A review of anatomy education during and after the COVID-19 pandemic: Revisiting traditional and modern methods to achieve future innovation

Joe Iwanaga1,2,3,4 | Marios Loukas5,8 | Aaron S. Dumont1 | R. Shane Tubbs1,6,7,8

1Department of Neurosurgery, Tulane University School of Medicine, New Orleans, Louisiana
2Department of Neurology, Tulane University School of Medicine, New Orleans, Louisiana
3Dental and Oral Medical Center, Kurume University School of Medicine, Fukuoka, Japan
4Department of Anatomy, Kurume University School of Medicine, Fukuoka, Japan
5Department of Anatomy, University of Warmia and Mazury, Olsztyn, Poland
6Department of Structural & Cellular Biology, Tulane University School of Medicine, New Orleans, Louisiana
7Department of Neurosurgery and Ochsner Neuroscience Institute, Ochsner Health System, New Orleans, Louisiana
8Department of Anatomical Sciences, St. George’s University, St. George’s, Grenada

Correspondence
Joe Iwanaga, DDS, PhD, Department of Neurosurgery, Tulane Center for Clinical Neurosciences, Tulane University School of Medicine, 131 S. Robertson St. Suite 1300, New Orleans, Louisiana 70112, USA.
Email: iwanagajoeca@gmail.com

Abstract
The coronavirus disease 2019 (COVID-19) pandemic has had enormous effects on anatomy education. During the pandemic, students have had no access to cadavers, which has been the principal way to learn anatomy since the 17th century. As it is difficult to predict future access to cadavers for students or in-person classes, anatomy educators are encouraged to revisit all possible teaching methods in order to develop innovations. Here, we review anatomy education methods to apply to current and future education.

KEYWORDS
anatomy education, teaching, cadaver, COVID-19, dissection, medical education, novel coronavirus, SARS-CoV-2, technology, virtual

1 | INTRODUCTION

Anatomy is considered the “basis of the medical sciences”, through the study of which healthcare providers acquire basic knowledge to build a solid background (Saverino, 2020). The coronavirus disease 2019 (COVID-19) pandemic has had enormous effects on anatomy education (Franchi, 2020). It was believed that students’ experience of dissection had decreased before the pandemic, although cadaveric dissection is invaluable for developing skills (Drake, McBride, & Pawlina, 2014; Krähenbühl et al., 2017). Saverino (2020) indicated that anatomy education with cadaveric dissection has decreased in many medical schools because the number of donated bodies has been far outstripped by the growing number of students, particularly during the pandemic, although the situation could differ among areas and countries. It is understandable that both the quality and amount of education that students can receive from schools is now lower than before the pandemic (Franchi, 2020). According to the Centers for Disease Control and Prevention (CDC), the COVID-19 outbreak could be of a long duration (CDC, 2020), which no one can yet estimate.

The use of technology in anatomy classes has increasingly become popular, as it can allow students to learn more interactively. Further, many studies have concluded that students are motivated and interested in using such technologies as augmented reality (AR) and virtual reality (VR) (Saverino, 2020; Triepels et al., 2020). These technologies can enable students to understand anatomical structures three-dimensionally, as they can observe them from many different viewpoints. Thus, such technologies could significantly contribute to learning anatomy during the pandemic. Technologies could
also provide an alternative teaching method to cadaveric dissection if social distancing is required for a protracted period or schools do not allow students to dissect cadaveric specimens (Longhurst et al., 2020). Surprisingly, Brenner, Maurer, Morigli, and Pomaroli (2003) proposed using six techniques for anatomy education as early as 2003: in-person lectures, cadaveric dissection, inspection of prosected specimens, models, living and radiological anatomy teaching, and computer-based learning, including VR, AR, and 3D.

Active learning methods such as flipped classrooms, problem-based, team-based, and case-based learning, and audience response systems, are learner-centered methods developed for use beyond traditional large group lectures (Bell et al., 2019; Gleason et al., 2011; Tsang & Harris, 2016). However, some believe that no other type of learning can replace human cadaveric dissection.

Cadaveric dissection has been the “gold standard” for anatomy teaching in the medical curriculum since the 17th century (Hidebrandt, 2010). It is widely accepted that the human cadaveric dissection process helps students understand the 3D relationships among anatomical structures and reinforces the contents of textbooks and lectures (Aziz et al., 2002; Ghosh, 2016; McLachlan, Bligh, Bradley, & Searle, 2004; Moore, 1998). However, it is becoming ever more difficult to hold cadaveric dissection laboratories because of COVID-19, as it is nearly impossible for students to engage in social distancing in that context. Accordingly, anatomy educators require alternative teaching methods. Most studies have compared one or two newly-developed methods to traditional teaching, revealing their advantages/disadvantages. The number of students and educators, the number of available specimens, the modalities, spaces, and classrooms, and even access to the internet, vary among schools. Therefore, educators should be prepared to use all innovative methods in any situation. The goal of this paper is to review the different learning methods reported, from traditional to innovative, to discuss the future of anatomy education.

2 | DISSECTION

It has been considered that cadaveric dissection is useful not only for learning anatomy but also in the interests of ethics and humanity (Souza, Kotian, Pandey, Rao, & Kalthur, 2020). As the expansion of “medical education” has limited the time and lab space available for “anatomy education”, the quality of anatomy teaching could be seriously impaired (Zhang et al., 2019). At the end of the debate following a symposium entitled, “Do we really need cadavers any more to learn anatomy in undergraduate medicine?” (McMenamin et al., 2018), the audience was evenly split on the need to use cadavers to teach anatomy to medical undergraduates; and of course, this subject is controversial (Dharmasaroja, 2019). Stephens, Rees, and Lazarus (2019) conducted a cross-sectional and longitudinal qualitative study to analyze the contribution of cadaveric dissection to modern anatomy pedagogy. Their study revealed a rich synergy between students’ anatomical education and their ethical perceptions and highlighted the potential for integrating anatomy with ethics education. Participants in this study perceived five major themes related to the cadaveric dissection of donated bodies and medical ethics, that is, dignity, beneficence, consent, and justification versus the necessity of dissection, and the dichotomy between objectification and personification.

3 | PROSECTION

Lackey-Cornelison, Bauler, and Smith (2020) compared the effectiveness of learning via dissection or prosection and found no difference. However, different studies have given varied results (Cuddy, Swanson, Drake, & Pawlina, 2013; Whelan, Leddy, & Ramnanan, 2018; Winkelmann, 2007). Interestingly, even today’s students recognize the benefits of dissection and indicate a strong preference for having the choice to participate in cadaveric dissection during their anatomy education (Whelan et al., 2018). In addition, anatomical knowledge prior to prosection or dissection influenced the short-term retention of knowledge more than the learning modality did (Lackey-Cornelison, Bauler, & Smith, 2020).

4 | PLASTINATION

Outcomes of studies on the use of plastination in anatomy education are limited and are based mostly on students’ reactions and perceptions (Chytas et al., 2019). The value of using plastinated rather than fresh-frozen cadavers in teaching is unclear, although one study found that plastination was more acceptable to second-year than first-year medical students (Baker, Slott, Terracio, & Cunningham, 2013; Haque et al., 2017). According to Azu, Peter, Etuknwa, and Ekandem (2012), 33.3% of the participants believed that cadavers could not be replaced with plastination, and Bhandari, Acharya, Srivastava, Kumari, and Nimmagada (2016) reported that approximately two-thirds of their respondents wanted to have the additional experience of cadaveric dissection.

5 | VIDEO

Several studies of dissection videos have shown that anatomy exam scores are generally no better than historical controls (Granger & Carleson, 2007; Mahmud, Hyder, Butt, & Aftab, 2011; Saxena, Natarajan, O’Sullivan, & Jain, 2008). According to Topping (2014), dissection videos are useful for bridging the gap created by an 11% curriculum reduction. Another study showed that students in osteology scored higher marks with the traditional method than the visually-aided method (Viswasom & Jobby, 2017). In general, students tend to like video learning and report that it enhances their learning satisfaction (Alameddine, Englesbe, & Waits, 2018; Autry et al., 2013; Chen & Wu, 2015).
However, Langfield, Colthorpe, and Ainscough (2018) indicated that anatomy videos alone do not improve students' learning outcomes because they constitute passive learning. They suggested that videos should be used as active learning tools. Grosser, Bientzle, Shiozawa, Hirt, and Kimmerle (2019) emphasized that the key to successful education using videos was to strengthen the link between clinical and anatomical knowledge.

6 | ONLINE RESOURCES

In 2012, the first traditional face-to-face systemic human anatomy course with a prosection laboratory using Blackboard Collaborate (BBC) 12 video conferencing software (Blackboard Inc., Washington, DC) and the Netter 3D Anatomy computer model (Netter, 2014) was conducted fully online. This allowed teachers and students to interact live online while using 3D models (Attardi, Choi, Barnett, & Rogers, 2016; Attardi & Rogers, 2015). However, the students’ performance was consistent with that in the previous year and was predicted by prior academic achievement, not the course format (Attardi, Barbeau, & Rogers, 2018). Other authors have developed audio-visual dissection resources to help students prepare for a dissection course, revise after it, and prepare for their examination, although many students still prefer traditional learning (Choi-Lundberg et al., 2016).

7 | SOCIAL MEDIA (FACEBOOK, TWITTER, YOUTUBE)

Social media have gained popularity in anatomy education (Pollock & Rea, 2019), and anatomists have developed Facebook pages to help students learn (Jaffar, 2012, 2014; Pickering & Bickerdike, 2017). Interestingly, the Jaffar and Eladl (2016) study of Facebook showed that students who performed well on the pages engaged more deeply in discussions than did lower-performing students who contributed with a single “like” or comment. The authors concluded that the deeper engagement of those who performed well proved that Facebook could be a suitable platform for engaging students in an educational context rather than a distractor. Another Facebook survey showed that most respondents did not consider the cadaveric video excessively graphic (Rai et al., 2019). A Twitter hashtag set up by Hennessy et al. (2016) also helped students to learn, and those who used Twitter valued the way it facilitated simple and quick communication between students and educators. Students are also familiar with YouTube videos for learning anatomy (Mustafa, Taha, Alshboul, Alsalem, & Malik, 2020), and their effectiveness has also been studied (Barry et al., 2016). However, educators need to ensure that photos and videos of cadavers or cadaveric materials are handled sensitively (Hennessy et al., 2020; Miller & Lewis, 2016). Nevertheless, many people maintain that the best way to learn and teach anatomy is through cadaveric dissection; but laypersons who want to learn anatomy have limited access to such facilities, so social media could fill this gap (Rai et al., 2019).

8 | 3D PRINTING

Three-dimensional printing (3DP) digital models can be made of various materials, for example, nylon, polyvinyl alcohol, polyacetic acid, acrylonitrile butadiene styrene, wood, metal, and carbon fiber filaments (Baguley, 2017). Fasel et al. (2016) suggested that 3DP specimens have a very good quantitative and excellent qualitative correlation with anatomical reality, so 3DP could be incorporated into an undergraduate anatomy curriculum. Many authors have compared the test scores after learning using 3DP group with other tools (e.g., text, atlas, 2D images, dried specimens, and disarticulated skulls), and most of them have concluded that the 3DP group is more likely to gain higher scores (Backhouse, Taylor, & Armitage, 2019; Chen et al., 2017; Garas, Vaccarezza, Newland, McVay-Doornbusch, & Hasani, 2018; Kong et al., 2016a, 2016b; Lim, Loo, Goldie, Adams, & McMenamin, 2016; Mogali et al., 2018; Smith, Tollemache, Covill, & Johnston, 2018). Chytas et al. (2020) concluded that learning through 3DP is generally perceived to be enjoyable and effective; however, there is limited evidence of its educational effectiveness compared to cadaveric dissection, so further study is required.

9 | AUGMENTED REALITY (AR)

AR is a new generation of 3D-visualized technology, defined as “...the concept of digitally superimposing virtual objects onto physical objects in real space so the individual can interact with both at the same time” (Azuma, 1997). It has been explored recently in anatomy education and research (Kuehn, 2018; Moro, Štromberga, Raikos, & Stirling, 2017). The most distinctive feature of AR is its ability to represent an anatomical model in three dimensions without losing the sense of the user’s own environment (Bogomolova et al., 2019). An example of the implementation of AR in anatomy education is its application in a mobile display device, the camera in which it scans images of books (Küçük, Kapakin, & Goktas, 2016). One study showed that AR resulted in better test scores than traditional lectures and dissection, although students preferred the traditional methods (Peterson & Mlynarczyk, 2016). Another study showed that students who used mobile AR had significantly higher test scores than those who used two-dimensional pictures, graphs, and text (p < 0.05) (Küçük et al., 2016). Chytas et al. (2020) also encouraged the use of AR, although available research outcomes on AR in anatomy education are relatively limited.

10 | VIRTUAL REALITY (VR)

One of the most interesting aspects of VR is that users can interact with the virtually generated environment (Izard, Juanes Méndez, & Palomera, 2017; Kletoni, Normand, Sanchez-Vives, & Slater, 2012). VR has been used and its effectiveness in learning evaluated (Codd and Choudhury, 2011; Khot, Quinlan, Norman, & Wainman, 2013; Kockro...
et al., 2015; Solyar, Cuellar, Sadoughi, Olson, & Fried, 2008; Uruthiralingam & Rea, 2020; Zhao, Xu, Jiang, & Ding, 2020). Although some studies have promoted the use of VR (Kockro et al., 2015; Solyar et al., 2008; Zhao et al., 2020), the structures on which the VR focuses could affect the results. Birbara, Sammut, and Pather (2019) compared the perceptions of anatomy using 3D skull models and suggested that a desktop could be appropriate for delivering VR resources. Interestingly, the authors emphasized that the more important factor was prior knowledge.

11 | CONCLUSIONS

Many studies evaluating the effectiveness of these education methods/modalities have been relatively subjective, as it is difficult to compare them with traditional methods under equal and unbiased conditions. The meta-analysis by Wilson et al. (2018) showed that when traditional dissection was compared to other laboratory approaches, that is, 3D models, prosection, digital media, and hybrid approaches, the students’ scores were statistically equivalent. The authors encouraged educators to select the educational method on the basis of its purpose, not the inherent attributes of the method itself. As Lackey-Cornelson, Bauler, and Smith (2020) indicated, prior anatomical knowledge has a greater influence on the short-term retention of knowledge than the learning modality does. Not only does cadaveric dissection help medical students to learn human structure and function, but the dissection experience can also promote the development of teamwork, self-reflection, interprofessional and communication skills, and ethical qualities (Ghosh, 2016; Moore, 1998). Lastly, rather than arguing whether human cadavers should or should not be used for anatomy education, we should argue for using them as one of many parallel approaches (McMenamin et al., 2018) (Figure 1).

ORCID
Joe Iwanaga https://orcid.org/0000-0002-8502-7952
Marios Loukas https://orcid.org/0000-0003-2811-6657
R. Shane Tubbs https://orcid.org/0000-0003-1317-1047
REFERENCES

Alameddine, M. B., Englesbe, M. J., & Waits, S. A. (2018). A video-based coaching intervention to improve surgical skill in fourth-year medical students. *Journal of Surgical Education, 75*, 1475–1479.

Attardi, S. M., & Rogers, K. A. (2015). Design and implementation of an online systemic human anatomy course with laboratory. *Anatomical Sciences Education, 8*, 53–62.

Attardi, S. M., Choi, S., Barnett, J., & Rogers, K. A. (2016). Mixed methods student evaluation of an online systemic human anatomy course with laboratory. *Anatomical Sciences Education, 9*, 272–285.

Attardi, S. M., Barbeau, M. L., & Rogers, K. A. (2018). Improving online interactions: Lessons from an online anatomy course with a laboratory for undergraduate students. *Anatomical Sciences Education, 11*, 592–604.

Athy, A. M., Knight, S., Lester, F., Dubowitz, G., Byamugisha, J., Nsubuga, Y., … Korn, A. (2013). Teaching surgical skills using video internet communication in a resource-limited setting. *Obstetrics and Gynecology, 122*, 127–131.

Aziz, M. A., McKenzie, J. C., Wilson, J. S., Cowie, R. J., Ayeni, S. A., & Dunn, B. K. (2002). The human cadaver in the age of biomedical informatics. *The Anatomical Record, 269*, 20–32.

Azu, O. O., Peter, A. I., Etuknwa, B. T., & Ekandem, G. J. (2012). The awareness of medical students in Nigerian universities about the use of plastinated specimens for anatomical studies. *Macedonian Journal of Medical Sciences, 5*, 5–9.

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments, 6*, 355–385.

Backhouse, S., Taylor, D., & Armitage, J. A. (2019). Is this mine to keep? Three-dimensional printing enables active, personalized learning in anatomy. *Anatomical Sciences Education, 12*, 518–528.

Baguley, R. (2017). *3D printing materials: The pros and cons of each type*. Retrieved from https://www.tomsguide.com/us/3d-printing-materials, news-24392.html

Baker, E. W., Slott, P. A., Terracio, L., & Cunningham, E. P. (2013). An innovative method for teaching anatomy in the predoctoral dental curriculum. *Journal of Dental Education, 77*, 1498–1507.

Barry, D. S., Marzouk, F., Chulak-Oglu, K., Bennett, D., Tierney, P., & O’Keeffe, G. W. (2016). Anatomy education for the YouTube generation. *Anatomical Sciences Education, 9*, 90–96.

Bell, F. E., 3rd., Neuffer, F. H., Haddad, T. R., Epps, J. C., Kozik, M. E., & Warren, B. C. (2019). Active learning of the floor of mouth anatomy with ultrasound. *Anatomical Sciences Education, 12*(3), 310–316.

Bhandari, K., Acharya, S., Srivastava, A. K., Kumari, R., & Nimmagada, H. K. (2016). Plastination: A new model of teaching anatomy. *International Journal of Anatomy and Research, 4*, 2626–2629.

Birbara, N. S., Sammut, C., & Pather, N. (2019). Virtual reality in anatomy: a pilot study evaluating different delivery modalities. [published online ahead of print, 2019 Oct 6]. *Anatomical Sciences Education*. https://doi.org/10.1002/ase.1921

Bogomolova, K., van Der Ham, I. J. M., Dankbaar, M. E. W., van Den Broek, W. W., Hovius, S. E. R., van der Hage, J. A., & Hierck, B. P. (2019). The effect of stereoscopic augmented reality visualization on learning anatomy and the modifying effect of visual-spatial abilities: a double-center randomized controlled trial [published online ahead of print, 2019 Dec 30]. *Anatomical Sciences Education*. https://doi.org/10.1002/ase.1941

Brenner, E., Maurer, H., Moriggli, B., & Pomaroli, A. (2003). General educational objectives matched by the educational method of a dissection lab. *Annnals of Anatomy, 185*, 229–230.

CDC. (2020). *Coronavirus disease 2019 (COVID-19)*. Retrieved from https://www.cdc.gov/coronavirus/2019-ncov/daily-life-coping/get-your-household-ready-for-COVID-19.html#:~:text=A%20COVID%2019%20outbreak.spread%20of%20the%20disease

Chen, C. M., & Wu, C. H. (2015). Effects of different video lecture types on sustained attention, emotion, cognitive load, and learning performance. *Computers in Education, 80*, 108–121.

Chen, S., Pan, Z., Wu, Y., Gu, Z., Li, M., Liang, Z., … Pan, H. (2017). The role of three-dimensional printed models of skull in anatomy education: A randomized controlled trial. *Scientific Reports, 7*, 575.

Choi-Lundberg, D. L., Cuellar, W. A., & Williams, A. M. (2016). Online dissection audio-visual resources for human anatomy: Undergraduate medical students’ usage and learning outcomes. *Anatomical Sciences Education, 9*, 545–554.

Chytas, D., Piagkou, M., Johnson, E. O., Tsakotos, G., Mazarakis, A., Babis, G., … Natsis, K. (2019). Outcomes of the use of plastination in anatomy education: Current evidence. *Surgical and Radiologic Anatomy, 41*, 1181–1186.

Chytas, D., Johnson, E. O., Piagkou, M., Tsakotos, G., Babis, G. C., Nikolaou, V. S., … Natsis, K. (2020). Three-dimensional printing in anatomy teaching: Current evidence. *Surgical and Radiologic Anatomy, 42*, 835–841.

Chytas, D., Johnson, E. O., Piagkou, M., Mazarakis, A., Babis, G. C., Chronopoulos, E., … Natsis, K. (2020). The role of augmented reality in anatomical education: An overview. *Annals of Anatomy, 229*, 151463.

Codd, A. M., & Choudhury, B. (2011). Virtual reality anatomy: is it compatible with traditional methods in the teaching of human forearm musculoskeletal anatomy? *Anat Sci Educ, 4*(3), 119–125. https://doi.org/10.1002/ase.214.

Cuddy, M. M., Swanson, D. B., Drake, R. L., & Pawlina, W. (2013). Changes in anatomy instruction and USMLE performance: Empirical evidence on the absence of a relationship. *Anatomical Sciences Education, 6*, 3–10.

Dharmasaroja, P. (2019). Do we not really need cadavers anymore to learn anatomy in undergraduate medicine? *Med Teach, 41*(8), 965–966. https://doi.org/10.1080/0142159X.2018.1548760.

Drake, R. L., McBride, J. M., & Pawlina, W. (2014). An update on the status of anatomical sciences education in United States medical schools. *Anatomical Sciences Education, 7*, 321–325.

Fasel, J. H., Aguiar, D., Kiss-Bodolay, D., Montet, X., Kalangos, A., Stimac, B. V., & Ratib, O. (2016). Adapting anatomy teaching to surgical trends: A combination of classical dissection, medical imaging, and 3D-printing technologies. *Surgical and Radiologic Anatomy, 38*, 361–367.

Franch, T. (2020). The impact of the Covid-19 pandemic on current anatomy education and future careers: A Student’s perspective. *Anatomical Sciences Education, 13*, 312–315.

Garas, M., Vaccarezza, M., Newland, G., McVay-Doornbusch, K., & Hasani, J. (2018). 3D-printed specimens as a valuable tool in anatomy education: A pilot study. *Annals of Anatomy, 219*, 57–64.

Ghosh, S. K. (2016). Cadaveric dissection as an educational tool for anatomical sciences in the 21st century. *Anatomical Sciences Education, 10*, 286–299.

Gleason, B. L., Peeters, M. J., Resman-Targoff, B. H., Karr, S., McBane, S., Kelley, K., … Denetclaw, T. H. (2011). An active-learning strategies primer for achieving ability-based educational outcomes. *American Journal of Pharmaceutical Education, 75*, 186.

Granger, N. A., & Calleson, D. (2007). The impact of alternating dissection on student performance in a medical anatomy course: Are dissection videos an effective substitute for actual dissection? *Clinical Anatomy, 20*, 315–321.

Grosser, J., Bientzle, M., Shiozawa, T., Hirz, B., & Kimmner, J. (2019). Acquiring clinical knowledge from an online video platform: A randomized controlled experiment on the relevance of integrating anatomical information and clinical practice. *Anatomical Sciences Education, 12*, 478–484.

Haque, A. M. E., Haque, M., Than, M., Khassan, L. H. B. M., Ishak, A. M. B., Azmi, A. D. B. N., & Rezal, M. A. D. B. (2017). Perception on the use of plastinated specimen in anatomy learning among
preclinical medical students of UNIKL RCMP, Malaysia. *Journal of Global Pharma Technology*, 9, 25–33.

Hennessy, C. M., Kirkpatrick, E., Smith, C. F., & Border, S. (2016). Social media and anatomy education: Using Twitter to enhance the student learning experience in anatomy. *Anatomical Sciences Education*, 9, 505–515.

Hidebrandt, S. (2010). Lessons to be learned from the history of anatomical teaching in the United States: The example of the University of Michigan. *Anatomical Sciences Education*, 3, 202–212.

Izard, S. G., Juanes Méndez, J. A., & Palomera, P. R. (2017). Virtual reality educational tool for human anatomy. *Journal of Medical Systems*, 41, 76.

Jaffar, A. A. (2014). Exploring the use of a Facebook page in anatomy education. *Anatomical Sciences Education*, 7, 199–208.

Jaffar, A. A. & Eladl, M. A. (2016). Engagement patterns of high and low academic performers on Facebook anatomy pages. *Journal of Medical Education and Curricular Development*, 3, JMECD.S36646.

Khot, Z., Quinlan, K., Norman, G. R., & Wainman, B. (2013). The relative effectiveness of computer-based and traditional resources for education in anatomy. *Anatomical Sciences Education*, 6, 211–215.

Kilteni, K., Normand, J. M., Sanchez-Vives, M. V., & Slater, M. (2012). Use of instructional anatomy videos on student performance. *Anatomical Sciences Education*, 5, 158–164.

Lackey-Cornelison, W. L., Bauler, L. D., & Smith, J. (2020). A comparison of three-dimensional printed models of the upper limb for anatomical education. *Anatomical Sciences Education*, 11, 54–64.

Li, J. (2016a). Do ... anymore to learn anatomy in undergraduate medicine? *Anatomical Sciences Education*, 9, 16–21.

Liu, J., Maurya, M., & Vyas, A. (2017). Use of instructional anatomy videos on student performance. *Anatomical Sciences Education*, 10, 205–214.

McMenamin, P. G., McLaughlan, J., Wilson, A., McBride, J. M., Pickering, J., Evans, D. J. R., & Winkelmann, A. (2018). Do we really need cadavers anymore to learn anatomy in undergraduate medicine? *Medical Teacher*, 40, 1020–1029.

M但仍, G. W., & Lewis, T. L. (2016). Anatomy education for the YouTube generation: Technical, ethical, and educational considerations. *Anatomical Sciences Education*, 9, 496–497.

Mogali, S. R., Yeong, W. Y., Tan, H. K. J., Tan, G. J. S., Abrahams, P. H., Zary, N., ... Ferenczi, M. A. (2018). Evaluation by medical students of the educational value of multimaterial and multi-colored three-dimensional printed models of the upper limb for anatomical education. *Anatomical Sciences Education*, 11, 54–64.

Moore, N. A. (1998). To dissect or not to dissect? The Anatomical Record, 253, 8–9.

Mo, C., Stromberga, Z., Raikos, A., & Stirling, A. (2017). The effectiveness of virtual and augmented reality in health sciences and medical anatomy. *Anatomical Sciences Education*, 10, 549–559.

Mustafa, A. G., Taha, N. R., Alshboul, O. A., Alsalem, M., & Malki, M. I. (2020). Using YouTube to learn anatomy: Perspectives of Jordanian medical students. *BioMed Research International*, 2020, 6861416.

Netter, F. H. (2014). *Netter 3D anatomy*. Philadelphia, PA: Elsevier. http://netter3d anatomy.com

Potterton, P. D., & Mlynarczyk, G. S. (2016). Analysis of traditional versus three-dimensional augmented curriculum on anatomical learning outcomes. *Anatomical Sciences Education*, 9, 529–536.

Pickering, J. D., & Bickerdike, S. R. (2017). Medical student use of Facebook to support preparation for anatomy assessments. *Anatomical Sciences Education*, 10, 205–214.

Pollock, W., & Rea, P. M. (2019). The use of social media in anatomical and health professional education: A systematic review. *Advances in Experimental Medicine and Biology*, 1205, 149–170.

Rai, R., Shereen, R., Protas, M., Greaney, C., Brooks, K. N., Iwanga, J., ... Tubbs, R. S. (2019). Social media and cadaveric dissection: A study survey. *Clinical Anatomy*, 32, 1033–1041.

Saverino, D. (2020). Teaching anatomy at the time of COVID-19 [published online ahead of print, 2020 Apr 29]. *Clinical Anatomy*. https://doi.org/10.1002/ca.23616

Saxena, V., Natarajan, P., O’ Sullivan, P. S., & Jain, S. (2008). Effect of the use of instructional anatomy videos on student performance. *Anatomical Sciences Education*, 1, 159–165.

Smith, C. F., Tollemache, N., Covill, D., & Johnston, M. (2018). Take away body parts! An investigation into the use of 3D-printed anatomical models in undergraduate anatomy education. *Anatomical Sciences Education*, 11, 44–53.

Soloy, A., Cuellar, H., Sadoughi, B., Olson, T. R., & Fried, M. P. (2008). Endoscopic sinus surgery simulator as a teaching tool for anatomy education. *American Journal of Surgery*, 196, 120–124.

Souza, A. D., Kotian, S. R., Pandey, A. K., Rao, P., & Kalthur, S. G. (2020). Cadaver as a first teacher: A module to learn the ethics and values of cadaveric dissection. *Journal of Taibah University Medical Sciences*, 15, 94–101.

Stephens, G. C., Rees, C. E., & Lazarus, M. D. (2019). How does donor dissection influence medical students’ perceptions of ethics? A cross-sectional and longitudinal qualitative study. *Anatomical Sciences Education*, 12, 332–348.

Topping, D. B. (2014). Gross anatomy videos: Student satisfaction, usage, and effect on student performance in a condensed curriculum. *Anatomical Sciences Education*, 7, 273–279.

Triepels, C. P., Sneets, C. F., Notten, K. J., Kruivwagen, R. F., Futterer, J. J., Vergeldt, T. F., & Van Kuijik, S. M. (2020). Does three-dimensional anatomy improve student understanding? *Clinical Anatomy*, 33, 25–33.
Tsang, A., & Harris, D. M. (2016). Faculty and second-year medical student perceptions of active learning in an integrated curriculum. *Advances in Physiology Education, 40*, 446–453.

Uruthiralingam, U., & Rea, P. M. (2020). Augmented and virtual reality in anatomical education - A systematic review. *Advances in Experimental Medicine and Biology, 1235*, 89–101.

Viswasom, A. A., & Jobby, A. (2017). Effectiveness of video demonstration over conventional methods in teaching osteology in anatomy. *Journal of Clinical and Diagnostic Research, 11*, JC09–JC11.

Whelan, A., Leddy, J. J., & Ramnanan, C. J. (2018). Benefits of extracurricular participation in dissection in a prosection-based medical anatomy program. *Anatomical Sciences Education, 11*, 294–302.

Wilson, A. B., Miller, C. H., Klein, B. A., Taylor, M. A., Goodwin, M., Boyle, E. K., … Lazarus, M. (2018). A meta-analysis of anatomy laboratory pedagogies. *Clinical Anatomy, 31*, 122–133.

Winkelmann, A. (2007). Anatomical dissection as a teaching method in medical school: A review of the evidence. *Medical Education, 41*, 15–22.

Zhang, X., Yang, J., Chen, N., Zhang, S., Xu, Y., & Tan, L. (2019). Modeling and simulation of an anatomy teaching system. *Visual Computing for Industry, Biomedicine, and Art, 2*, 8.

Zhao, J., Xu, X., Jiang, H., & Ding, Y. (2020). The effectiveness of virtual reality-based technology on anatomy teaching: A meta-analysis of randomized controlled studies. *BMC Medical Education, 20*, 127.

**How to cite this article:** 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: 108–114. [https://doi.org/10.1002/ca.23655](https://doi.org/10.1002/ca.23655)