Virtual delivery: a panacea for the financial and ethical challenges associated with physiology laboratory classes?

Running head: Financial and ethical issues with physiology laboratory classes

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After more than a year of adapting physiology courses for remote learning, course coordinators are now asking themselves: What should our laboratory classes look like as we return to in-person teaching? Should we reinstate our laboratory classes that utilise animal tissue even though we continue to face pressures from university administrators and members of animal ethics committees to justify their cost and use? How will we safely conduct volunteer student-as-subject and team-based laboratory classes given the likely persistence of COVID-19? What are effective ways to incorporate the virtual resources that we developed and/or used in our courses during the COVID-19 pandemic, or should these continue to completely replace our pre-pandemic laboratory classes?

Here, we, a group of physiology educators, who previously shared our experiences of rapidly transitioning our on-campus in-person laboratory classes to remote virtual learning (1), argue that this is an opportune time for course coordinators to review their physiology course learning outcomes and then decide how best to meet them. We focus on the financial and ethical challenges, and in doing so address technological and educational opportunities and constraints of both virtual and in-person approaches to the delivery of laboratory classes. Our views stem from our reflections analyzed for the Choate et al., 2021 paper and our ensuing discussions.

Rationale for physiology laboratory classes and their evolution over time

For us, physiology laboratory classes serve to reinforce knowledge and help students develop hands-on laboratory skills, teamwork, analytical and communication skills. They also introduce students to the ethics of animal and human experimentation, and in many cases, begin to train students for independent research work and/or clinical careers. To achieve these outcomes, physiology course coordinators have adopted a variety of curriculum delivery approaches, many of which have evolved over the years due to financial and animal ethics challenges.

Historically, many science and medical courses included classical physiology demonstrations (2) involving, for example, the use of animal sciatic nerve, skeletal muscle, heart, eye, and intestinal preparations. These types of laboratory classes are typically expensive to run as they are labour intensive, involve the purchase and maintenance of animals, and require suitable spaces, equipment, and consumables. Ethical concerns including pressures from the animal rights movement (3), together with a growing population of students who are morally and ethically averse to animal use, has led to a reduction or removal of laboratory classes involving the sacrifice of animals and a shift to alternative approaches. Discussions within our group of educators revealed that those who had previously used, or were still using, animal tissues within physiology laboratory classes had faced difficulties in finding suitable animal sources and/or resistance in obtaining and maintaining ethics approval for their use. Despite these challenges, in some of our institutions, these laboratory classes were retained because it was felt they were superior to a virtual alternative since they helped students develop hands-on technical skills and gain an understanding of biological variability and experimentation.

Over the years, as financial and ethical pressures escalated and class sizes often increased, many of our classical animal laboratory classes have been replaced by an alternative approach. Changes made to decrease costs included reducing the number and/or duration of on-campus laboratory classes; reducing the number of teaching assistants and support staff; sourcing cheaper consumables; and using equipment that had been reconditioned or built in-house. Changes to the physiology curriculum have included the addition of laboratory classes that involved students working together in groups, with themselves as both ‘researchers’ and ‘participants’ to investigate physiological concepts and making alterations to the assessment formats to reduce time spent marking assignments. With pedagogical pressure to include open inquiry and to avoid ‘recipe-based’ protocols, some of us have transitioned from pure demonstrations of physiological concepts with fully anticipated endpoints to students serving as *research participants* within student-led investigations. This negated the need to purchase and maintain animals and reduced staffing and consumable costs. However, it has raised new concerns around educators' duty of care in protecting students' health and safety and the need to consider obtaining informed consent from participating students in order to provide a safe and meaningful student learning environment.

Since the 1990s, the expansion of digital technologies has allowed educators to address some of these financial and ethical challenges (Table 1): These technologies have allowed us to take advantage of economies of scale, for example by accommodating our increasing class sizes and by reducing the number of teaching staff required to run classes. Technology has enabled us to address some of the ethical challenges, and provides a platform for pedagogically sound alternatives where students are still 'active' in their learning. Using digital alternatives, educators can present physiological concepts in new ways with the promise of improved accessibility, portability, and versatility to simulate 'experimental' conditions where students can do sampling in a virtual environment (4). For example, during the COVID-19 lockdowns, coordinators were able to deliver an alternative to the spirometry practical class where a combination of video and digital resources were provided to students for analysis of authentic physiological data. Many of us explored and some have adopted digital technologies and online platforms as a supplement, and in several cases a replacement, for our traditional laboratories. However, pre-2020 – before the pandemic, we were reluctant to fully embrace these technologies mainly because we felt they would not allow us to meet all of our course learning outcomes, including development of students' research and transferable skills.

The COVID-19 pandemic 'lockdowns' dramatically forced educators to move to remote teaching using whatever virtual laboratory resources that were available. In our group of ten educators, three of us were already using existing paid subscriptions to online laboratory platforms to guide on-campus laboratories. During the pandemic, some of us took advantage of limited-time *gratis* licences for these types of laboratory platforms (those authors used AD Instruments' Lt platform, but other virtual lab platforms include BIOPAC®, McGraw-Hill's Connect®, and Pearson's PhysioEx®). Others in our group took a more home-grown approach, developing videos of laboratory procedures or adopting resources that had been developed within their own or other institutions, e.g. Experiments - Monash Physiology. In all cases, the virtual resources were used in conjunction with our learning management systems and video conferencing software, allowing us to deliver course materials either synchronously and/or asynchronously (1).

As many of us begin to transition out of pandemic lockdowns and move back to our campuses, educators are now asking how the virtual teaching experiences during the pandemic will shape the future of our pedagogical approach and higher education as a whole. Here, we consider whether virtual delivery is a panacea for the historic financial and ethical challenges associated with physiology laboratories. To help answer these questions, we discussed our views of the opportunities and constraints of virtual laboratory classes and concluded that a carefully considered mixed (hybrid) approach of both traditional and digital course delivery is the way forward.

Opportunities and constraints of virtual laboratory classes and other digital technologies

Virtual laboratory classes offer a high degree of utility and versatility. Through web-based platforms, students can access preparatory content in their own time and make sure they are suitably prepared for any related group activity, whether it be facilitated via online conferencing applications (such as Zoom) or in a physical in-person environment. A virtual approach can also be used in cases when access to animal tissue is limited, when there are concerns for human safety, and to reduce costs. Virtual laboratory classes also eliminate concerns related to animal ethics, and in the short-term, the use of digital platforms is particularly attractive to deliver the curriculum online to students who are not yet able to return to campus.

A few of us are also using digital platforms such as Lt (ADInstruments) in conjunction with recording devices that allow students to collect original data via an in-person laboratory setting. We also use this platform to provide pre-laboratory classes that are accessible asynchronously, and post-laboratory classes that are similarly available, but require students to access, analyze and incorporate into their post-laboratory class the physiological data they acquired during the in-person laboratory.

The use of virtual laboratory classes and resources, however, comes with its own financial, ethical and educational challenges. For example, educators who wish to use these resources often face institutional reluctance or hurdles to enter into third-party agreements with external companies. The caution, in-part, involves the intellectual property of bespoke teaching resources that are generated by their employees and if there is discontinuation of the digital third-party services. Whilst course coordinators are increasingly recognising the potential of third-party digital platforms to guide virtual or blended laboratories, reluctance of institutional managers to fund cohort-wide subscriptions to digital platforms may lead to the cost of individual subscriptions being passed on to students. This may occur as an increase in course fees, or in the form of an alternate or additional course expense (e.g., a platform subscription as well as, or instead of a textbook). Passing costs on to students is likely not a desirable solution for coordinators in developed and developing countries. It is important to recognise that whilst the use of digital technologies in developing country education systems is increasing, substantial gaps in internet infrastructure and service still exist. It has been recommended that the economic burden of digital technologies to educational institutions within developing countries can be reduced by drawing on the experiences of developed countries, so that the appropriate digital education resources are not simply taken up but instead appropriately integrated and used cost-effectively (5, 6, 7).

The security of student data is also of ethical concern since, more often than not, these data are ‘stored’ on external cloud-based servers, as “cyber-crime” is the most frequent threat agent in higher education (8). Thus, there is a potential vulnerability of exposing students’ personal information, e.g., name, ID, and any other inputs, at risk of cyber-hacking and data theft. That said, with appropriate user agreements and vetting, these hurdles can potentially be overcome.

In terms of ‘home-grown’ digital resources, there is somewhat of a grey area in terms of whether ethical approval is needed for using members of the teaching staff as research subjects for demonstrations or recording real or simulated patients to produce educational resources. This extends to restrictions on digitising patient samples or cadaveric specimens. For example, maintaining compliance with government policies that prohibit unauthorised electronic imaging, such as the Transplantation and Anatomy Act of South Australia (9), potentially restricts the use of digital platforms for teaching and learning purposes. Approval for the development of such resources often falls outside the mandate of institutional research and clinical ethics committees.

Digital equity amongst students, especially low socioeconomic groups, is also a concern. This includes a proportion of students with inadequate access to the internet, which is essential for accessing the online laboratories, particularly for online synchronous contributions to teamwork. Not owning or having access to a suitable device, or poor compatibility of student-owned devices with digital platforms were also problems encountered by students away from their institutions (during COVID-19 restrictions). New ethical considerations for course coordinators include ensuring off-campus students can access online laboratory classes despite regional access limitations, country-specific firewalls or other geo-political restrictions. These ethical concerns remain for those academics entertaining ongoing ‘hybrid’ laboratory classes (in-person and remote) moving into the future.

In addition, despite strides in animation and digital software technologies, simulated laboratory tasks can be somewhat rudimentary, and often the same results are presented to all students at the conclusion of the virtual ‘experiment’. Thus, the key drawback of these digital resources is that they do not allow us to fully meet all our course learning outcomes, particularly those pertaining to the development of research and transferable skills. Missing or limited are the opportunities to develop student hands-on laboratory skills, troubleshooting and team-work skills, along with the ability to foster student appreciation for biological variability. Although further advances in artificial intelligence and virtual reality will likely help solve some of these issues in the future, we are not there yet.

The case for including carefully considered hands-on, in-person laboratory classes

We believe that a strong case can still be made for hands-on, in-person laboratory classes. Course coordinators should take note of the financial and ethical challenges presented here and reconsider an all-or-nothing approach according to their intended course learning outcomes to perhaps embrace a more flexible way forward. Recent literature arising from evaluation of the COVID-19-enforced online transition of laboratory curriculum suggests that despite some limitations, virtual laboratory classes can be as good as those attended in-person for conceptual understanding and academic performance (10). There is further support in the literature for the inclusion of digital learning when a simpler level of understanding is desired (11, 12). However, it appears that students tolerated the online learning environment, yet preferred the social learning opportunities offered by in-person laboratory classes, thus exposing deficiencies in student experience (13). Hands-on and in-person laboratories, in our view, help to reinforce key physiological concepts in a more meaningful way than do virtual alternatives. Watching the heart contract upon the addition of adrenaline (epinephrine), for example, is more engaging than watching the same thing in a computer simulation. This view is supported by the literature, where active learning in physiology is advocated over a more passive approach (14, 15). Social, hands-on and inquiry-based approaches to physiology teaching engage deeper structures for cognition and provide opportunities for discourse where "knowledge is not simply transmitted but actively constructed" (16, 17).

A suggested way forward may involve intentionally positioned pre- and post- virtual learning tasks that are integrated with in-person group laboratory classes for technical and research skills acquisition and group work. This would allow for authentic data acquisition, support a higher-order level of learning and help to develop students who are inquiry-minded and job-ready (18).

Laboratory classes that utilise biological tissue provide opportunities to emphasize the uncertainty of experimentation and the extent of biological variability, to understand ethics, and to develop hands-on laboratory skills. A key issue, therefore, is to ensure that financial constraints and the pressure to reduce animal use does not result in students spending more time *observing* rather than *doing*. We must work to ensure that budget contractures do not impair opportunities for mastery of skills, attainment of deep knowledge, and skills-based assessment. Thus, as we plan our future courses, we encourage educators to look for alternative sources of tissues, e.g., cell culture and, if available, organoids derived from appropriate stem cell sources and only use animals when there are no better alternative specimens available.

In terms of student-as-subject laboratories, these afford an opportunity for inquiry-based exercises and build teamwork, communication, and analytical skills. Therefore, we believe they are a key part of future physiology courses. Importantly, as always, we will need to protect the health and safety of our students. To reduce risk, students should be provided with, and understand, standard operating procedures of any equipment they are using and/or tests they are performing. As educators, we have a duty to our students to minimise risk of disease transmission and will likely have to adopt new safety protocols as recommended by public health units and health and safety committees. These measures will include, but will not be limited to, promoting good hand hygiene, maintaining physical distancing when possible and educating students regarding the appropriate use of consumables such as lancets and spirometer filters.

While we plan to continue to use digital resources in our courses, it is our view that their sole use would not allow us to achieve all of our course learning outcomes. Thus, the educational benefits of laboratory classes that use either animal tissues or students-as-subjects currently outweigh the challenges associated with their use. We also value the time in the teaching laboratory to provide need-dependent differentiated learning experiences for our diverse cohorts, and to foster a compassionate and effective learning environment and learning community (1).

Summary

The format and focus of physiology laboratory classes have undergone a gradual evolution over the past 30 years: from explorations of physiological principles using animal tissues to student-led small group investigations in which students often serve as their own research participants. The parallel development of digital devices, software applications and, more recently, internet-based platforms to host physiology simulations and virtual experiments have increased accessibility, accommodated larger student cohorts, and reduced the need for using animal tissues. Collectively these changes have helped address some of the ethical and financial issues surrounding this critical component of physiology education.

We now have the ability to deliver an online physiology curriculum, which has not only enabled mobilisation but also internationalisation of our physiology courses. The collective attitude within our group both prior to, and following the transition to a remote format, however, is that although virtual alternatives are an excellent and important tool to use in our educational offerings, they are not a panacea for the financial and ethical challenges associated with physiology laboratory classes, since their sole use does not allow us to meet all our intended course learning outcomes. Instead, we believe that the way forward is a carefully considered mixed approach of both traditional and digital course delivery. In this approach, virtual tools would be used to supplement or assist in the delivery of on-campus experiences that provide opportunities for students to observe real-life, authentic, and variable physiological mechanisms *and* to actively participate in data capture, analysis, and interpretation.

While this is our collective opinion, we acknowledge that not all institutions have the same priorities. But as we return to on-campus teaching, we believe that this is an opportune time for all of us to ask: “What knowledge and skills do I want my students to have acquired by the end of their physiology course?” and “What are the best approaches to achieve these learning outcomes?”, taking into account both our own remote teaching experiences and the opportunities and constraints that we have outlined above. We believe that careful consideration of these questions will allow us all to deliver the best educational experience for our students.

Table 1: A representative list of financial and ethical benefits and concerns relevant to virtual physiology laboratory classes*

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**Qualitative reflection data extracted from (1); **Relates to use of third-party purchased digital software platforms.*

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Virtual laboratory classes potentially reduce the reliance on animal models and biological specimens, since they can be better utilised with students more fully prepared for and guided through wet-lab experiments when they take place.	
Widens access to off-campus students - inclusivity for these students improves course financial viability.	Enhanced access for geographically diverse student cohorts and non-institutional staff, i.e., specialists contributing to course delivery.
Reduces reliance on non-tenured academic staff as digital platforms can help guide and direct students.	More equitable access for students who may not be able to attend on-campus laboratories, i.e., due to family or work commitments or disability.
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Some institutional contracts allow annual paid subscriptions to be swapped over and used in a second teaching period, i.e., halving the licence cost per student, and increasing the usability of subscriptions across disciplines.	Consented patient cases immediately available with some third-party applications.
	Reduces risk of harm to students using biological specimens (i.e., urine, blood sampling, respiratory measurements) and potential for communicable disease spread (COVID-19, hepatitis, HIV, etc)
More environmentally friendly / improved sustainability as less paper wasted, reduced carbon footprint associated with students traveling to and from on-campus laboratory classes.	
Concerns	
Institutional reluctance to enter into subscription charges** due to industry-wide cutbacks.	Digital inequity is a possibility i.e., students may have limited access to: digital devices, compatible computer equipment, and/or internet connectivity.
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