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To the Editor of *Anatomical Sciences Education*:

We read, with great interest, the review article recently published in the *Anatomical Sciences Education* by Santos et al. (2022), who explored and synthesized the technological resources used to teach anatomy. Recent randomized studies have demonstrated the significant importance of new innovations in anatomy courses as they can increase student satisfaction, involvement, and knowledge acquisition (Guze, 2015; Gloy et al., 2022). These improvements can largely be attributed to variety of methods providing more authentic learning contexts, realistic practice environments, and improved visualizations. Therefore, the use of technology in medical education has been aimed at facilitating the acquisition of basic knowledge while also improving decision-making and clinical reasoning. To this end, many novel avenues have been explored to achieve these goals (Camilo et al., 2021).

In December 2019, the city of Wuhan, China experienced an outbreak of pneumonia of unknown cause (Cavalcante et al., 2020). In January 2020, Chinese researchers identified a new coronavirus (SARS-CoV-2) and determined it to be the etiological agent of the severe acute respiratory syndrome termed Covid-19 (Coronavirus disease—2019) (Cheng & Shan, 2019). Soon after, the disease was documented in other countries in Asia, Europe, and North America, reaching more than 110,000 cases distributed across 114 countries, which led the World Health Organization to declare Covid-19 a pandemic on March 11, 2020 (WHO, 2020). Since then, approximately 29,350,134 cases and 654,945 deaths have been recorded in Brazil (Ministry of Health, 2021). In response to the increasing spread and mortality of Covid-19, on March 17, 2020, the Brazilian government enacted ordinance No. 343, which mandated face-to-face classes be replaced with virtual teaching while the pandemic was ongoing (Diário Oficial da União, 2020). Brazil accumulated one of the highest numbers of Covid-19 cases and deaths, and thus the pandemic has had lasting effects on educational environments (Cavalcante et al., 2020). After initial decreases in global case counts, a second wave occurred in many regions (North America, Europe), and since this second wave, some countries, such as Brazil, Argentina and India, have maintained a high burden of Covid-19 infection rates. (Camilo et al., 2021; Prezotti et al., 2021).

It is essential to highlight that the effects of the pandemic had consequences reaching beyond the educational context for many students. Studies have identified that students experienced

economic concerns, decreases general wellbeing, and mental health struggles related to social isolation, estrangement, frustration, confusion, and anger (Loscalzo & Giannini, 2022). They now face considerable uncertainty about their present and the future, and because of this, students have become despondent about their personal and professional development (Butnaru et al., 2021; Cheng et al., 2021; Leal Filho et al., 2021; Rahiem et al., 2021). León-Manco et al. (2021) concluded that “the pandemic has influenced the personal, social, labor, and everyday life of dental staff and affected the mental health of this population”. To partially mitigate these concerns and support students in this trying time, innovative methods of teaching and institutional support have been shown to be key in increasing student motivation.

The pandemic has highlighted and accelerated the need for universities to reinvent teaching methods, particularly in subjects that requiring practical classes, such as anatomy, which retains broad relevance to all areas of clinical practice (Erie et al., 2013; Davis et al., 2014; Iwanaga et al., 2021; Kudzinskas & Giddins, 2021). These new realities impressed upon universities, academic departments, and course instructors the importance of adapting quickly to prevent or reduce a drop in pedagogical efficacy and content delivery, which would subsequently affect the safety and quality of higher-level medical education. In anatomy, these changes affected almost every aspect of teaching because anatomists were unable to rely on their main teaching resource, i.e., the human body (Border et al., 2021). In this sense, the use of modern technologies in anatomy has even more relevance compared to medical education more generally (Davis et al., 2014; Dua et al., 2021; Chytas et al., 2022).

Unfortunately, the challenges of Covid-19 compounded in Latin American and developing nations because of preexisting structural barriers. In Brazil, not all students have the computers or hardware necessary to participate in live streamed simultaneous participation classes, and others are in more complex positions of socioeconomic vulnerability. We noticed that private educational institutions in Brazil were able to continue with less interruption to their academic calendars compared to public institutions during the switch to online learning. Indeed, public hospitals have been documented to lack online learning environment and more advanced active teaching technologies in several studies (Carvalho et al., 2020; Sousa et al., 2021).

In medical education, new technologies are created to facilitate knowledge acquisition, improve clinical decision-making, build

psychomotor skills, and enhance teamwork capacity. Such innovations have taken the form of digital applications (apps), games, and medical simulations with realistic dummy simulators (Guze, 2015). Today's students expect technology to be integrated into both the classroom and remote learning (Border et al., 2021) and have a native ability to integrate new digital tools into their personal studying workflows.

For these reasons, the implementation of technology-enhanced teaching into radiological anatomy e-learning is effective and popular with many students and educators alike, especially during the pandemic period. E-learning encompasses a wide range of tools, including computer-based atlases and tutorials, and e-learning/traditional hybrid methods (Davis et al., 2014; Border et al., 2021). In anatomy specifically, the expanding role of medical imaging such as magnetic resonance imaging (MRI), computed tomography (CT), and radiography mandates a greater emphasis on correlating anatomy and imaging examinations. Radiologic anatomy e-learning provides a greater number and variety of images which allows students to engage in deeper and more comprehensive activities (Border et al., 2021). In this way, students become more invested and adapted to incorporating imaging examination into their future careers (Webb & Choi, 2014; Border et al., 2021). Thus, in this era, the task of medical educators will be to transform learning into a more collaborative, personalized, and empowering experience through technological innovation and enhancement (Kourdioukova et al., 2011; Guze, 2015; Bork et al., 2019),

Medical images are crucial to clinical diagnosis, planning, and monitoring of patient health (Durfee et al., 2003; Chew & O'Dwyer, 2020). As such, a general understanding of the different imaging modalities, as well as the basic interpretation skills required for these studies, have become increasingly important in medical practice (Zwaan et al., 2017). In the context of the growing relevance of medical imaging, an increase in educational activities devoted to radiology is required to explore recent developments and prepare health care students for future practice. However, recent studies have shown that radiology education is still deficient in many respects, which is attributed to factors such as limited teaching time and gaps between anatomical and radiological education (Saha et al., 2013; Straus et al., 2014). Integration among the classical disciplines of undergraduate medicine is recognized as an effective method for student learning due to the inherent interdisciplinarity among these subjects (Bork et al., 2019). According to Mirsadraee et al. (2012), Lo and Awan (2020), and Corrêa et al. (2022), radiology is an integral part of patient diagnosis and management. In this sense, students must acquire basic knowledge of radiology and its use in contemporary medical practice, regardless of their chosen specialty (Durfee et al., 2003; Kourdioukova et al., 2011; Oris et al., 2012). In this regard, radiological anatomy e-learning helps students to see the clinical relevance of anatomy, with a concurrent increased interest in radiology. Thus, technology can help overcome many challenges facing clinical radiology, anatomy education and, more broadly, the modern medical curriculum. These challenges include (1) the facilitation of active and autonomous student-centered learning, (2) the implementation of practical experiences early in medical curricula, and (3) the integration of basic and clinical sciences to help

students appreciate the relevance of basic science to medical practice (Rizzolo et al., 2010; Ahmed et al., 2011).

In this context, active methodology and modern technologies have improved radiological anatomy education. Chen et al. (2022) highlighted some forms of radiology teaching during the pandemic, namely, microlearning, digital learning, visual learning, tablet drawing and digital human atlases. Iwanaga et al. (2021) drafted an important review that contrasted traditional and modern methods of anatomical study, while Chytas et al. (2022) highlighted the potential of virtual reality. Finally, the teaching of ultrasound and its inclusion into anatomy courses should be noted. Camilo et al. (2021), Toledo et al. (2021), Lufler et al. (2022), and Olivares-Perez et al. (2022) have all emphasized the importance of ultrasound in the teaching of students and physicians, which can even be done remotely.

Scientific production during academic training allows students to become self-motivated in the pursuit of increasing levels of knowledge and to put that knowledge into practice (Doubleday & Wille, 2014). In this way, students become more prepared for the job market, as they have already become familiarized with the scientific environment during their training. Such early scientific involvement contributes to the realization of evidence-based medicine in clinical practice. Scientific production also allows academics to diversify their areas of expertise and delve into relevant topics, which are sometimes superficially addressed during training due to fast paced high content courses. Participation in scientific pursuits also prepares students for academic positions, which is a major criterion for entry into the best medical residency programs (Peluso & Hafler, 2011; Erie et al., 2013). Finally, scientific production is guided by specialists in the research area which enhances the level of expertise gained and reinforces the importance of learning by doing. This approach makes students part of the scientific and teaching process, in addition to strengthening the student-professor relationships. For teachers, it provides valuable opportunities for adopting students into both the institution and the subject area community, transmits skills and responsibilities, and updates educational concepts and technologies (Erie et al., 2013; Davis et al., 2014; Sousa et al., 2021). Finally, student involvement in scientific research improves students' communication skills and prepares them for their future roles as teachers (Erie et al., 2013).

Given interdisciplinary nature of anatomy and radiology, the importance of technology (especially radiological anatomy e-learning) for improving medical education, the emphasis of scientific production in academia, and the need of new materials for anatomy courses during the pandemic period, the Department of Anatomy of the Faculty of Medical and Health Sciences of SUPREMA and the Department of Anatomy of the Federal University of Juiz de Fora in Brazil produced two digital atlases of anatomic radiology. One details the musculoskeletal systems, and the other focuses on the digestive, respiratory, cardiovascular, urinary, endocrine and genital systems (Camilo et al., 2021a,b). These digital atlases have been incorporated into the institution's library collection, and they can be accessed free of charge and online by all university students through the institution's platform, where they have had received more than

600 hits since publication. For this project, the authors used radiographs, computed tomography images, and magnetic resonance images from the authors' personal collections in addition to photographs of anatomical specimens taken from the anatomy laboratory. The use of these images was approved by the university's ethics committee (decision number CAAE: 01508418.8.0000.5103). The authors' intention in publishing the digital atlas was to familiarize students with anatomical structures in imaging examinations from the beginning of their medical education in addition to encouraging clinical reasoning and facilitating access to new study materials. The authors would particularly like to highlight the active role of anatomy students in this project. By contributing to the atlas' creation, participating students reinforced anatomy concepts while simultaneously gaining agency in building parts of their own academic curriculum. Finally, the students' contributions were formalized into research projects which is of great relevance for their entry into the best medical residency programs.

A total of six students and three professors from the institution's anatomy and radiology departments participated in the project. The students contributed to the photography of the anatomical specimens, the identification of the anatomical structures on the images and assembly and editing of the e-book. The professors not only curated radiological images from their personal collections but also engaged in active discussions of the images and planning of assembly and content e-book. The e-book was constructed through the PowerPoint platform (Microsoft Corp., Redmond, WA). The material was reviewed by the institution's anatomy professors, as well as by a radiologist and other specialists at the institution to guarantee and corroborate the quality of the material. Finally, the e-book received professional editing and was published under registration by the Brazilian National Library, thereby indicating the scientific quality and definitive character of the work.

Since its publication in 2021, the e-book has had more than 600 hits and has remained on loan for more than 80% of the time, according to institutional library data. This demonstrates broad acceptance of e-book, which has been praised for its: (1) systematic content organization; (2) presentation of radiological and anatomical images which facilitates easy comparison between the two; (3) the direct and didactic content; (4) the pdf formatting which enables distribution through even a cell phone; and (5) the high-resolution image quality, which helps orient viewers to the 3D nature of anatomy. These characteristics have been confirmed by the professors of the institution's anatomy department, who noted the continued use of the e-book even after the return of face-to-face classes and a concomitant improvement of overall student performance on tests. The professors also observed that the ease of access allowed for the better consolidation of knowledge due to the practicality of, for example, quickly checking an anatomical structure that a student may be studying on a cell phone.

In-depth knowledge of anatomy and translating anatomical knowledge to image examinations are of great relevance to clinical and surgical disciplines. Thus, the development of effective modalities for teaching anatomy is essential for safe medical practice, and the best way to teach modern anatomy is the combination of various

pedagogical resources as complements. This includes active methodologies and opportunities for students to act as teachers (Estai & Bunt, 2016). Many studies have demonstrated the importance and effectiveness of teaching radiology and anatomy with new technologies during active and distance courses; thus, universities need to correctly utilize these methods, which have become essential during the pandemic. It is also worth emphasizing the importance of including student teacher collaboration in the process, letting students "learn by doing" and telling instructors "how to teach" (Davis et al., 2014; Camilo et al., 2021). In this context, the authors of the e-book hope that the atlas will be a useful tool in medical education and facilitate improvement at the local level and hopefully, with greater circulation in the future, at other institutions. Finally, it is imperative to continue research into students' adoption and experience of new teaching methodologies and the effects of these methodologies on learning outcomes.

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