

Flexible teaching and learning modalities in undergraduate science amid the covid...

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Introduction

Throughout the world there has been significant disruption caused by the 2019 novel coronavirus disease (COVID-19), as well as the subsequent medical and economic fallout that has followed. Significant restrictions have been placed on the day-to-day functioning of societies, with so-called “lockdowns” occurring in many developed countries in order to contain the spread and lessen the impact of this disease. In response to the unprecedented health crisis gripping the world and the associated restrictions, many universities have been faced with the difficult decision on whether to shut down and suspend teaching, or to rapidly adapt their approach to learning through online course delivery and streaming.

Prior to the COVID-19 pandemic, the delivery of university programs online has steadily increased with the arrival of enhanced digital technology, growth in student enrolments, and accessibility to high-speed internet and home-based computers ([Capra, 2011](#) ; [Christensen et al., 2011](#) ; [Hart, 2012](#)). While improved digital technology has enabled virtual classrooms and considerably changed the delivery of undergraduate teaching, such changes have not completely been adopted in many undergraduate health, science, and medical programs as they require a “ hands-on” aspect ([Regmi and Jones, 2020](#)). For instance, in undergraduate anatomy and physiology classes, student learning is often centered around anatomical dissections and practical classes, which are often peer- or group-based in nature. Similarly, both biological and physical sciences are dependent on practical

laboratory classes, often entailing small groups, in an aim to replicate real-world laboratory conditions ([Rice et al., 2009](#)).

As these aforementioned undergraduate programs necessitate a practical component, the disruptions caused by the COVID-19 crisis have left educators with a dilemma on how best to maintain student learning in the present circumstances. This review will outline the challenges associated with a rapid transition to online teaching and learning for undergraduate science programs, and evaluate strategies and consequences that may arise as a result.

The Unprecedented Disruption

Since the outbreak of COVID-19 was reported in Wuhan in December of 2019 ([Yang et al., 2020](#)), the virus has been declared a pandemic by the World Health Organization ([Jebri, 2020](#)). This virus shares similarities with previous coronaviruses that have been responsible for both the Severe Acute Respiratory Syndrome (SARS) and the Middle East Respiratory Syndrome (MERS) epidemics ([Sarzi-Puttini et al., 2020](#)). Collectively, these viruses affect different parts of the respiratory system; commonly result in symptoms such as fever, cough and malaise; and leave some patients unable to cope with the consequences of infection ([Ding et al., 2004](#) ; [Nassar et al., 2018](#) ; [Ragab et al., 2020](#)). Unlike these other viruses, the novel coronavirus has presented an additional challenge as transmission is thought to occur from pre-symptomatic and asymptomatic cases, making containment efforts ever more difficult ([Ren et al., 2020](#) ; [Tindale et al., 2020](#)). As the disease spread alarmingly from China to the Americas and

across Europe ([Holshue et al., 2020](#) ; [Lescure et al., 2020](#)), economies and society as a whole have been crippled. Throughout the world, limitations on social interaction have been enforced, leading to a fundamental shift in the way workplaces, social services, healthcare and education are provided and conducted. Disturbingly, these changes have occurred rapidly in many countries, with an overwhelming number of reactive policies, draconian restrictions, and daily changes in lockdown measures ([Alexander et al., 2020](#) ; [D'Auria and De Smet, 2020](#)). It is clear, the scale of this pandemic is enormous.

In Australia, universities predominantly remained open, and therefore rapidly raced to move all classes and additional content online. Therefore, in many cases, academic staff have rushed to move learning material and resources to online learning platforms, while simultaneously adapting lecture material for streaming and or home-based recording ([Heitz et al., 2020](#) ; [Prata-Linhares et al., 2020](#)). However, in some instances, institutions canceled classes for up to a week to enable the transition ([Parker, 2020](#)). Though academic staff should be commended for the speed of this transition, practical and laboratory content delivered in undergraduate health, science, and medical programs have been forced to dramatically change. The delivery of many practical and laboratory classes in such an online environment requires careful consideration, particularly in the hopes of balancing the desired learning outcomes with the essential practical skills ([Regmi and Jones, 2020](#)). This must also be coupled with student engagement and learning in mind ([Cook et al., 2008](#) ; [Regmi and Jones, 2020](#)). Amidst this fast transition, it remains to be seen how such classes

will be affected and whether students will face medium or long-term changes in these programs. Equally, it is not yet known whether these changes will be sustained or if this transition will be reverted ante COVID-19.

Strategies Being Considered and Employed for Undergraduate Science Programs

Delivery of Lecture and Theoretical Work Online

While COVID-19 has stunned the world across various facets of life, the education sector, considered to have been significantly impacted, was perhaps one area best braced for a rapid change toward a digital world. Since the early years of the twenty-first century, many universities across the world have been transitioning courses and curricula toward online learning, by developing networks and interactive digital platforms in order to allow the education of those from afar ([Palloff and Pratt, 2007](#) , [2010](#) ; [Salmon, 2013](#) ; [Bao, 2020](#)). In the process of moving to a large-scale digital learning environment, many education providers have re-evaluated effective teaching strategies when utilizing digitized platforms. Such re-evaluation has led to modifications in not only course structure and content, but particularly the method of delivery. One such strategy has been to divide online learning content into smaller modules and packages of information, including shorter 10–20-min videos that better optimizes student interest and engagement; a shift from the typical 60 min lecture ([Bao, 2020](#)). While these changes have been slowly developing over the last two decades, COVID-19 has been a stimulus for their rapid large-scale introduction, with lecture recordings being posted on mediums such as BlackBoard (a virtual learning environment and learning management system) allowing for asynchronous review as well as

the option to pause, rewind and replay content ([De Tantillo and Christopher, 2020](#)). Thus, online learning has provided the major platform for universities to combat the impact of COVID-19 on education. A comparable transition of this has been seen within the medical field, with a movement toward online learning seminars, discussion groups, virtual patient assessments as well as large group presentations ([Purdy et al., 2015](#) ; [Sharif et al., 2020](#)).

Successful platforms in this instance have included: Aliem (a virtually based social enterprise, medical education start-up), CanadiEM (a virtual community of practice for Canadian Emergency Medicine practitioners) and many others ([Roland et al., 2017](#) ; [Chan et al., 2018](#) ; [Ting et al., 2019](#)).

Overall, it would appear that COVID-19 has brought forward both a medium change, as well as a delivery strategy change. Together, such changes have not only optimized the use of technology, but also student learning and engagement.

Delivery of Laboratory and Practical Work Online

Over the past few decades, there has been increasing emphasis on moving many biology, medical, and undergraduate science courses online. This serves many benefits, including increased access and availability for distant and remote students, maximizing the capacity and scale of information which can be taught, providing innovative platforms aimed at enhancing student learning through modern technology, and digital uptake encouraging regular updating and refinement of resources ([Cook, 2005](#) ; [Appana, 2008](#)).

While the online environment has been embraced by many universities, numerous issues surrounding practical activities and delivery have been raised. For example, anatomical dissections and surface anatomy have

always presented an issue, especially as the discipline requires a physical learning approach ([Korf et al., 2008](#)), and to forgo or reduce such exposure to anatomy learning would likely lead to student disengagement and academic struggle ([Vitali et al., 2020](#)). In addition, practical components that require specific equipment, access to certain software, or involve any chemicals or reagents are unable to be completed online. To overcome this, academics have developed simulated and interactive tutorials to supplement laboratory learning where required. Previous studies have shown that supplementation of online content in anatomy and physiology classes does not affect grades when compared to traditional learning ([Granger and Calleson, 2007](#)), and is often positively received by students ([O'Byrne et al., 2008](#) ; [Pettersson et al., 2009](#)). However, a recent systematic review and meta-analysis by [Pei and Wu \(2019\)](#) described that there is no evidence that offline learning works better in undergraduate medical education. Moreover, delivery of undergraduate science courses completely online has been a routine feature of many distance-based degrees ([Driscoll et al., 2012](#)).

In the context of the COVID-19 global pandemic, and the accelerated transition to online learning, it is important to research and apply successful online teaching techniques from other fields, particularly those that heavily require a practical component. For instance, in the teaching of nursing students, significant consideration and planning has been dedicated to creating web-based simulations in order to develop clinical reasoning skills ([De Tantillo and Christopher, 2020](#)). Software programs such as EHR Go and NovEx have been identified as being beneficial for such virtual practical training ([McAlearney et al., 2012](#) ; [Brenner, 2020](#)). Similar methods have

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been applied in the training and education of emergency department staff, whereby *in situ* simulations can be transitioned to virtual platforms ([Hanel et al., 2020](#)). In this instance, a method worth giving consideration is the inclusion of a “ facilitated debrief,” an aspect of online learning which may not always be included ([Raemer et al., 2011](#) ; [Esposito and Sullivan, 2020](#)). Other strategies that have been used in facilitating the application of theoretical knowledge have been referenced, such as problem-based online tutorial meeting using tools such as Google Meet, Skype, or Zoom ([Prata-Linhares et al., 2020](#)). Despite such modalities of teaching, there are shortfalls worth acknowledging when teaching practical or clinical skills online ([Costa et al., 2020](#)).

Social Distancing in Undergraduate Classes

For undergraduate science students, tutorial and laboratory classes allow students to consolidate learning and provide practical training for real-world application ([Rice et al., 2009](#)). Most importantly, these classes provide students with peer-to-peer and group-based learning opportunities ([Dalziel and Peat, 1998](#) ; [Rice et al., 2009](#)). As the COVID-19 situation has evolved and as there have been restrictions lifted, institutions have maintained varying degrees of social distancing. While the importance of distancing in reducing transmission of viruses is clear ([Rashid et al., 2015](#) ; [Ahmed et al., 2018](#) ; [Chen et al., 2020](#) ; [ECDC, 2020](#) ; [Fong et al., 2020](#) ; [Lewnard and Lo, 2020](#) ; [World Health Organization, 2020](#) ; [Zhang et al., 2020](#)), these measures significantly affect the normal operation of undergraduate laboratory sessions. In some cases, recommended social distancing significantly impacts the normal running of group-based medical science and

life science laboratories, such as anatomical dissections, which are typically run in groups of 2–4 students. As the full scale of the global pandemic has not yet been realized, many universities have committed to maintaining social distancing for the remainder of the academic year, regardless of when government and healthcare guidelines are changed. As such, the modified nature and delivery of learning material will inevitably continue for the remainder of 2020, and perhaps for the unforeseeable future.

Impact of Online Mediums on Assessments in Undergraduate Classes

As education and teaching have shifted to a grossly digital medium, so too has assessment. Both formal assessment and students' self-assessment form a crucial part of the teaching and learning process, providing a marker for successful attainment of necessary knowledge and allowing students to develop their learning strategies ([Colthorpe et al., 2018](#)). Online summative examinations and assessment have been less commonplace when compared to the progressive shift toward online teaching over the last two decades, which is currently being attributed to issues with both reliability and dishonesty ([Khan and Jawaid, 2020](#)). However, the COVID-19 pandemic has also led to the fast-tracked development of new forms of online exam invigilation through the use of webcam and microphone technology, or through invigilation software such as Examplify ([Camara, 2020](#) ; [ExamSoft, 2020](#)). Assessment has also been altered in the techniques that are used to judge a student's knowledge, including the introduction of online viva (oral) examinations and a shift toward open book exams, which have been used traditionally for decades, but are less common in the science field ([Khan and Jawaid, 2020](#)).

The Potential Long-Term Consequences

At the time of writing this article, transmission of this virus has continued to increase with cases surpassing 31 million worldwide. While the number of new cases in many countries has declined, it is expected that restrictions and disruption of education delivery will continue for several months to come. It is likely that the disruptions facing secondary school students will also impact the tertiary sector in the medium to long-term. While some countries have avoided closure and mass disruption of secondary schools, it is yet to be seen whether a significant impact on the academic performance of individuals is going to occur, especially when university entrance examinations are considered. It is widely documented that secondary school mathematics and science subjects are significant contributors to overall performance in science and health related university degrees ([Anderton et al., 2017](#) ; [Vitali et al., 2020](#)). Therefore, it is possible that the disruption caused by the current pandemic may have longer term consequences on future students transitioning from secondary school. The mechanisms by which this may occur include a possible reduction in exposure to key concepts of science and maths education ([Singh et al., 2002](#)), a lack of engagement ([DeBerard et al., 2004](#)) and overall poor academic performance—a predictive factor for tertiary success ([Evans and Farley, 1998](#) ; [Kumwenda et al., 2018](#)).

Practical and Laboratory Related Learning

In the context of undergraduate science classes, practical activities serve purpose to reinforce theory, but have an added function of familiarizing students with a scientific laboratory, promoting laboratory techniques and

technical dexterity, and facilitating peer-to-peer learning and interaction ([Kemm and Dantas, 2007](#) ; [Rice et al., 2009](#)). Therefore, in comparison to other courses, practical classes are an essential form of traditional face-to-face learning. The consequences of not providing students with some of these fundamental learning opportunities is likely exacerbated the further they continue throughout their science degrees. As with most courses, challenging and application focused practical work typically coincides with the latter part of the degree ([Finkelstein and Winer, 2020](#)). As such, practical and laboratory heavy final years are crucial, and more vulnerable to rapid changes such as those delivered from COVID-19. In many cases, it is the experiences of this cohort of students, both theoretically and practically that need to be considered.

In the most optimistic scenario, classes may gradually return to traditional delivery, with a focus on prioritizing undergraduate science-based classes where technical skills are most important. In such an event, the disruption caused by this virus would not be significant. However, the uncertainty of COVID-19 translates to a difficulty in predicting the delivery of undergraduate science teaching in the near future. While this optimistic scenario could allow for many of the acute issues surrounding online delivery and curriculum issues to be resolved, it may also present a prolonged period of practical deficiencies within many undergraduate programs. Online programs have been successfully employed in numerous health and allied health courses; however, the careful initiation of these programs came gradually with adequately trained and prepared educators ([Purdy et al., 2015](#) ; [De Tantillo and Christopher, 2020](#) ; [Prata-Linhares et al., 2020](#) ; [Sharif](#)

[et al., 2020](#)). Moreover, studies suggest that online teaching programs alone, in teaching practical skills, are not superior to a mixed approach that combines aspects of face-to-face learning ([McDonald et al., 2018](#)).

Student and Academic Mental Health

As the current pandemic evolves, there has been increasing focus on the mental health and well-being of individuals who are working from home ([Carvalho Aguiar Melo and de Sousa Soares, 2020](#) ; [Torales et al., 2020](#)).

Such an impact extends, of course, to students currently enrolled in academic courses. It stands to reason that, in many cases, these students are working in isolation, without guidance or social supports. While distance education itself is not a new concept, a large proportion of students in undergraduate science programs have dramatically adapted their learning rituals—by a means of altered study habits, schedules and techniques, which are likely impacted significantly. While numerous reports have commented on the mental health consequences of learning from home, these focus predominantly on secondary school students ([Almanthari et al., 2020](#) ; [Cao et al., 2020](#) ; [Sintema, 2020](#)). Although a growing number of reports have also outlined the effects of COVID-19, and the consequent closure of university campuses, on tertiary student mental health ([Cao et al., 2020](#) ; [Patsali et al., 2020](#) ; [Sahu, 2020](#) ; [Zolotov et al., 2020](#)). In previous examples during global crises, the consequences of global stress and altered learning environments have seeded the development of mental health complications. This was highlighted by [Al-Rabiaah et al. \(2020\)](#) who looked at the impact of Middle-Eastern Respiratory Syndrome-Corona Virus (MERS-CoV) on a cohort of medical students, identifying the need to establish psychological support

programs for these students during an infectious outbreak due to increased psychological distress. Furthermore, the September 11 attacks in 2001 saw a significant mental health response in students, even those beyond ground zero ([Phillips et al., 2004](#)).

Lesser known are the consequences of such a disruption on the mental health and well-being of academics. While it is hoped that the current circumstances may promote resilience in those delivering undergraduate science content, significant impact on workload and delivery may have longer lasting consequences. For example, workload is known to be one of the biggest contributors to poor mental health in University sector employment ([Bos et al., 2013](#)). During this pandemic the workload of academics delivering undergraduate science courses has significantly increased, as academic staff have been forced to rapidly build online resources, which is a labor-intensive task in even normal circumstances ([Illanes et al., 2020](#) ; [Parker, 2020](#)). Moreover, adapting to be able to deliver both in person and online practical and laboratory-based content staff may experience significant stress, particularly if they do not have adequate training or experience in online teaching methods. In addition, it is well-documented that peer-to-peer interactions and a positive working environment are some of the strongest determinants of job satisfaction and well-being within a university sector ([Matzler and Renzl, 2006](#) ; [Bozeman and Gaughan, 2011](#) ; [Raziq and Maulabakhsh, 2015](#) ; [Szromek and Wolniak, 2020](#)). While the latter point has the potential to be facilitated by video-based interactions, such an approach has been shown to be a poor substitute the face-to-face social interactions in workplaces. Though there

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remains a paucity of studies addressing the impacts of workload on academic staff emotional and psychological well-being, a number of studies have indicated that university academics appear to have lower anxiety and stress ([Odriozola-González et al., 2020](#) ; [Rakhmanov et al., 2020](#)). Such findings may be attributed to both a greater understanding in the field of science, in particular virology, and the overall impact of mental health, allowing appropriate early interventions to be employed where required.

Conclusions

At the time of writing this, numerous countries have eased restrictions on many sectors of the economy, and many schools and universities have adapted to function all in a post virus way. However, there are many challenges remaining in the teaching of undergraduate science courses. Resuming classes in a safe traditional form is difficult, especially in health and science based practical and laboratory sessions. As such, it is likely that many institutions will continue with some form of online or simulated practical learning. While the latter has been shown to be effective, as outlined in this article, implementation of these approaches requires careful consideration and implementation, both of which have been difficult in the current climate. It remains to be seen what, if any, long-term consequences may come out of this pandemic. However, particular focus and thought needs to be given to the well-being of students and academics adjusting to online science-based teaching and learning. It must be noted that this review is limited in its discussion of the impact of COVID-19 focusing on the developed world, where technology and a means of improving student engagement over the internet has been possible. Unfortunately, in less

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developed nations, even in low socioeconomic settings in some first world countries, where internet and technological resources are more sparse, students have been struggling significantly along with their families ([Corlatean, 2020](#)). Perhaps this epidemic is a forecast of what may become a more frequent event in the modern VUCA (Volatility, Uncertainty, Complexity, and Ambiguity) global environment, and perhaps it has pushed education to become more aligned with modern technology and the future.

Author Contributions

RA completed the majority of the original article, with the foundational topic, writing, and major contribution. JV, CB, and MB completed a series of edits, adding additional content, and reviewing the final submission article. All authors contributed to the article and approved the submitted version.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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