### **REVIEW ARTICLE**

### Teaching and Learning of Biosciences in a Digital World: Challenges and Effective Teaching Strategies During and After Covid-19 Pandemic

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#### ABSTRACT

The global pandemic of COVID-19 has had a huge influence on bioscience education in which digital technology and transformation has gained momentum and this pattern appears to be set to persist for the foreseeable future. Adopting new technology and changing biosciences education models, processes, and procedures has posed challenges to all stakeholders within the ecosystem. Aside from the move to online or distance learning, bioscience courses in higher education also necessitate the development of critical practical skills, which is yet to be fully addressed in digital platform context. This article examines the challenges and issues that biosciences education faces, as well as the tactics, methodologies, and alternatives that have been employed in the present pandemic context to reform biosciences education to enhance its resiliency and sustainability. This article also defines effective teaching criteria in biosciences education and considers whether higher education institutions can use virtual learning to offer the newest bioscience skills and knowledge to be future-proof and job-ready.

Malaysian Journal of Medicine and Health Sciences (2022) 18(14)144-152. doi:10.47836/mjmhs18.s14.16

**Keywords:** Bioscience, Challenges, COVID-19, Online learning, Teaching quality

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#### INTRODUCTION

As of March 19th, 2022, the coronavirus disease 2019 (COVID-19) has spread to 221 countries and territories, resulting in over 468 million cases, over 6 million deaths, and a worldwide death-to-case ratio of 1.3 percent (1, 2). Each country undertook exceptional measures to protect its citizens, keep economies afloat, maintain national activities, and guarantee its functioning despite the pandemic. Implementation of vaccination programme, social distancing, hand sanitisation, good hygiene, travel restrictions, number of passengers in a car, restricted number of family members allowed to leave house, guarantine and movement restrictions, complete or partial lockdown of economic sectors are some of the approaches taken in the attempt to stop the spread of the disease and lessen its effect (3-6). Inevitably, certain sectors, particularly those that rely largely on people's mobility, such as restaurants, airlines, travel and tourism, hospitality and leisure and education have been heavily affected by the COVID-19.

Approximately, 98.6% of the world's student population or about 1.725 billion learners have been forced out of the classroom as a result of school and university closures around the world (7). This has forced higher education to revisit and revise their modus operandi by changing application processes, enhancing crisis management techniques, and eventually redefining the teaching and learning pedagogies (8). This led to the radical transformation of traditional style of learning to online and digital learning, hence establishing a new standard for higher education motivated by the need to quickly digitise education and training procedures (9). COVID-19's disruptive impacts have provided not only opportunities for reforming higher education institutions, but also obstacles and hurdles in this process, as universities must critically rethink and reorganise their educational programmes to address this 'new normal'(10). As a result, a notable surge in online learning has occurred, in which instruction is done remotely and via digital platforms (11). In a very short timeframe, the whole higher education systems had to radically restructure their operations in order to transition to an online teaching-learning environment. Due to the sudden 'forced' transition, academics, students and institutions have found themselves in "unfamiliar territory" and as such has impacted the learning quality and delivery. While increased digital technology has permitted virtual classes and significantly altered the delivery of undergraduate education, many undergraduate medical, biosciences, engineering and other sciences programmes also require a "hands-on" component, and such improvements have yet to be fully addressed or even implemented (12) since it relies on physical presence and small- or peer-centred learning approaches (13). This paper discusses the barriers and challenges of making a quick shift to online teaching and learning in undergraduate biosciences programmes from the students, academics and institutions perspectives and describes the adaptations and responses addressing these challenges. Over the past decade, the complexity and ambiguity in higher education including biosciences education due to increase in student diversity; increasing accountability; the growth of transdisciplinary and global learning, digital transformation; the rise of big data and data analytics, evolving assessment philosophy and practise, work-integrated learning; the students as learning partners movement; and so on, necessitates the criteria that have characterised effective teaching so successfully to this point must now be re-examined, reassessed, amended, and updated, which will be addressed in this paper.

## EXPERIENCES AND CHALLENGES OF BIOSCIENCES EDUCATION DURING COVID-19

As a result of the worldwide COVID-19 pandemic, tertiary institutions all across the world were forced to cancel on-campus classes, forcing academic sessions to migrate to online delivery in a relatively short amount of time (14-16). The consequences of unexpected online learning have their own set of benefits and drawbacks to not only students but also to academics and institutions itself. Evaluating the advantages and disadvantages can assist in the development of approaches for more successful class delivery, ensuring that students have an uninterrupted learning experience.

### Advantages of online learning

Because lessons may be done either synchronously or asynchronously, online learning gives students the freedom to study anywhere and whenever they choose (17, 18). This approach is preferred by institutions where their students are scattered all over the world and relies on pre-recorded lectures due to time differences between countries. Moreover, online learning software, video conferencing applications and tools, and e-tutoring are all available and were used to provide free access and long term retrieval of information (19). Online learning

ensures learning can be easily managed with convenient and quick learning material accessibility and retrieval (20). It also caters to students' different learning styles and needs (21). Students benefited from these methods in a variety of learning ways, including the option to study materials after the allotted lecture time, alter the speed, and repeat certain sequences (22). According to data provided in Forbes by the Research Institute of America, learning retention rates are increased by 25% to 60% when using e-learning. Face-to-face instruction, on the other hand, has a substantially lower retention rate at about 8%-10% (23). In addition, learners learn nearly 5 times more material with e-learning without increasing time spent (24). Nonetheless, during the pandemic, online learning has more detrimental than good consequences.

### Students' challenges with online learning during COVID-19

Generally, the challenges faced can be divided into three major challenges: technology, pedagogical and social. The major online learning problem encountered during the pandemic of COVID-19 is the lack of internet accessibility and connectivity and availability of technology (25). Students struggle to participate in online learning due to poor internet access, network and connectivity and insufficient bandwidth. Without reliable internet access and/or technology, it will create and widen educational inequalities. This is more so evident among students from underprivileged and underrepresented backgrounds (26-28). Students who do not have dependable internet access or technology find it difficult to engage in digital learning; this divide exists across countries and between income levels within countries. For instance, students in Global North almost all have a computer to use whilst only 30-40% of students in Global South do. Students also complained of lack of attention and easily felt boredom as the learning process happens in isolation and solitude (10). In addition, there are also unavoidable disruptions at home. This is because some of the students have siblings, parents or relatives that stay together and they find it difficult to control their learning environment. Students often lack self-regulation skills while studying at home as they are prone to distraction from other matters (29). Poor motivation behaviour led to poor time management and individual learning abilities (30, 31). The sudden unplanned shift towards online learning during the pandemic exacerbated by the internet connectivity issues further dampens the transition, acceptance in coping abilities of students that may result in poor management of mental health status (32-34). Issues with motivation and engagement, personal scheduling, teacher communication, and increased stress and anxiety were among the major student concerns (35, 36). Online learning also resulted in lack of interaction and engagement not only between students but also between students and academics that greatly impacts the effectiveness of online learning (21). It is difficult

to stay motivated to learn when students are socially isolated during a pandemic and this is heightened by unfavourable external factors such as internet connectivity and household environment (37, 38). As a result of online learning, concerns about cyber security, cyberbullying, online aggression and exploitation, and other psychological difficulties have grown especially the breach of data privacy by unauthorised parties (39-41). For the delivery of learning goals aligned with each degree programme, a high-quality student experience is essential. This has caused a challenge throughout the higher education sector, requiring academics to switch to remote teaching and a variety of laboratory delivery methods. As a result, students have had limited or no access to laboratory facilities as face-to-face laboratory teaching has been unavailable. It has a restriction on how the students can improve their practical laboratory abilities (42). Experimenting, for example, would introduce the students to a variety of valuable and technical tools and machinery. E-learning, on the other hand, restricts crucial hands-on exposure to such facilities and the ability to understand the complexities of being involved in such an environment (43). Additionally, challenges were noted among students participating in placements. Due to companies and organisations refusing to allow students access to their premises, students are having trouble finding facilities to complete their placement.

### Academics' challenges with online learning during COVID-19

The challenges faced in online learning are also overwhelming for academics. The majority of academics were unprepared for this transformation and found themselves struggling to conduct their courses in an unfamiliar environment, having been given only a limited amount of time to transform their course material and teaching procedures to an online delivery format. The monitoring of students' progress was difficult compared to traditional classrooms as some students are non-active participants and many tend to disable the video function of teleconferencing software. On top of that, there are also compatibility issues whereby the online learning environment is not conducive for courses or programmes that relies heavily on handson or psychomotor skills such as medical, biosciences and engineering (19, 44-46). This compatibility gap has yet to be addressed, therefore online learning cannot be utilised successfully and efficiently in these fields despite the availability of remote or virtual laboratories. Academics are also bogged down by the heavy workload as the pandemic necessitates the transfer of all physical classes to online learning. Therefore, the learning contents, materials and activities had to be online friendly. In addition, academics are responsible for creating interactive sessions to ensure students' motivation, engagement and a smoother running class for their students (47). The competency and operating skills in using online tools and technology are not only the responsibilities of students but the academics too. Academics with low and limited digital competencies and without proper and adequate training would have difficulties in keeping pace with online teaching and learning (10). In an online context, unbiased and impartial evaluation assessment is challenging. Academics are restricted to proxy monitoring of students in online assessments, making it difficult to monitor and handle cheating. In addition, insufficient instruments for student assessment in online learning programmes adds to this complexity (41, 45, 48, 49).

# Higher education institutions' challenges with online learning during COVID-19

The spontaneous and unexpected move towards fully online learning has resulted in inadequate preparedness and readiness of universities. Curriculum adjustments, the availability of digital infrastructure and services, changes in the academic calendar, and rules on instructional delivery and evaluation are only a few of the problems that university and management confront in limiting the pandemic's negative impact on higher education (50). Adequate financial and investment were required to purchase devices and equipment, maintaining equipment, educating human resources, and creating online content to ensure a smooth transition towards online learning. The financial and stability implications were much more evident among the Global South. The government funding distributed to each university was reduced compared to previous years. For instance, IT infrastructures could be affected by the economic condition of a country (10). Before the pandemic outbreak, international students were one of the main sources of income for university. However, universities have seen reduction in revenues from reduced international student recruitment and enrolment (51) as well as matters concerning impending tuition fees (52). The shift to online learning led to decline in internship opportunities (34) and participation in international mobility programmes (53, 54) thus further reducing income generation. Another challenge facing higher institutions is coming up with strategies and mitigation plans for depleting quality and social aspects of students in higher education. There are risks including teleconferencing security issues, network vulnerabilities and Phishing attacks. They can be easily breached if the system is unsafe and for phishing attacks, official email may direct the recipient to malicious sites (18) thus resulting in privacy issues.

### EFFECTIVE TEACHING CRITERION IN BIOSCIENCES EDUCATION POST-COVID-19

In previous practices, effective teaching criterion are usually aligned with the context in which it takes place. However, due to COVID-19 pandemic, the current evolving scenario has changed enormously and has significantly affected the concept of effective teaching in both, inter- and multidisciplinary contexts (55, 56). Disruption across the higher education sector has shifted the format of conventional teaching from physical to either fully online or hybrid. Hence, digital transformation has significantly revolutionised the conduct of effective teaching especially on how it may best fit biosciences programmes. The hurdles are obvious and pervasive, but educators may overcome them by implementing tactics and approaches that best suit their teaching and learning requirements. In the next section, numerous techniques and best practices will be described.

## Intensify the use of digital technologies and humanising online learning in biosciences education

With the help of technology, educational institutions and educators will be able to rethink teaching and learning and alter the university experience for students of all ages, demographics, and socioeconomic backgrounds by providing cheap, engaging courses with rich material. Online or hybrid learning improves the engagement and power sharing between academic and student through customised digital platforms, online peer assessments with in-built feedback. Several articles have suggested key areas in shifting towards digital learning which includes online capabilities and management, content creation and growth, educator's scholarship, assessment, learners' experience and quality assurance and control (25, 57).

Numbers of new applications are now available for better teaching such as artificial intelligence, blended and hybrid courses, micro-credentialing, and open educational resources. In addition, these new pedagogies also create more collaborative approaches to constructing better knowledge than previous conventional teaching settings. Another beneficial outcome of digital transformation is the increment of student enrolment especially from abroad (58). Thus, it is important for academics to also consider student learning and experience in culturally relevant content, particularly in teaching approaches and assessment. This is to ensure that academic standards are upheld across multiple contexts (59). Furthermore, to comply with the current need of effective teaching, the digital transformation has steered the education institutions to invest in sophisticated, integrated systems and complex technologies. As a result, data collected from any generated systems can now be easily assessed by anyone. However, this assessable data may have pro and con effects on students' performance. While these 'big data' could be used as added reference for students to refer to, it might as well raise ethical questions as if these sources are plagiarised if they are not carefully monitored. Nowadays, higher education is more highly regulated than before. For that, it required greater accountability, better quality assurance and transparency (60). Transparency measures have increased accountability in higher education as it provides detailed information in evaluating the effectiveness of teaching and

accountability of the assessed universities or academics (61). For these purposes, a number of national quality and standards agencies have been created to regulate and assure the quality of higher education, making institutions more accountable for the standards of which they are responsible. For example, Malaysian Qualifications Agency (MQA) has been established by the Government of Malaysia to regulate and monitor the quality of higher education under the agency called the National Accreditation Board. The MQA is assigned to monitor that the effective teaching criterion are in compliance with the set standards.

### Redefine biosciences curriculum design and authentic assessment

Based on the demand for graduates to be prepared with work-ready skills (62), existing curriculum with embedded assessments that align with workplace outcomes, and industry-community connection need to be re-designed. This work-integrated learning is believed to benefit students with more experiences within the curriculum. Unlike previous conventional teaching, in which the academic is superior, the current setting of education between academic and student is shifting towards a partnership. Good practice should nurture power-sharing and relationships through dialogue and reflection (63). Effective teaching can be achieved if students and other voices in higher education (e.g. communities, industries, etc.) are given the opportunity to express their ideas and fostered to cocreate their educational experiences (64). Next, teamteaching has been a common practice for academics to collaborate with peer colleagues, industry associates and other specialists with aims to improve experiential and integrated learning has become one of the key components in effective teaching. Such collaborations will facilitate better learning systems and provide extensive specialist input (65).

In addition, teaching strategies that work best with biosciences students are peer-to-peer structured interaction in either competitive, individualistic or cooperative learning. These forms of learning can be used depending on the type of work whether individual or group based, learning outcomes and tasks and grading structure (66, 67). Different learning models can be utilised depending on the cognitive learning domains. If the domain requires cognitive knowledge, mental skills and psychomotor skills, inquiry-based learning would be the best option whereas problem-based learning would suit domains that require only cognitive knowledge, mental skills. Collaborative and role-play learning would better suit the learning domains that require interactions, interpersonal and social skills (66).

### **Rethinking biosciences laboratory practical, project** and placement to be online friendly

Unfortunately, less precedence was given in the aspect of laboratory practical, final year projects

and placements, which forms crucial elements in biosciences programmes that help students to gain the knowledge and skills sought by future employers. Many instructors have devised inventive, easy and cheap ways to provide practical and projects online, although some may be replaced by a 'capstone' activity. A "Bioskills at Home" kit was created by Nottingham Trent University to give first-year undergraduate students the opportunity to develop laboratory skills by using online support tools to guide their activities and form learning communities. Students could use the equipment and activities in this kit to practise key skills like pipetting, data handling, experimental design, and microscopy, but also build virtual peer-learning communities via discussion forums and microscopy competitions that motivated them to investigate their local surrounding ecology. This has increased engagement, increased self-assurance in crucial practical skills and achieved equal learning outcomes compared to pre-pandemic sessions (68).

In the long run, the use of virtual laboratories would be one such approach. Virtual laboratories and virtual fieldworks would aid in student's transition to university and develop their laboratory skills (69). There are several readily available and open content such as Virtual Labs, a programme of India's Ministry of Human Resource Development, has built over 700 web-enabled experiments that can be operated and seen remotely (http://www.vlab.co.in/). The 'Laboratory Skills Open Educational Resources' established by De Montfort University were designed to help students transition into labs and were used in a remote manner and had access to laboratory skills videos, problem solving, and test exercises (69). The 'Open Science Laboratory', an initiative of The Open University and The Wolfson Foundation supplies ready-to-use tools and realistic simulations that may be included into curriculum. Investigation on the use of augmented reality technologies in science laboratories showed significant improvement in student's laboratory skills and builds a positive attitude towards science laboratories (70). Augmented reality laboratories provide more dimensions employing mobile devices to scan bar codes to access multimedia materials and might be utilised in a socially remote lab or as a resource for students to use at home if they had access to a smartphone. However, integrating new technologies into the curricula effectively would need careful planning and a large number of resources.

Capstone projects are final year projects that students do at the end of their academic programme. It necessitates a host of cognitive processes and teaches students on how to discover and understand information as well as how to work effectively with it, thus contributing to their own professional portfolio. Capstone projects to also be conducted in conjunction with collaboration between communities, governments and industries. This would build a network and students are able to gain realworld insights that would enhance their employability. These work- and community-integrated projects would be a way forward in conducting biosciences final year projects in a post-pandemic world. Equally important, this approach can also be utilised as a means to address issues pertaining to student placements and internships. The Royal Society of Biology has provided a list of capstone project ideas that can be used and adopted into the biosciences curricula. Capstone choices for bioscience students' final year projects, including projects that could be completed remotely or in groups has been discussed by (71). Conducting an audit or questionnaire is another final year project approach that is of value. Bioscience students may be able to conduct an audit of their laboratory or clinical setting (69). Therefore, there is a need for the final year project to be diversified and able to be carried out remotely with great emphasis on pair and group work to provide relevant knowledge and skills for the work-force.

Hence, it is important for academics to totally understand the disruptions and adapt to this new norm. Followed with implementation of suitable practice accordingly. Effective teaching criterion will not be sufficient without the support of those who are involved, mainly the students. It is important for the students to be cooperated as well in this environment to create symbiosis of effective teaching practices. With significant transformative waves in higher education teaching approaches, the urge for the re-interrogation, reconsideration, revision of the previous effective teaching criterion is needed. As educators, we must consider the long-term incorporation of online teaching and learning into university curricula that places a premium on quality (72);

I. The necessity for open educational platforms to continue to evolve in order to provide access to high-quality learning content.

II. The need for quantitative and qualitative research to assess the efficacy of present online teaching and learning approaches, with a focus on long-term viability. III. The requirement to build educator capacity for online instruction as well as professional staff ability to support educators and offer technological assistance when necessary.

IV. The importance of fostering collaboration among universities, local and international organisations and companies, society, and other stakeholders in order to promote high-quality online materials and content.

### CONCLUSION

The COVID-19 exposed a number of flaws and inadequacies in online learning strategies, including social isolation, a lack of engagement and immersion, inadequate learning evaluation methodologies, and the difficulty of providing online hands-on activities. The issues of online learning discussed here, as well as their implications for global, local, disciplinary, and interdisciplinary learning should be revisited and readdressed owing to the complexity and diversity of the learning needs and learning environments. The new criteria of effective teaching should therefore be globally relevant and remains open. Effective future educators are those who are insightful and are able to adapt their thing and practice according in times of uncertainties (55). Educators, students and institutions needs to reconsider and streamline their teaching and learning practices and/ or policies. It is likely that revolutionary change and new higher education teaching methodologies may emerge as a result of this process, possibly even a new paradigm of effective teaching in biosciences education. Moving forward, biosciences education should therefore be that of resiliency, adaptability and sustainability.

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