INTRODUCTION

The impact of the coronavirus disease 2019 (Covid-19) pandemic on anatomy education has been dramatic. Studies have shown that during the pandemic there was a dramatic shift in the provision of both gross and microscopic anatomy teaching from a face-to-face environment to one relying on online platforms and digital technologies (Moszkowicz et al., 2020; Srinivasan, 2020; Darici et al., 2021). Gross anatomy education has been particularly impacted by the traditional format of cadaver-based laboratory setting (Harmon et al., 2021; Attardi et al., 2022). The Covid-19 pandemic, for example, resulted in a sharp decline in gross anatomy learning using traditional hands-on tools across many countries such as Australia (Pather et al., 2020), New Zealand (Pather et al., 2020), Korea (Yoo et al., 2021) and the United States (US) (Harmon et al., 2021; Attardi et al., 2022). In response, anatomy educators around the world have demonstrated the ability to be agile and creative, adapting to the needs of learners and navigating various logistical challenges to develop and make available new digital and related resources (Srinivasan, 2020; Attardi et al., 2022; Babacan & Dogru Yuvarlakbas, 2022). There has been a dramatic increase in the adoption of digital tools including virtual dissection media and interactive software in the US (Attardi et al., 2022), Canada (Attardi et al., 2022), United Kingdom (UK) (Dulohery et al., 2021) and the Republic of Ireland (ROI) (Dulohery et al., 2021). Digital modules have been developed to supplement operative anatomy programs with alternative and innovative teaching and learning strategies having been trialed and implemented for almost two years, the key question now is what the pedagogy will be for anatomy education beyond the pandemic. Here we discuss some of the changes in anatomy education that have taken place as a result of the Covid-19 pandemic and importantly present some outlooks for evidence-based anatomy pedagogy as the world enters the post-pandemic phase and beyond. The authors conclude that the anatomy discipline is ready to further modernize and has the opportunity to use digital technologies to evolve and enhance anatomy education to ensure students are provided with the learning experience which will prepare them best for the future.

KEYWORDS

Covid-19, digital anatomy, gross anatomy education, hybrid learning, pandemic, post-pandemic
The pandemic, only one-third of them preferred to continue online teaching during the Covid-19 pandemic (Dulohery et al., 2021). Despite this, students demonstrated reasonable satisfaction and resilience in response to the emergency switch to online teaching, the change of teaching modalities, and the provision of learning materials (Kim et al., 2020; McWatt, 2021; Mahdy & Sayed, 2022). Notably, students expressed divergent but consistent preferences for the provision of lectures and laboratory classes. Post-class surveys revealed that most students preferred online lectures over traditional large group didactic teaching and wanted to maintain online lectures in the future (Kim et al., 2020; Yoo et al., 2021; Mahdy & Sayed, 2022; Saverino et al., 2022). On the contrary, the learning opportunities that were consistently missed by students were the face-to-face practical laboratory classes (Dulohery et al., 2021), in particular, cadaveric dissection classes for medical students (Basavanna et al., 2022). This is, however, not a pandemic-induced change in student preference, but an ongoing issue that has been reported since pre-pandemic (Attardi et al., 2016, 2018), suggesting a need to address the future anatomy learning experience.

In contrast, educators held mixed perceptions of continuing online teaching beyond the Covid-19 pandemic. A survey in the UK and ROI showed that the vast majority of participating anatomists preferred traditional on-site teaching rather than remote learning for both lectures (78.3%, n = 18) and practical (95.8%; n = 23) sessions (Dulohery et al., 2021). Similarly, a national survey in China indicated that, whilst half of the teachers (359 participants) were very satisfied or satisfied with the effectiveness of online teaching during the pandemic, only one-third of them preferred to continue online lectures after the pandemic (Cheng et al., 2021). A survey in Korea showed that less than 10% of academics preferred online lectures and over half of them wanted to go back to the traditional offline courses when the pandemic ends (Kim et al., 2020). The remaining 40% preferred a hybrid model of delivery blending both online and offline learning (Kim et al., 2020). Educators’ mixed perception of online teaching could be partially due to the negative experience of educators as a result of the workload intensity required to produce online delivery in an extremely short timeframe and without staff peer interaction and support (Longhurst et al., 2020; Pather et al., 2020; Dulohery et al., 2021; Jones, 2021; Yan et al., 2021). Turning teaching from face-to-face to online is not a simple technical conversion because it requires a time investment in session design, content preparation, and staff upskilling (Evans et al., 2020), however, the Covid-19 pandemic provided limited planning and preparation time. Encouragingly, over 95% of academics in the UK and ROI reported that they have upskilled in new technologies to meet the demands of online teaching in the future (Dulohery et al., 2021).

As universities resume the on-campus experience, educators need to reflect on and learn from the highs and lows of the pandemic approach to anatomy teaching and learning and assess what the post-pandemic pedagogies will look like going forward. The authors present here some outlooks that should be considered as educators develop the next phase of anatomical sciences education provision and take advantage of the opportunities of what and for evidence-based anatomy pedagogy as the world enters the post-pandemic phase and beyond.

**FUTURE OUTLOOKS**

**Outlook 1: A learner-driven design of digital learning**

The population of students that anatomy educators are providing for is becoming more diverse in terms of age, gender, culture, and geography (Vnuk et al., 2017; Avci et al., 2019; Bliss et al., 2020; Eansor et al., 2022). Students are also showing increasing preferences and need to personalize their learning as they contend with additional and off-campus commitments (Franzoi et al., 2021; Legan & Zupan, 2022). However, one important additional factor for anatomists to appreciate is that increasing numbers of their students are now “digital natives” (Jones, 2010; Evans & Robertson, 2020), with many students currently studying at universities born in the new millennium. These young students are among the iGen (Twenge, 2017) or Generation Z (Seemiller & Grace, 2018), the first generation who have experienced ubiquitous mobile technologies since birth. Digital literacy for these students has been an integral part of their learning journey since primary school and it is essential that anatomy educators recognize and respond to this as their perspectives and preferences on learning engagement are different. The anatomy community also needs to support their learning as educators enter a technology-dominant work environment in which they need to succeed. Given this predominance of information and communication technologies and the changing population of learners in the current environment, the extent to which learners can access and utilize the digital resources for learning anatomy imposes an important issue for educators to reflect on, especially as a result of the Covid-19 pandemic. Whilst the majority of anatomists appear to prefer traditional on-site teaching over online learning (Kim et al., 2020; Cheng et al., 2021; Dulohery et al., 2021; Yan et al., 2021), during the pandemic, students indicate a clear interest in learning some of their anatomy such as lecture-type material online whilst practical classes should be delivered face-to-face (Kim et al., 2020; McWatt, 2021; Singal et al., 2021; Yoo et al., 2021; Mahdy & Sayed, 2022; Ortadeveci et al., 2022; Saverino et al., 2022), suggesting a learner-driven preference for a hybrid teaching model over the long term. Such an approach needs to balance intuitive technological solutions that effectively connect students to
relevant and supporting resources without losing teacher interaction and peer support. Anatomy teaching can be delivered via a careful combination of asynchronous and synchronous delivery, a spatially and temporally hybrid teaching model feasible for gross and microscopic anatomy teaching (Caruso, 2021; Xiao & Adnan, 2022). The asynchronous activities are applied to enable students to learn at times and in locations most convenient for them, while the synchronous sessions maintain a structure that focuses on interaction and collaboration in a real-time manner (online or face-to-face). Both formats of teaching can be structured to motivate students to stay engaged with the content of the course and maintain effective and timely teacher-student communication. In this context, anatomy educators need to challenge whether large-scale didactic teaching should remain a key part of the current teaching approach into the future and instead new digital resources and learning interventions can be delivered, allowing greater personalized learning flexibility and more effective preparative learning opportunities. In contrast, synchronous sessions would focus on hands-on practical and applied sessions that encourage a community learning experience with educator facilitation, peer collaboration, and problem-solving.

Outlook 2: Establishing reliable digital networks for a student-centered learning environment

Appropriate and dynamic approaches to student communication are vital when employing digital learning. Communication between educators and students in face-to-face interactions is easily adaptable and can be quickly individualized as needed, whereas the ability to enable such communication in an online or digital environment is more difficult. Provision of various communication conduits including virtual discussion boards, blogs, and social media interactions will need to be seriously considered and effectively employed. Hybrid learning can provide a comparable learning experience and outcomes compared to face-to-face learning when students have adequate access to online resources and maintain effective communication with teachers and peers (Kim et al., 2020; Sadeesh et al., 2021; Mahdy & Sayed, 2022; Saverino et al., 2022). The current generation of digital natives communicate with their peers via a range of online “communities” such as social media and digital learning platforms, therefore it is important for educators to be aware of and interact with different communication channels to maintain teacher learning support and engagement.

Outlook 3: Evaluation of learning effectiveness

It is clear that there has been a plethora of papers published in the literature (with many cited within this viewpoint commentary) reporting on the innovative approaches introduced and changes made to the way in which the anatomical sciences have been taught as a result of the Covid-19 pandemic. In the main, these reports have focused on sharing of practice and discussions on the challenges faced by educators and students. An online survey was conducted from 961 student participants from over 87 countries to assess the shift to remote teaching of veterinary anatomy during the Covid-19 pandemic based on students’ perspectives (Mahdy & Ewaida, 2022). This study reported that over 80% of students were comfortable with technological skills, and more than half of them understand online anatomy well via remote learning during the lockdown (Mahdy & Ewaida, 2022). Findings like this have been insightful and useful, and for some have informed the approaches for anatomy education provision post-Covid. However, it is yet unclear what effect the changes and new approaches introduced have had on the learning gain of students. Many reports have used analytical approaches that focus primarily on the views of staff and students via surveys and focus-group discussions and while this is an important, more in-depth, and systematic evaluation of the methods used and resulting outcomes such as controlled and/or longitudinal studies are required including appropriate comparative analysis. Such evaluative work is critical if anatomy educators are to properly assess the real efficacy and value of the various approaches introduced and use this to decide what might form the basis of anatomical learning and teaching in the future including the place of digital technologies. The post-Covid-19 pandemic approach must not be a simple matter of going ‘back to normal’, but rather ‘back to better’ as a result of evidence-informed reflection and design and should focus on improving the learning experience and increasing learning gain potential. At present, there has been a tendency to focus on the negative effects of the Covid-19 pandemic on the learning and teaching experience with less focus on the downstream outcomes. Since challenges presented by the pandemic have been well described in the literature, there is now a demonstrated need for future research focusing on defining the strengths and strategic applications of digital learning tools in anatomy education.

Outlook 4: New requirements for training future anatomists

The changing modes of delivery and increased use of digital technologies in anatomy education require the ability to provide ongoing training and support to educators. The competence and attitude of anatomists toward digital technologies in teaching and research is a key factor in determining the way in which the anatomy curriculum will develop. The decline in trained anatomists has been an ongoing challenge in the anatomy discipline (Fraher & Evans, 2009; Sugand et al., 2010; Duffy, 2021). Leaders of anatomy-related departments in the US, Canada, and the European Union have expressed difficulties in hiring anatomy educators in the next 5 years (Wilson et al., 2020). Such trends pose a clear obstacle to discipline development beyond the pandemic. Future anatomists will not only require well-equipped
anatomical knowledge but demonstrated self-autonomy for ongoing upskilling of fast-developing technologies and pedagogies. Institutional support for blended and digital learning may be available; however, anatomy-specific professional development and training opportunities will be required for current and future new generations of anatomists. In this context, anatomy professional societies should play a pivotal role in the initiatives for training future anatomists, involving cross-institutional collaboration and academic-industry partnerships. In addition, anatomists should not be viewed as the passive consumers of digital technologies, but as the driver and co-designer of more sophisticated and authentic digital tools targeted for anatomy teaching. Such engagement will provide anatomists with opportunities to inform other disciplines and developments that could contribute to medical advancements (Konttila et al., 2019). For example, digital simulation is now part of clinical training for a range of surgical disciplines such as otolaryngology (Huang et al., 2015), orthopedics (Brouwers et al., 2020), ophthalmics (Pahuta et al., 2012), and neurosurgery (Coelho et al., 2020). Equipping the next generation of anatomy educators with both discipline knowledge and digital technology know-how is critical to the success of the anatomy discipline of the future. The staff upskilling during the Covid-19 pandemic (Dulohery et al., 2021) is an investment for the future and should be built upon to ensure such professional development is adopted, embraced, and supported.

Outlook 5: An opportunity for collaborative anatomy teaching and increased inclusivity

The fast development of digital technology will not only revolutionize the delivery of anatomy knowledge but should be used to catalyze cross-disciplinary collaboration at all levels including pedagogy, curriculum design, content delivery, resource development, and research. Digital technologies that target anatomy are becoming more sophisticated, accessible, and affordable and are likely to increase in their availability due to the needs and opportunities identified during the Covid-19 pandemic. As well as enhancing and providing a new approach for the delivery of existing provisions, this also creates an opportunity for anatomists to develop new courses and offerings via collaborative efforts that overcome previous technical variations, ethical constraints, and geographical barriers. Digital technologies create a new dimension for anatomy teaching with the ability to offer anatomical learning to new audiences or those who have previously not had access to effective anatomical materials (Baptiste, 2021). In light of the disruptions caused by the Covid-19 pandemic, digital anatomy resources have the ability to increase the accessibility of the future anatomy laboratory. Delivering anatomy using digital resources via a remote setting (Iwanaga et al., 2021) was found particularly beneficial to trainees who have limited access to advanced resources and training opportunities due to geographic barriers. The pandemic has informed and/or reminded us of the need to respond to the needs of remote learners and anatomy educators should use this as a driver to connect with potential new learners and focus on a more inclusive approach to learning.

Outlook 6: Digital anatomy is emerging as a new discipline

Digitization of anatomy education and resource development is not only driven by the need to engage with learners differently, but also because of logistical reasons such as increasing student numbers, financial and ethical constraints, as well as the expansion of digital technologies more widely. This shift in digitalization has inevitably been accelerated by the Covid-19 pandemic (Harmon et al., 2021). The significant adjustments to education strategies including digital transformation seen during the pandemic have created an opportunity to reconsider anatomy laboratory classes (Lachman & Pawlina, 2022), and raised the question as to whether digital anatomy can provide technical and non-technical skills teaching over the long term. Proficiency in surgical skills has already been influenced by digital technologies with augmented reality (AR) and virtual reality (VR) being introduced into surgical operations, approaches increasingly likely to be integrated into surgery in the future (Sparwasser et al., 2018). Although just one example, such developments demonstrate the need for educators to consider how best to integrate appropriate and relevant digital interventions and approaches into anatomy education provision not only for the benefit of enhancing the learning experience but to provide preparation for the working environments students will enter. The delivery of nontraditional discipline-independent skills (NTDIS) is seen as an important part of contemporary anatomy training (Evans et al., 2018; Evans & Pawlina, 2020). Although NTDIS have also been traditionally incorporated into the physical laboratory environment there is an opportunity for educators to use digital platforms to provide more varied and advanced experiences that develop these skills (Lachman & Pawlina, 2022). With all this in mind, the prevailing ecosystem of the future anatomy laboratory is likely to incorporate both physical and digital bodies (Baptiste, 2021).

It is envisaged that the growing breadth and depth of anatomy teaching involving digital technologies has established digital anatomy as a new emerging discipline of growing importance and significance. For the past 5 years, the relatively nascent domain of digital anatomy has advanced, encompassing medical imaging, three-dimensional (3D) reconstruction and printing (Soler et al., 2021), AR, VR, and mixed reality (Logeswaran et al., 2021) and an array of other technologies (Trelease, 2016). As digital anatomy develops further it will create new opportunities for future generations of anatomists not only in terms of their teaching delivery but also in their own scholarship and research development. Digital anatomy has not only begun to revolutionize anatomy education but is shifting the paradigm of pre- and vocational training for healthcare professionals at multiple levels (Wickramasinghe et al., 2022). However, if digital anatomy is to make a real ongoing impact there will need to be a
commentary, a systemic review by Papa et al. (2022) identified a
classical pedagogical strategies in the past 2 years are analyzed, there is a real
resources.
organization networks, communities of practice, and the sharing of materials and
institutional leaders will be essential with cross-institutional
Digital possibilities as well as appropriate investment in tech-
As the impact and outcomes of the significant adjustments in edu-
DISCUSSION
As the impact and outcomes of the significant adjustments in edu-
cation in the anatomy education of the future. Consistent with what has been presented in this viewpoint
commentary, a systemic review by Papa et al. (2022) identified a
clear distinction between those students and educators that
endorse the primacy of traditional dissection and those that believe that
digital-based learning approaches can provide the necessary training. Despite this discordance, future anatomy teaching practice
will require the careful adaptation of emerging methods, tools, and
resources to meet the adapting demands of the learner and appropriately prepare them for a healthcare industry increasingly underpinned by new and transformative technologies. A digital anatomy
laboratory should not be viewed as a replacement for cadaveric dissection class but as an augmented and relevant approach to advance
the delivery of applied anatomy content, technical and non-technical
skills, as well as other competencies that most effectively enable the
training of next-generation health professionals. Digital simulation of operative skills is forming an integral part of pre-vocational health professionals’ training (Kantar et al., 2018; Shi et al., 2019; Iwanaga et al., 2021). As anatomy education faces its further modernization,
ever-changing technologies, new teaching practices, and equipped educators with supporting policies all play integral roles in the transformation of anatomy pedagogy that focus on a more rounded and inclusive approach to learning (Evans & Pawlina, 2022).

CONCLUSIONS
The anatomy discipline is facing a new generation of learners and the increasing availability and sophistication of digital technologies. Anatomy educators need to be cognizant of learner needs and what technologies are available to help provide an appropriate learning experience in the future and advance anatomy education. Student competency toward digital literacy and their expectations for digital anatomy will increase over time, especially as digital technologies expand further and are more universally understood. The authors recommend that the long-term adoption of digital anatomy into the curriculum be embraced and supported during the post-Covid pandemic phase. This does not mean a total shift toward digital anatomy, at the expense of more traditional modes, but rather an appropriate integration and blending of digital technologies into learning delivery whether that be online versus face-to-face or synchronous versus asynchronous. The authors conclude that the anatomy discipline is ready to further modernize and has the opportunity to use digital technologies to evolve and enhance anatomy education to ensure students are provided with the learning experience which will prepare them best for the future. However, this relies on a commitment to change and the necessity to evaluate the efficacies of new interventions and existing approaches.

ACKNOWLEDGMENT
Open access publishing facilitated by Swinburne University of Technology, as part of the Wiley - Swinburne University of Technology agreement via the Council of Australian University Librarians.

CONFLICT OF INTEREST
The author declares no conflict of interests.

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How to cite this article: Xiao J, & Evans DJR. 2022. Anatomy education beyond the Covid-19 pandemic: A changing pedagogy. Anat Sci Educ 15:1138–1144. https://doi.org/10.1002/ase.2222