
31. Riva G, Wiederhold BK. What the metaverse is (really) and why we need to know about it. *Cyberpsychol Behav Soc Netw*. 2022;*25*:355–9.
32. Takahashi Y, Chang H-t, Nakai A, Kagawa R, Ando H, Imakura A, et al. Decentralized learning with virtual patients for medical diagnosis of diabetes. *SN Comput Sci*. 2021;*2*:239.
33. Alraddadi A. Literature review of anatomical variations: clinical significance, identification approach, and teaching strategies. *Cureus*. 2021;*13*:e14451.
34. Silverman J, Kinnersley P. Doctors'non-verbal behaviour in consultations: look at the patient before you look at the computer. *Br J Gen Pract*. 2010;*60*:76–8.
35. Benrimoh D, Chheda FD, Margolese HC. The best predictor of the future-the metaverse, mental health, and lessons learned from current technologies. *JMIR Ment Health*. 2022;*28*(9):e40410.
36. Thom ML, Kimble BA, Qua K, Wish-Baratz S. Is remote near-peer anatomy teaching an effective teaching strategy? Lessons learned from the transition to online learning during the Covid-19 pandemic. *Anat Sci Educ*. 2021;*14*:552–61.
37. Wilhelm J, Mattingly S, Gonzalez VH. Perceptions, satisfactions, and performance of undergraduate students during Covid-19 emergency remote teaching. *Anat Sci Educ*. 2022;*15*:42–56.
38. Huh S. Application of computer-based testing in the Korean medical licensing examination, the emergence of the metaverse in medical education, journal metrics and statistics, and appreciation to reviewers and volunteers. *J Educ Eval Health Prof*. 2022;*19*:2.
39. Moro C, Štromberga Z, Raikos A, Stirling A. The effectiveness of virtual and augmented reality in health sciences and medical anatomy. *Anat Sci Educ*. 2017;*10*:549–59.
40. Petrigna L, Musumeci G. The metaverse: a new challenge for the healthcare system: a scoping review. *J Funct Morphol Kinesiol*. 2022;*7*:63.
41. Park SM, Kim YG. A metaverse: taxonomy, components, applications, and open challenges. *IEEE Access*. 2022;*10*:4209–51.
42. Scheidegger G, Raghubir P. Virtual currencies: different schemes and research opportunities. *Mark Lett*. 2022;*33*:351–60.
43. Balta JY, Supple B, O'Keeffe GW. The universal design for learning framework in anatomical sciences education. *Anat Sci Educ*. 2021;*14*:71–8.

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