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International educators' attitudes, experiences and recommendations after an abrupt transition to remote physiology laboratories

Running head: Educators experiences of remote physiology laboratories

Julia Choate,[a] Nancy Aguilar-Roca,[b] Elizabeth Beckett,[c] Sarah Etherington,[d] Michelle French,[e] Voula Gaganis,[f] Charlotte Haigh,[g] Derek Scott,[h] Terrence Sweeney[i] and John Zubek.[j]

[a] *Department of Physiology, Monash University, Australia;*

[b] *School of Biological Sciences, University of California, Irvine, U.S.A.;*

[c] *Medical School, Faculty of Health and Medical Sciences, University of Adelaide, Australia;*

[d] *College of Science, Health, Engineering and Education, Murdoch University, Australia;*

[e] *Department of Physiology, University of Toronto, Canada;*

[f] *College of Medicine and Public Health, Flinders University, Australia;*

[g] *School of Biomedical Sciences, University of Leeds, U.K.;*

[h] *School of Medicine, Medical Sciences & Nutrition, University of Aberdeen, U.K.;*

[i] *Department of Biology, The University of Scranton, U.S.A.;*

[j] *Department of Physiology, Michigan State University, U.S.A.*

Corresponding author: Julia K. Choate, julia.choate@monash.edu. Department of Physiology, Faculty of Medicine, Nursing and Health Sciences, Monash University, Australia, 3800.

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ABSTRACT

The COVID-19 pandemic triggered university lockdowns, forcing physiology educators to rapidly pivot laboratories into a remote delivery format. This study documents the experiences of an international group of ten physiology educators surrounding this transition. They wrote reflective narratives, framed by guiding questions, in order to answer the research question *'What were the changes to physiology laboratories in response to the COVID-19 pandemic?'* These narratives probed educators' attitudes towards virtual laboratories before, during and after the transition to remote delivery. Thematic analysis of the reflections found that before COVID-19, only a few respondents had utilized virtual laboratories, and most felt that virtual laboratories could not replace the in-person laboratory experience. In response to university lockdowns, most respondents transitioned from traditional labs to remote formats within a week or less. The most common remote delivery formats were commercially available online physiology laboratories, home-made videos and sample experimental data. The main challenges associated with the rapid remote transition included workload and expertise constraints, disparities in online access and workspaces, issues with academic integrity, educator and student stress, changes in learning outcomes and reduced engagement. However, the experience generated opportunities including exploration of unfamiliar technologies, new collaborations and revisiting the physiology laboratory curriculum and structure. Most of the respondents reported planning on retaining some aspects of the remote laboratories post-pandemic, particularly with a blended model of remote and on-campus laboratories. This study concludes with recommendations for physiology educators as to how they can successfully develop and deliver remote laboratories.

INTRODUCTION

COVID-19 pandemic and the need to transition from on-campus to remote teaching of physiology laboratories

The spread of COVID-19, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was declared a pandemic on 11th March, 2020 (39). In response to the COVID pandemic, university leaders reacted to rapidly evolving information and government restrictions, making critical decisions that impacted undergraduate physiology education, particularly for laboratories. Many governments restricted the movement of people and introduced physical or social distancing requirements, to help prevent the spread of the virus. This resulted in university educators working from home, with prohibition of access to physical laboratories, precipitating an urgent need to implement remote learning arrangements for laboratories. Many physiology educators were forced to abruptly pivot a laboratory course that had traditionally been on-campus and in-person (i.e. face-to-face or 'live') to a remote (predominantly virtual) format. Normally, a successful transition to virtual delivery involves planned, systematic, time-consuming and collegial design of the content and development of new skills (30). With a rapid transition to remote laboratories, most of these processes were not possible, particularly the availability of support staff and resources. Hence, a COVID-induced expression 'Emergency Remote Learning', which acknowledges that this process was quite different from the 'normal' planned online learning experiences (36).

Context of physiology education: what are laboratories?

The opportunity for students to engage in hands-on laboratory work is considered an essential component of physiology courses or degree programs. Laboratories provide a unique learning environment that not only facilitates scientific discovery and develops technical familiarity, but also reinforces students' knowledge and understanding of physiology concepts and provides opportunities for students to develop research skills (e.g. experimental design, data collection, analysis and interpretation) and transferable, or employability, skills (e.g. critical thinking, communication, resilience, problem solving and team-work) (16, 23). Furthermore, laboratories enhance student engagement, thereby supporting the social constructivist theory of learning (20).

Laboratories are traditionally taught on-campus, with in-person sessions in a laboratory setting. In addition to the faculty or academic lead teaching the laboratory, teaching associates or assistants (TAs), also called PhD demonstrators or demonstrators, facilitate the teaching of physiology laboratories and support students as they complete their experiments. TAs have conceptual knowledge and technical skills for the laboratories and may be graduate or higher-level undergraduate students. At some universities the graduate TAs are the lead, or independent, instructors for the laboratory. Whilst acknowledging that there is variability across universities for the terminology and type of teaching support staff for teaching laboratories, for this paper all will be referred to as TAs. Further, technical laboratory staff assist the educators in setting up the laboratory experiments, calibrating and checking equipment and making solutions. Prior to the pandemic, some educators had replaced traditional hands-on (on-campus) physiology laboratories with non-traditional, virtual alternatives (13, 37). The terminology for non-traditional laboratories in the research literature is confusing, with inconsistent use of terms such as simulation and virtual, remote and distance laboratories (15). For this study virtual laboratories are defined as students using virtual experiments, instruments or equipment via a computer. A virtual laboratory can be completed individually or in teams, allowing students to explore topics in a manner that has no immediate physical reality (7). Synchronous virtual laboratories are completed by students at a scheduled time, whereas asynchronous virtual laboratories are not scheduled and do not require real-time interactions. Examples of virtual physiology laboratories include those developed by faculty/academics and freely shared online (31) and commercial products (ADInstruments®, https://www.adinstruments.com; Pearson® PhysioEx™, https://www.pearson.com.au/9780136447658). Past drivers for moving to these virtual undergraduate laboratories were lower costs (especially staffing) and concerns with animal use (27, 32). In many cases, rather than replacing traditional laboratories, virtual physiology laboratories have been used to supplement traditional laboratories, often using a blended model of teaching (8, 10, 31). For this study, when the virtual laboratories were completed online, and outside of instructional laboratory space, they were considered to be 'remote' laboratories. Remote laboratories also included hands-on laboratories that can be completed by the students off-campus, for example via portable laboratory kits (15).

Since the initial pandemic-related university shutdowns in March, 2020, there have been further shutdowns triggered by additional waves of the pandemic in both the northern and southern hemispheres. While the development of effective vaccines against SARS-CoV-2 provides hope that these shutdowns will end, faculty and university administrators are now asking what teaching will look like post-COVID, especially for resource-intensive laboratory courses. Thus, it is important to document the successes and challenges with the move to remote laboratories. The aim of this study was to document the experiences of physiology educators in rapidly transitioning their laboratories for remote teaching during the COVID-19 pandemic. Ten physiology educators from Australia, Canada, the U.K. and the U.S.A. wrote reflective narratives in order to answer the research question *'What were the changes to physiology laboratories in response to the COVID-19 pandemic?'* Reflective writing methodology was used, as reflection on experiences contributes to understanding and learning about practice (22). The study outcomes will provide recommendations for physiology educators as to how they can successfully develop and deliver remote laboratories, or use aspects of remote laboratories in future on-campus laboratories.

METHODS

Participant Recruitment

The ten respondents for this study are all physiology educators (academics/faculty) at universities. They were voluntarily recruited in June 2020, via an email invitation from the chief investigator to an international community of physiology educators involved with the Physiology Majors Interest Group, the Australian Physiological Society and/or The Physiological Society. As all of the respondents for this study were also the researchers for the study, ethical approval was not required for the study.

Protocol

The research is situated within a theoretical perspective of interpretivism with an exploratory qualitative research design used to investigate the research question (9) '*What were the changes to physiology laboratories in response to the COVID-19 pandemic?*' Written reflective narratives, essentially autobiographical in nature, were used as the basis to describe the personal experiences and actions of respondents as they transitioned physiology laboratories from a physical to a remote mode of delivery (in response to the COVID-19 pandemic). Respondents were asked to write reflectively, sharing their feelings, personal experiences and concerns. Written narratives have been shown to have considerable value in research (22). The narrative essays were written independently and were framed around five guiding questions that were initially developed by the researchers for this study (see below). In addition to a question probing the respondents' experiences of transitioning to remote laboratories, the other questions aimed to understand the respondents pre-COVID attitudes and experiences of virtual laboratories, and to determine if these were altered by the COVID-induced shift to remote laboratory delivery. It was decided that the term 'remote' rather than 'virtual' laboratory would be used, as this acknowledged that in addition to the use of virtual laboratories, some educators replicated the hands-on laboratories, with students experimenting on themselves at home.

Guiding questions for the written reflective narratives

(1) What were your experiences of virtual laboratories pre-COVID?

(2) Pre-COVID, what was your attitude to replacing on-campus laboratories with virtual alternatives?

(3) How did you convert the on-campus laboratories to remote laboratories?

What challenges and opportunities did you encounter?

Do you have any informal feedback from students or teaching associates about the remote laboratories?

(4) Has this experience changed your attitudes to remote laboratories?

(5) In the future, assuming we can resume on-campus laboratories, will you be retaining remote laboratories?

Analysis

The narrative essays, from now on referred to as reflections, were written by the respondents in July 2020, then de-identified for thematic analysis, with the names of the respondents, institutions and subjects/topics/units/courses removed. Thematic analysis of the reflections followed the six-phase process described by Braun and Clarke (4): (1) familiarization with the data; (2) initial coding of the data; (3) searching for themes; (4) reviewing the themes; (5) defining and naming themes; and (6) producing the report. The analysis was performed by all of the researchers. In order to build a narrative knowledge, each respondent read all other reflections (22). Narrative knowledge uses the particular experiences of one situation to create a link from the personal nature of reflective writing to findings that are more widely applicable and disseminated publicly. While reading the reflections, respondents identified common themes. Each person, in a pair of respondents, independently analyzed one of the guiding questions across all of the reflections, using an open-coding approach to highlight common and interesting aspects of the reflections (35). The codes and quotations to support these codes were put into an *Excel* spreadsheet. The analysis pairs met to discuss the data from their assigned question and to reach a consensus on the codes. Whilst the initial coding was used as a foundation for this process, pairs revisited the reflections, in particular to determine if aspects of the question had been answered elsewhere in the reflection.

RESULTS

All respondents in this study were full-time physiology educators (academics/faculty) at a university in either Australia, Canada, the U.K. or the U.S.A. See Table 1 for information about the respondents and their laboratory courses before the onset of the COVID-19 pandemic.

Table 1. Information about the study respondents and their pre-COVID laboratories

Years as physiology educator	Average: 17 (SD 5); Range: 8 - 25+
Degree programs	Bachelor (Science, Biological Science, Health/Medical Science).
Level(s) of students	1=11%; 2=33%; 3=33%, 4=23% *(Australia doesn't have 4-year programs)*
Cohort size	Average: 295 students; Range: 50 - 600
Learning outcomes	Mix of physiology concepts and research skills
Types of laboratory assessments	Multiple choice question quizzes (pre, post, in-class), laboratory reports, short answer questions, laboratory/practical test
Assess research skills?	Yes = 70%; No = 20%. Research skills assessed: experimental design, data

	collection and recording, statistical analysis, referencing, communication, critical and data analysis/interpretation, problem solving.
Teamwork	Yes (n=10). Average team size: 4 students (SD 1); Range: 2 - 6
Number of students assigned to each instructor (faculty/academic or TA)	Average: 15 students to 1 instructor (SD 5); Range: 8 - 24
Pre-laboratory online content	Yes (n=8; 6 with pre-lab online quizzes based on the lab content and/or protocols). No (n=2; one asked the students to review the relevant lectures and one asked the students to come to the lab with a protocol flow chart – neither were assessed)
Are the laboratories compulsory? Was attendance taken?	Yes (n= 8; attendance registered); No (n=2; attendance not registered)

What were your experiences of virtual laboratories pre-COVID?

Within the respondent group only one person had previously converted to predominantly virtual laboratories, with limited hands-on activities. Four of the ten respondents ran only in-person laboratories. One respondent hosted in-person laboratories with some use of a virtual laboratory to either preface the actual laboratory or as an alternate format. As one respondent explained "*we had been forced to adopt simulations (due to [lack of] animal availability)"*. For another respondent, online pre-laboratory activities were being used to prepare students for in-person laboratories. This "*helped with the smooth/trouble-free completion of the actual practical class*".

Pre-COVID, what was your attitude to replacing on-campus laboratories with virtual alternatives?

There was unanimous agreement between respondents that in-person, on-campus laboratories were worth offering despite financial and ethical challenges. This attitude was explicitly stated by seven of the ten respondents and could be inferred from comments made by the others. Key themes that emerged for this question were that respondents thought that remote laboratories would not be as engaging or authentic as on-campus laboratories, they would not support social engagement and active learning, and they would not achieve the learning outcomes for laboratories. In addition, it was noted that students and their parents' value and expect in-person laboratories. See Table 2 for the main themes related to virtual laboratories, with selected quotes from respondents that reinforce the themes.

Table 2. Respondent attitudes to replacing on-campus laboratories with virtual alternatives

Theme	**Selected quotes**
Virtual laboratories would not be engaging or authentic	"*We had previously found it hard to get students to engage during such [virtual] sessions and some staff always found them predictable and boring."* *"I felt for my students, clicking their way through relatively uninspiring (though scientifically thorough) virtual simulations of experiments."* "*I felt students didn't get to grips with understanding the techniques and the experiments themselves were very repetitive. The students performed the experiment, following the protocol with very little thought or understanding."* *". . . nor would they [students completing virtual laboratories] have to deal with something like troubleshooting when something goes wrong"*; *"most online simulations lacked the uncertainty that occurs with different experiments, and there was a lack of diversity for any human experiments, videos or data.*"

On-campus laboratories support learning and build social connections better than virtual laboratories	*"face to face practical classes . . . provided opportunities for students to interact with teaching assistants, academics and with each other and the general consensus that this social environment supported student learning and engagement."* "*My teaching philosophy is based on . . . on active learning pedagogy and inspiring and supporting students to learn . . .*" *"it was a time [in-person laboratories] where you could really spend more time with students and find out what they were struggling with and whether the class had really understood what you had been talking about in class.*
Virtual laboratories would not meet the learning outcomes	"*We felt students would not have as adequate an opportunity to practice and hone these [research] skills using an online interface. We wanted students to appreciate the subject to subject variability that comes with authentic research."*
Belief that positive personal experiences of on-campus laboratories cannot be replicated online	"*These experiments, in my memories, were a complex tapestry of olfactory, tactile, ethical and emotional reactions – will the next snip of the scissors sever the sciatic nerve?... These experiments had their roots in some of the earliest and most fundamental physiology experiments."*
Student, parent and educator expectations that on-campus laboratories will be provided	"*students frequently commented about how much they enjoyed the practical laboratory classes and how they supported their understanding of physiology content."* *"students and their parents often associate the quality of the courses with the number of hours the student spends in face to face teaching including practical classes*."
Challenges of getting colleagues to embrace virtual laboratories	"*Trying to change the mindset of colleagues within the school, many [of] whom have been part of the original team designing practical courses of the past was a difficult challenge. They could not see how using virtual lab experiments, or even pre-or post-lab work, would train students to be competent in the research skills required to be proficient in their labs during the final year of study."* "*I think a lot of my colleagues were actually quite scared about what would happen if a class failed if the technology didn't work. . ."*
Virtual laboratories can prepare students for on-campus laboratories	"*A simulation/online practical might be good to provide preparatory experience before doing the actual lab work."* "*Online or virtual labs seemed like a reasonable approach for specific lab protocols that weren't feasible because of financial, facility and/or safety limitations. I felt that these were good supplements to a course that was otherwise taught in person with hands-on activities."*

How did you convert the on-campus laboratories to remote laboratories?

The educational response to COVID-19 was abrupt and shocking. Half the respondents taught their first remote laboratory within 48-hours to one week of being notified. A few were given some reprieve when their institutions transitioned to a non-teaching week to allow staff time to prepare for the transition. Others had experience implementing remote teaching for a small group of international students before they were locked down locally. Since the respondents teach at institutions around the world with different academic years and teaching terms (e.g. semesters, quarters), the move to remote laboratories (mid to the end of March) occurred at different points in the delivery of their courses (see Figure 1). For one respondent the laboratory course had been completed in the previous semester, but for others the disruption came at the start of the semester (Australia), in the middle of the semester/term (U.S.A) or towards the end of the semester/quarter (U.S.A. and U.K.).

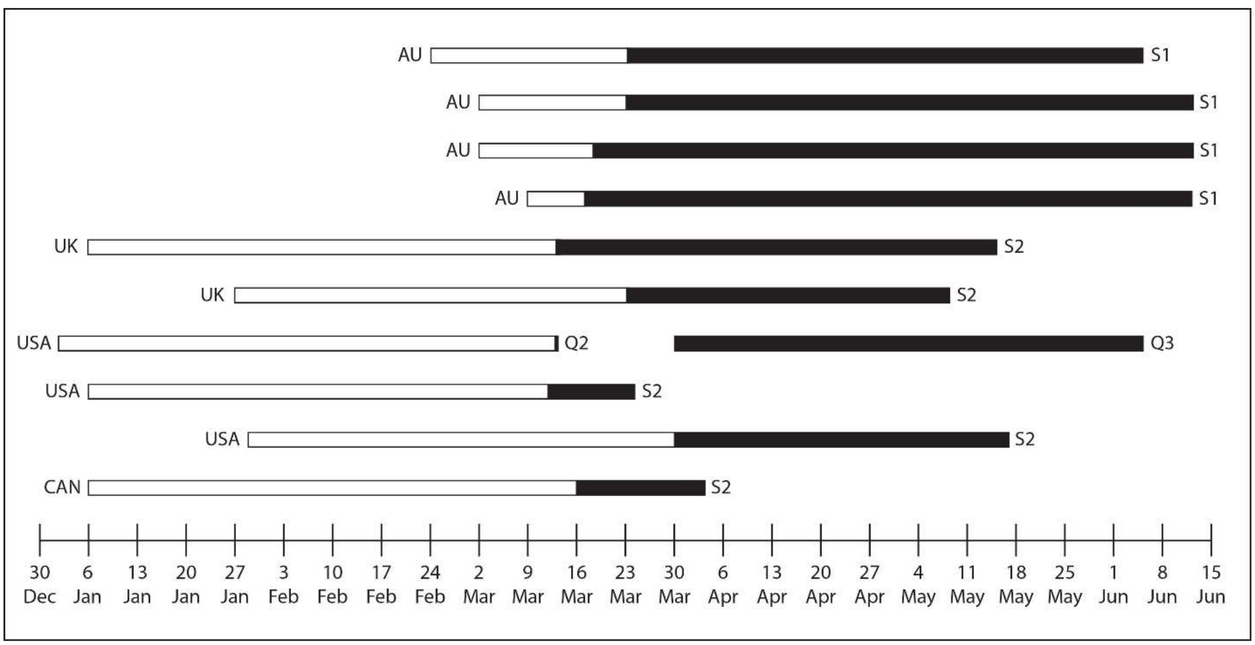

Figure 1. Critical academic term (or semester) dates at the universities of the respondents. *White bars begin at the start date of each term. Black bars begin when each university switched to remote delivery due to COVID-19; black bars terminate at the end of each instruction period for the term (excluding final exams). Countries of respondents: Australia (AU); United Kingdom (U.K.); United States (U.S.A.); Canada (CAN). S1, S2, Q2, Q3: Semester 1, Semester 2, Quarter 2, and Quarter 3, respectively.*

With such a short timeframe to pivot to remote teaching, it is notable that six out of ten respondents converted all of their laboratories to remote delivery, with another three cancelling only one or two labs that were considered unsuitable for remote delivery. In general, this required modifications to laboratory content to ensure content and learning outcomes were "*still feasible*" and "*made sense*".

Many respondents (60%) used commercially available online physiology laboratory resources for all or some of their remote laboratories (e.g. Lt™ by ADInstruments®; (https://www.adinstruments.com/lt). Videos were also widely used to present preparatory material, explain equipment usage and/or demonstrate experiments, thus preserving some content delivery from the in-person laboratories. A majority of respondents also reported using sample data, collected internally in preceding years or provided by a commercial partner, to allow students to practice the skill of data interpretation (e.g. ECG, lung capacities).

Many respondents wrote about the contributions of experienced TAs, or demonstrators, and laboratory technicians who helped re-design and develop remote laboratories. Laboratory technicians "*rapidly retrained to provide expert support for teaching online*", leading the development of videos to accompany remote laboratories and updating or generating experimental data. TAs also took on new roles for the first time, assisting with video development and online marking, responding to student emails and discussion board posts, and chatting with students online "*in an attempt to remove the sense of isolation*" felt by students.

Approximately half of the respondents identified a need for greater flexibility in laboratory delivery to accommodate students who were travelling, in other time zones or seeking paid work to support their families. Changes included making laboratories non-compulsory for all students or for some students in some instances; allowing more class swapping; and only assessing "*4 out of 5*" labs to give students a buffer to adjust to the new delivery mode. Increased flexibility also included providing asynchronous lab options. Only three of the five respondents had entirely synchronous remote laboratories with four offering entirely asynchronous labs and three respondents describing combined synchronous/asynchronous offerings (e.g. synchronous laboratories that were recorded for absent students).

What challenges did you experience?

Making the transition to remote laboratories was a challenge for all respondents, especially given the brief transition time from on-campus to remote teaching. Specific challenges such as workload and expertise constraints, disparities in online access and workspaces, issues with academic integrity, and educator or student stress were directly related to the pandemic. Other challenges such as changes in learning outcomes and reduced student-student and student-educator engagement, are commonly encountered with remote learning and were similar to the concerns about virtual laboratories that the respondents had pre-COVID. Specific challenges are summarized below.

Workload and expertise constraints

The reformatting of the laboratories and assessments involved retraining both educators and TAs and resulted in additional TA hours. Many assignments that had been team-based or group projects became multiple individual projects. To make the grading workload manageable, some respondents shortened or simplified assignments. Eight out of the ten respondents saw an increase in the number of students to each instructor for remote laboratories (compared to past on-campus laboratories). Reasons cited for this increase included the changing institutional financial situation, some TAs being prevented from teaching due to personal health issues, or overwhelmed lead lab instructors not having the capacity to appropriately supervise less experienced TAs.

Students not only had to master course content, but also had to navigate the online environment. Educators had to become the technical support expert who trained TAs and other less technologically savvy educators. Consequently, respondents described making assessment allowances due to changing workloads, the inability to effectively deliver the same quality and quantity of content, and the reality of student inequities. Another respondent wrote of the technical challenge of online assessments: "*We resorted to emailing students questions, who wrote out answers, photographed them and sent them back. This was the easiest way to overcome technology and connectivity issues.*"

Educator and student disparities for online access and a quiet workspace

Disparities in internet access were common in terms of both the speed of internet connectivity and in the time of access and were experienced by students and instructors alike. For international students, internet access was further constrained by national firewalls. For many, "*facing*" one's students meant overcoming webcam problems on both sides of the video exchange. One respondent reported "*A few students had to sit in the parking lot of a local library to access the internet when their internet was down*". External socio-economic ramifications of the pandemic led to non-ideal study environments, and conflicting priorities both for family internet access and for time-sharing between work and school in families that had lost income. From another respondent "*I was also aware that some of our students did not have a private working space at home, or may have been embarrassed by their living conditions, and so made a point of not requiring students to use cameras in my classes*". In some instances, alternate assignments were required for these students. Further, university representatives had to vet user agreements of online platforms to safeguard user and network security.

Educator and student stress

The challenges outlined previously greatly increased both educator and student stress (as perceived by the educators). Respondents reported that they felt panic or that things were out of control. This anxiety was multifactorial, reflecting a concern about the quality of educational materials developed in such a short timeframe, as well as more generalized anxiety around the social impact of COVID-19 and the physical and/or mental wellbeing of colleagues and personal connections. One respondent reported that "*out of my 7 TAs, 3 struggled [with]... overwhelming anxiety*". The reflections also included reports of shock, denial and anger – *"I could not believe what was happening, it made no sense", "initially I was pretty ticked off that this was happening…almost in denial"*. Together, these reflections suggest some educators went through a process akin to grief, perhaps for the teaching, or the normality, we had suddenly lost.

Loss of teamwork and educator-student or student-student interactions

Several respondents were challenged by the loss of in-person, face-to-face interactions with their students. They commented that it was difficult to communicate expectations and felt disconnected from their students. One stated *"Even during Zoom office hours, many never turned on their camera or microphone, choosing to communicate via chat box, so I only know them as a name on a screen."* In particular, the usual cues used to gauge learning were lost with the move to remote laboratories, especially since many students had their cameras turned off. *"With no way to look at students faces and gauge their understanding, or adjust my pace to their needs,"* one respondent wrote, *"I felt insecure about my teaching for the first time in a long time . . ."* and another reported "*the greatest challenge of ...delivering course content online was the loss of ongoing student feedback that drives my teaching in face-to-face labs*".

Student teamwork often defines the in-person laboratory experience. Respondents struggled to recreate this for remote laboratories. The shift to remote laboratories was associated with a reduction in teamwork for nearly half of the respondents. A range of reasons were given for the reduction or removal of teamwork after the start of the pandemic, including social distancing requirements and the lack of options for team logins and/or assignment submission with popular commercially-available online physiology lab platforms. One respondent insightfully reflected that *"the rapid nature of the transition meant that there was no time for a meaningful setup of teams in an online . . . environmen*t". Another stated that one of their core goals for remote laboratories was "*to maintain the interactive nature of on-campus laboratories*" and four others retained teamwork in their remote laboratories. Loss of teamwork led, together with diminished teaching funds, to increased workload, as described by this respondent *"Practical marking was an enormous task, approx. 2300 assessments, due to group assessments changing to individual assessments. We did not have access to any further casual funds and needed to absorb the extra workload..."*

Reduced student and TA engagement

Respondents reported that their students seemed less engaged with the course material, with fewer students prepared for the remote laboratories. Some students prioritized work over classes due to family job losses, and there was more absenteeism. One respondent stated "*Many undergraduates had their schedules upended by abruptly moving back home or taking an extra delivery job to make ends meet*". The virtual laboratory delivery made it harder to keep the attention of students, and students seemed to have difficulty visualizing or understanding content despite supplemental videos. In addition, students procrastinated and completed the virtual activities close to the due date rather than during the originally allocated laboratory session. One respondent reported that TAs were less prepared for remote delivery, perhaps because they were attempting to balance research, teaching, and marking or were preoccupied with closing their supervisor's laboratory. This respondent elaborated *"they [the TAs] were expected to do the simulations themselves so that they could answer student questions, but I can see from the simulation logs that only 2 TAs consistently did the simulations".*

Changes in learning outcomes and assessment

With the use of pre-recorded laboratory data, reduced contact time with students, and the simplification or reduction in the number of student assignments, for some respondents the learning outcomes had to be reconsidered and often modified in the transition to remote delivery. The inability to replicate some on-campus laboratory exercises, and the difficulty of arranging opportunities for students to design and carry out their own experiments diminished learning outcomes. Despite the advances in online laboratory platforms, the perceived need to give students "*good*" data to analyze had the consequence of taking away the "*Aha*" moment. It also robbed the students of the appreciation of biological variability and failed to convey the value of failure in the experimental endeavor. One respondent noted: *"One of the biggest losses in the online lab was students not being able to design and carry out some of their own experiments."*

There was further difficulty in assessing student learning, both through written exams and laboratory exercises. Exams, in many cases, were open book and online instead of closed book (proctored/invigilated) and on campus. Educators grappled with how to conduct tests and exams online and stated that they were concerned with academic integrity, including plagiarism and cheating. One respondent reported, "*there was concern with an increase in the incidence of student cheating, which appeared to students to be easier to carry out, despite the unbeknownst ability of faculty to use technical tools to reveal such cheating*". One respondent acknowledged that since it was very difficult to prevent cheating on laboratory assessments and exams in an online setting, that priority was now being placed on fostering student learning and engagement rather than ensuring closed book assessments.

What opportunities did you encounter?

Aside from the challenges faced by educators and students due to the sudden lockdown associated with the COVID-19 pandemic, many respondents found opportunities to grow and change, explore new technologies, fast track projects already in the works and initiate collaborations on a scale never seen before. No longer was there an "idea" or a "desire" to create an online learning platform, COVID-19 mandated it. Highlights are described below.

Staff development and collaborations

Many respondents found a unique opportunity to engage in their own professional development. One stated: *"I probably went to more faculty meetings in one quarter than the previous year to talk about the constantly evolving situation and share work [being done] in our remote classes. I came away with a lot of ideas for what to do differently in Fall."* Seven out of ten respondents described greater interdisciplinary collaborations and teamwork opportunities, both inside and outside their own institutions. The rapid nature of the shutdown made it imperative to work together. Technical staff became central learning partners assisting educators in developing learning platforms, demonstration videos, and resources that would be of long-term value. This also generated an openness amongst educators to form interdisciplinary teams to better meet the learning goals of their students. As one respondent noted: "*[the development of online labs was achieved through the] coordinated efforts of a team of unit and support staff, who contributed more than they ever had to…[their] level of commitment, and their flexibility and ongoing adjustments to accommodate the changing situation and continue to support academic staff, were extraordinary*". At many institutions, technical staff, but not educators, were considered as essential workers and they remained on campus during lockdown. This meant they took responsibility for developing recordings of human physiology experiments to support the remote laboratories.

Exploring new technologies for remote laboratories

Other opportunities included greater exploration and integration of technology and online learning platforms with education companies. Some companies, such as ADInstruments® (https://www.adinstruments.com), Biopac® (https://www.biopac.com/) and Pearson® (https://www.pearson.com/uk/educators/higher-education-educators/subjects/he-stem/he-anatomy-and-physiology.html), produced ready-made online integration tools, and other companies and professional societies sponsored webinars to help educators make better use of existing online tools. Three of the respondents were using Lt™ by ADInstruments® (https://www.adinstruments.com/lt) before the pandemic and continued to do so as their primary learning platform. They were able to substitute pre-recorded data of physiological parameters provided by the company for virtual instruction. Two of the respondents used Pearson® PhysioEx™ (Laboratory Simulations in Physiology, https://www.pearson.com.au/9780136447658) before and during the pandemic. Another technology program that was well regarded was Perusall® (https://perusall.com/), which allows students to continue to work in teams to annotate and comment on journal articles. A respondent stated (about Perusall®): "*The student comments are graded via artificial intelligence, so the time requirement for teaching assistants was minimal*."

Revisiting and redeveloping laboratory teaching curriculum and resources

At least half of the respondents found themselves rethinking the overall curriculum and laboratory structure, in addition to the types of laboratory assessments and topics traditionally taught. Many redeveloped their curriculum to better match the course learning outcomes. One respondent wrote, "*we are ironically grateful to have been forced to question our learning* *outcomes and the processes we have been using to achieve them*." Another wrote *"the pandemic situation has made us question whether the way we performed this class in person was giving the students the best experience in gaining the practical skills they required".* Similarly, from another respondent, *"Running entirely online practicals has forced me to acknowledge that we are not, and have not for a long time, been providing genuine practical training in my unit."* Many respondents rewrote various laboratory activities and generated new materials, including the recording of data sampling videos and laboratory protocols. Others employed asynchronous pre-laboratory lessons whose completion prior to the commencement of the laboratory exercise was mandated. This improved the clarity of laboratory activities and allowed for incorporation of case study and healthcare simulations that fostered laboratory professional skills. The changes gave educators and students time to discuss and interpret recordings with data that was cleaner to analyze. The streamlined approach allowed for greater accessibility and flexibility for students, while being potentially more cost effective for schools and departments.

Feedback on the remote laboratory experience

The respondents were asked to share their impressions of student engagement, as well as anecdotes and informal feedback from students, staff, and peers. Formal feedback (i.e. from student evaluations of teaching) was not provided due to institutional research ethics considerations.

Seven of the respondents reported that although the circumstances were difficult, they thought that educators, staff, and students had positive experiences. Students were satisfied and felt that they had been able to engage with the course as much as possible under the circumstances.

Others stated, "*student engagement was still high, attendance was good for optional tutorials*", and "*students thought the new remote systems were easy to use and were impressed at how quickly faculty put these together*." One respondent quoted a student as saying "*Having a virtual experiment to be able to observe the experimental setup gave really good context and helped me understand what was happening."* Almost half of the respondents reported that the remote laboratories *"were well received by students and added elements to my class that I didn't have previously."* Flexibility was mentioned several times as a positive aspect of remote delivery, especially for students who had had a change in employment or were in different time zones. In one reflection, there was clearly a desire to maintain that flexibility: *"My hope from all this is that it might make our degrees more accessible and flexible for those students and staff who have long needed this but haven't been able to have it."*

In the shift to remote laboratories, interactions between people changed in ways that were both positive and negative. A positive aspect was that students showed greater appreciation for educators' efforts and even enjoyed many of the demonstration videos and simulations that educators provided for students to engage with the data. The unorthodox feel of some home-made videos may have had increased appeal to students: "*Really liked the personal videos of* ___ *in her kitchen. Really made it entertaining."* Some respondents extended their interactions with students beyond the course material. One respondent described creating a weekly "check-in" to monitor students' well-being. Students "*felt like someone was looking out for them and cared about them as human beings*" and students with social anxieties reported increased engagement with the material due to less social stress. Nevertheless, some students missed the in-person laboratories as they placed *"a high value on being able to physically touch and manipulate*."

Has this experience changed your attitudes to remote laboratories?

In general, after the experience of transitioning to remote laboratories, many respondents still believed that the remote version was less holistic in its approach than the on-campus, in-person laboratory. Despite this, there was less resistance to and a new appreciation for remote teaching and indeed virtual laboratories, with a realization by at least one respondent that *"...we have not actually been providing a true lab experience for many years and will continue to offer an online option in future years"*. Another respondent found the new pre-laboratory activities beneficial *"the asynchronous pre-lab learning environment that we were able to create resulted in students actually being much better prepared for their laboratory exercise than occurred with our normal modality."* For some, the remote transition strengthened previous beliefs that virtual laboratories are a good supplement, but not a replacement, with students not having an appreciation of how challenging it can be to set-up and troubleshoot experiments. The lack of opportunities for teamwork, data collection, hands-on skill development, and poor understanding of the nature of biological variability were also concerns.

In the future, assuming we can resume on-campus laboratories, will you be retaining remote laboratories?

Respondents overwhelmingly supported retaining some element of remote delivery of laboratory teaching in the future. The remote laboratories provide flexibility to suit student preferences and circumstances (e.g. international students who could not immediately return to campus). One respondent wrote: *"Running entirely online practical classes has forced me to acknowledge that we are not, and have not for a long time, been providing genuine practical training. As such, the* *experience has confirmed an obligation to provide more flexibility for students in the future".* While another reported to be now *"better placed to design a more meaningful and contextualized practical curriculum".*

The concept of using a blended model where students are engaged more with pre- and post-learning outside of the laboratory (virtual) in addition to in-person laboratories appealed to some: *"it has strengthened my previous beliefs that online modules are a good supplement, but not a replacement".* A concern raised by one respondent was the cost of the commercial online laboratories, though the other respondents reported that their faculties/departments had covered the cost and planned to do so in the future. In some cases, the cost of the online laboratories is/would be borne by students.

DISCUSSION

This study illustrates a collective determination by physiology educators to retain physiology laboratories in extremely challenging circumstances, highlighting the importance that they place on laboratories as a learning experience. Even without a pandemic, the transition to online teaching is challenging, therefore it was not surprising that this involuntary and abrupt transition to 'emergency remote learning', or remote laboratory delivery, often with little institutional support and the isolation of working from home, was associated with poor educator (and student) wellbeing. While a strong theme in the reflections, the high levels of personal stress experienced by all involved will not be discussed here, to allow for discussion of results that have more explicit implications for the future of physiology laboratories. The pandemic-induced shift to remote laboratories was also associated with challenges such as excessive workloads, unfamiliar technologies and loss of interactions between educators and students. Conversely, this crisis triggered opportunities for staff development, international communities of practice and the rediscovery of why and how we teach physiology laboratories and what we hope they accomplish. In the future, even with on-campus laboratories, most of the respondents planned on retaining some successful aspects of the remote laboratories, particularly with a blended model of remote and on-campus laboratories. Thus, highlighting that there were successful aspects for the rapidly implemented remote laboratories. This discussion focuses on the key challenges and opportunities associated with remote laboratories and includes recommendations and practical strategies to improve the delivery of the online aspects of blended physiology laboratory courses in the future (see Table 3).

Educator-student and student-student interactions for remote laboratories

A majority of the respondents' attitudes pre-COVID reflected beliefs that virtual laboratories would not support social interactions, nor active learning, when compared to on-campus laboratories. It was thus not surprising that these beliefs also emerged as challenges for respondents when they transitioned to remote laboratories. It has been shown that limited social interactions during online courses diminish student engagement and contribute to higher attrition rates (38). Many respondents mentioned a drop off in student engagement with remote laboratories, as evidenced by students' unwillingness to contribute to online forums, with their cameras off and little appetite to communicate outside of the chat function. In most physiology courses, on-campus laboratories are the primary opportunity for social interactions, suggesting that physiology educators should be proactive about adopting remote laboratory replacements that facilitate student-student (and student-educator) interactions.

Four strategies that can be used to facilitate online interactions for remote laboratories include 1) synchronous, video-based delivery, 2) educator presence, 3) small teams and 4) collaborative assessments. Synchronous online communication, using a video tool to add human perspective (e.g. Zoom™; https://zoom.us/), increases online social interactions by providing essential visual social cues (21). Indeed, most of the respondents maintained a high level of educator presence within synchronous laboratories facilitated by online video-based platforms. However, most were unable to keep lower educator-student ratios or small teams, factors that reduce the transactional distance between the students and educators, increasing the possibility of interactions online (11, 21). Team-based collaborative activities and assessments, such as applied or problem-based projects, encourage student online interactions, especially when they are completed during a synchronous laboratory (12, 17). This could be achieved with remote laboratory assessments that involve data analysis and interpretations, or with team-members all accessing the remote laboratory data acquisition process at the same time (28).

Teamwork for remote laboratories

Student teamwork was a unifying feature of pre-COVID physiology laboratories for respondents. Skills around teamwork (working collaboratively and cooperatively with others, appreciating and valuing different views, communicating effectively) also feature among the transferable professional skills identified as important for physiology graduates (16). Despite this, nearly half of the respondents reported a removal or reduction of teamwork immediately following the transition to remote laboratories. Many factors contributing to this reduction were mostly transient and specific to this COVID-19 period, such as unfamiliar technologies, high stress levels, student and faculty health status, geographical location, and even shifting work and family obligations. In this context, it may not have been feasible, nor equitable, to require students to engage in teamwork. However, some factors may persist for years because of the broader global situation (e.g. ongoing financial consequences of COVID-19 for universities, travel restrictions and public health considerations, increased student demands for flexibility). Some respondents in this study, suggested that some aspects of their remote laboratories will be permanently retained. Thus, physiology educators will need to consider if and how learning outcomes around teamwork can be attained and assessed for remote laboratories, in spite of factors that make online teamwork challenging.

Successfully developing teamwork skills in online contexts may start with the acknowledgement that online and in-person teamwork require overlapping, but not identical, skill sets (34). This in turn requires a reconsideration of the parameters for, and scaffolding of, teamwork skills development in remote laboratories. Common requirements for online and in-personteams include the need for effective team leaders, equal distribution of workload between team members, shared ownership of the task to integrate the individual members contributions and a sense of "knowing" each other (38). However, online teams face particular challenges in maintaining communication (e.g. navigating the absence of nonverbal/facial cues, disparate time zones and cultural expectations) and developing trust within the team (1, 18, 24). In order to support these processes for virtual laboratory teams, it can help if teams, when they initially meet, agree upon a mode of communication, clarify the roles for the team members, are provided with training of model collaborative skills as well as facilitation and involvement of the educator throughout the teamwork process (29, 33).

Careful planning of online laboratory teams could mitigate some of the challenges for online teamwork. For example, when students are navigating online teams for the first time, it may be preferable to assign students to teams from the same time zone and geographical location. Software solutions that facilitate assigning students to teams based on their preferences and/or academic ability may also prove helpful in this space (6). A relatively straightforward strategy to accelerate establishment of trust within online teams is to schedule an initial in-person meeting before online teamwork starts. Ideally, this would incorporate an educator-guided discussion of online teams, particularly culturally diverse online teams, addressing potential challenges and strategies to address these challenges (2). Many of the respondents intend to maintain a mix of on-campus and remote laboratories. Ensuring that laboratory courses start with an on-campus laboratory, where possible, is a simple strategy to accelerate the development of trust in blended on-campus and remote physiology laboratory teams (18). Similarly, requiring students to work with the same online team over a sustained period (e.g. the whole teaching period) provides time for trust to grow in online teams (38).

Modified learning outcomes for remote laboratories

Respondents said that pre-COVID, they thought that virtual laboratories did not meet the same learning outcomes as on-campus laboratories, particularly research skills development. Similarly, a key challenge for the respondents with the transition to remote laboratories was modification or loss of laboratory learning outcomes, especially research skills and teamwork. Whilst there is evidence that virtual science laboratories are at least as effective for content knowledge as on-campus laboratories, there is negligible evidence that they support research skills development (5, 15, 27). Furthermore, they usually do not expose students to variability in scientific data, they lack the collaborative and experiential learning that students experience during a physical laboratory and they can lead to diminished student attention and knowledge retention when compared to in-person laboratories (27). Some of these aspects were apparent for the remote laboratories. For example, some respondents noted that students expected to be provided with 'perfect' experimental results. In addition, informal student feedback and performance on laboratory assessments suggested that even when provided with videos of the experimental processes, some students still did not seem to understand the experimental data they had been asked to analyze.

An inability to cover the laboratory learning outcomes for remote delivery opens up a conversation about what learning outcomes are required for a physiology program. For most undergraduates undertaking a physiology major in science or biomedicine there are no accreditation requirements for the attainment of specific physiology concepts or professional/research/laboratory skills. It is hoped that newly developed physiology professional skills, including laboratory proficiency, will be used to inform physiology laboratory curricula in these degree-programs (16). In contrast, undergraduate Exercise/Kinesiology programs are accredited. For example, Exercise and Sport Science Australia has Exercise Science Standards that include “Interpret, explain and analyze physiological data obtained during acute exercise.” (14). Whilst specific laboratory and research skills-based learning outcomes may not be compulsory for undergraduate physiology studies, there is no doubt that the hands-on experiences of human physiology experiments (i.e. students experimenting on themselves) contributes to their understanding of physiology concepts and the scientific process (19) and, as noted by a couple of the respondents, can trigger a passion for the discipline.

An additional consideration is whether or not post-bachelor programs (especially medical schools) will accept virtual laboratory courses. In the United States, each medical school sets its own standards for pre-requisite coursework. Most, but not all, require one year of laboratory experience (either as a course or in a research lab), including physiology. Some explicitly state that online courses are not acceptable, some are making an exception for COVID-19, and others do not have a stated policy.

Online Communities of Practice

A positive outcome of the rapid transition to remote laboratories was that it prompted active local (within their university) and global online collaborations (such as this study). This included online engagement with physiology communities, such as the American Physiological Society, The Physiological Society and The Human Anatomy and Physiology Society, which provided a steady stream of online education webinars, workshops and forums since the start of the pandemic. Locally, online teams formed with the technical laboratory staff, colleagues and TAs who worked together under time-pressure to rapidly learn new skills to develop the remote laboratories. Many respondents also reached out to international colleagues, particularly to share resources for remote laboratories. Interestingly, communities of practice research stresses learning through social interactions and collaboration (25), critical aspects of teamwork that respondents reported as being deficient with the remote laboratories. It is possible that respondents' experiences of these online communities of practice will help them to understand and support student social interactions and teamwork for future remote laboratories.

Table 3. Recommendations for the development of remote physiology laboratories. *Key considerations to take forward when developing future remote laboratories, developed from the main themes that emerged from the reflective narratives.*

Planning	Rather than re-purpose existing on-campus laboratories, prepare and plan for remote delivery (i.e. assuming it is not an acute transition). Reconsider the learning outcomes to reflect remote delivery and the physiology concepts and research skills that can be achieved. Consider the use of hands-on activities that the students can perform at home on themselves (26).

Delivery	Present remote laboratories in a consistent format, using a single platform. Film comprehensive videos that include the process of data acquisition for the laboratory. Reduce the content and timing for each remote laboratory (i.e. less content and time than an on-campus laboratory) – everything takes longer online, plus it is harder for students to maintain focus online. Encourage interaction and communication by providing and defining clear routes for two-way communication between educators and students (i.e. monitoring discussion boards, interactive feedback on the learning management system, weekly emails/forum posts/videos, online office hours, educator presence in synchronous remote laboratories). Use tools that facilitate collaborations such as polling, digital whiteboards and breakout rooms. Keep the educator-student ratio for online interactions as low as possible (11). Aim for at least some synchronous remote laboratories (as this will enhance instructor-student interactions) and monitor student attendance at these (12, 17). Use a blended model, with asynchronous online pre-laboratory content, followed by a synchronous remote laboratory. Use smartphone applications to allow students to recording physiological parameters from home (26). To facilitate teamwork, students could analyze physiological data from home, by remotely controlling the educator's computer (3).
Assessment	Assess pre-laboratory activities to increase understanding and preparation for remote laboratories (and to ensure that students complete them). Reduce the number of assessed elements for each remote laboratory (things take much longer online). Embed team-based assessments into synchronous remote laboratories to increase student engagement and facilitate teamwork (17). Assign students to teams, taking into consideration academic abilities and whether the students are local or international. Teams should meet up consistently, have team-based assessments and have a dedicated teaching associate (33). Consider peer review for team-based assessments (this enhances student engagement and team building).

Training	Train teaching associates for effective online teamwork and incorporate some of this training into the first student team-based session (which will preferably be on-campus) Develop online modules to support and train staff to create online materials and use online platforms.

Limitations and future directions:

This study only captures the reflections of ten Physiology educators from ten different universities. Thus, each reflection is the opinion of one educator from one institution. The reflections are a 'snapshot' of educator opinions and perspectives at a point in time (July, 2020), during which the educators were under considerable workload stress and experiencing a period of global crisis. As well, not all geographic continents were covered in this study, with no universities from Asia, Africa or mainland Europe. For this study, the geographical location also altered the impact of the pandemic on physiology laboratories, as the start of the pandemic coincided with the beginning of the 2020 academic year in Australia, whereas in the northern hemisphere respondents were nearing the end of the academic year.

As the pandemic continues into additional waves, the intention is to have a follow-up study (with the same respondents), preferably post-pandemic, as this will provide better insight into the changing attitudes to remote physiology laboratories.

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Table 1. Information about the study respondents and their pre-COVID laboratories

Years as physiology educator	Average: 17 (SD 5); Range: 8 - 25+
Degree programs	Bachelor (Science, Biological Science, Health/Medical Science).
Level(s) of students	1=11%; 2=33%; 3=33%, 4=23% *(Australia doesn't have 4-year programs)*
Cohort size	Average: 295 students; Range: 50 - 600
Learning outcomes	Mix of physiology concepts and research skills
Types of laboratory assessments	Multiple choice question quizzes (pre, post, in-class), laboratory reports, short answer questions, laboratory/practical test
Assess research skills?	Yes = 70%; No = 20%. Research skills assessed: experimental design, data collection and recording, statistical analysis, referencing, communication, critical and data analysis/interpretation, problem solving.
Teamwork	Yes (n=10). Average team size: 4 students (SD 1); Range: 2 - 6
Number of students assigned to each instructor (faculty/academic or TA)	Average: 15 students to 1 instructor (SD 5); Range: 8 - 24
Pre-laboratory online content	Yes (n=8; 6 with pre-lab online quizzes based on the lab content and/or protocols). No (n=2; one asked the students to review the relevant lectures and one asked the students to come to the lab with a protocol flow chart – neither were assessed)
Are the laboratories compulsory? Was attendance taken?	Yes (n= 8; attendance registered); No (n=2; attendance not registered)

Table 2. Respondent attitudes to replacing on-campus laboratories with virtual alternatives

Theme	Selected quotes
Virtual laboratories would not be engaging or authentic	"*We had previously found it hard to get students to engage during such [virtual] sessions and some staff always found them predictable and boring.*" "*I felt for my students, clicking their way through relatively uninspiring (though scientifically thorough) virtual simulations of experiments.*" "*I felt students didn't get to grips with understanding the techniques and the experiments themselves were very repetitive. The students performed the experiment, following the protocol with very little thought or understanding.*" "*. . . nor would they [students completing virtual laboratories] have to deal with something like troubleshooting when something goes wrong*"; "*most online simulations lacked the uncertainty that occurs with different experiments, and there was a lack of diversity for any human experiments, videos or data.*"
On-campus laboratories support learning and build social connections better than virtual laboratories	"*face to face practical classes . . . provided opportunities for students to interact with teaching assistants, academics and with each other and the general consensus that this social environment supported student learning and engagement.*" "*My teaching philosophy is based on . . . on active learning pedagogy and inspiring and supporting students to learn . . .*" "*it was a time [in-person laboratories] where you could really spend more time with students and find out what they were struggling with and whether the class had really understood what you had been talking about in class.*
Virtual laboratories would not meet the learning outcomes	"*We felt students would not have as adequate an opportunity to practice and hone these [research] skills using an online interface. We wanted students to appreciate the subject to subject variability that comes with authentic research.*"
Belief that positive personal experiences of on-campus laboratories cannot be replicated online	"*These experiments, in my memories, were a complex tapestry of olfactory, tactile, ethical and emotional reactions – will the next snip of the scissors sever the sciatic nerve?... These experiments had their roots in some of the earliest and most fundamental physiology experiments.*"
Student, parent and educator expectations that on-campus laboratories will be provided	"*students frequently commented about how much they enjoyed the practical laboratory classes and how they supported their understanding of physiology content.*" "*students and their parents often associate the quality of the courses with the number of hours the student spends in face to face teaching including practical classes.*"
Challenges of getting colleagues to embrace virtual laboratories	"*Trying to change the mindset of colleagues within the school, many [of] whom have been part of the original team designing practical courses of the past was a difficult challenge. They could not see how using virtual lab experiments, or even pre-or post-lab work, would train students to be competent in the research skills required to be proficient in their labs during the final year of study.*" "*I think a lot of my colleagues were actually quite scared about what would happen if a class failed if the technology didn't work. . .*"

Virtual laboratories can prepare students for on-campus laboratories	"*A simulation/online practical might be good to provide preparatory experience before doing the actual lab work.*" "*Online or virtual labs seemed like a reasonable approach for specific lab protocols that weren't feasible because of financial, facility and/or safety limitations. I felt that these were good supplements to a course that was otherwise taught in person with hands-on activities.*"

Table 3. ***Recommendations for the development of remote physiology laboratories.*** *Key considerations to take forward when developing future remote laboratories, developed from the main themes that emerged from the reflective narratives.*

Planning	Rather than re-purpose existing on-campus laboratories, prepare and plan for remote delivery (i.e. assuming it is not an acute transition). Reconsider the learning outcomes to reflect remote delivery and the physiology concepts and research skills that can be achieved. Consider the use of hands-on activities that the students can perform at home on themselves (26).
Delivery	Present remote laboratories in a consistent format, using a single platform. Film comprehensive videos that include the process of data acquisition for the laboratory. Reduce the content and timing for each remote laboratory (i.e. less content and time than an on-campus laboratory) – everything takes longer online, plus it is harder for students to maintain focus online. Encourage interaction and communication by providing and defining clear routes for two-way communication between educators and students (i.e. monitoring discussion boards, interactive feedback on the learning management system, weekly emails/forum posts/videos, online office hours, educator presence in synchronous remote laboratories). Use tools that facilitate collaborations such as polling, digital whiteboards and breakout rooms. Keep the educator-student ratio for online interactions as low as possible (11). Aim for at least some synchronous remote laboratories (as this will enhance instructor-student interactions) and monitor student attendance at these (12, 17). Use a blended model, with asynchronous online pre-laboratory content, followed by a synchronous remote laboratory. Use smartphone applications to allow students to recording physiological parameters from home (26). To facilitate teamwork, students could analyze physiological data from home, by remotely controlling the educator's computer (3).

Assessment	Assess pre-laboratory activities to increase understanding and preparation for remote laboratories (and to ensure that students complete them). Reduce the number of assessed elements for each remote laboratory (things take much longer online). Embed team-based assessments into synchronous remote laboratories to increase student engagement and facilitate teamwork (17). Assign students to teams, taking into consideration academic abilities and whether the students are local or international. Teams should meet up consistently, have team-based assessments and have a dedicated teaching associate (33). Consider peer review for team-based assessments (this enhances student engagement and team building).
Training	Train teaching associates for effective online teamwork and incorporate some of this training into the first student team-based session (which will preferably be on-campus) Develop online modules to support and train staff to create online materials and use online platforms.

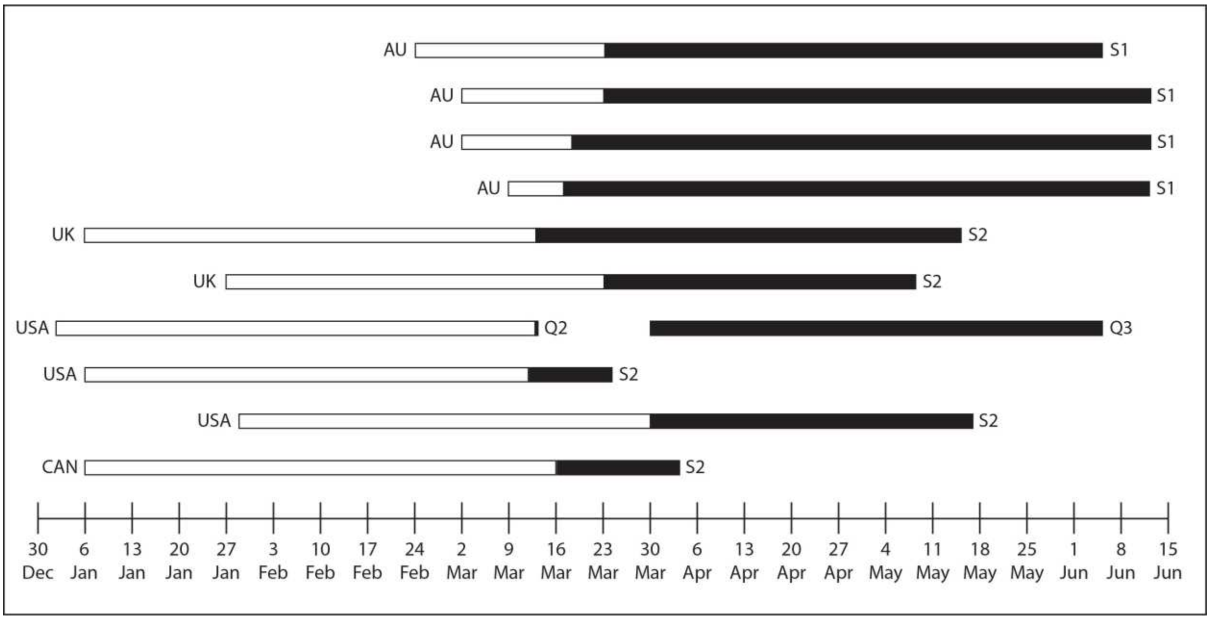

Figure 1. Critical academic term (or semester) dates at the universities of the respondents. *White bars begin at the start date of each term. Black bars begin when each university switched to remote delivery due to COVID-19; black bars terminate at the end of each instruction period for the term (excluding final exams). Countries of respondents: Australia (AU); United Kingdom (U.K.); United States (U.S.A.); Canada (CAN). S1, S2, Q2, Q3: Semester 1, Semester 2, Quarter 2, and Quarter 3, respectively.*