Online teaching for cell culture techniques as a new paradigm : A review

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Abstract: Due to its vast application in life sciences,mcell culture is one of the modes of choice for research and has been used extensively in antibody, vaccine and hormone production. Techniques in cell culturing are traditionally learnt hands-on in the laboratory setting. Instructors demonstrate the cell culturing techniques for students to emulate or re-perform. However, the lack of trained instructors, limited number of equipment and increased costs are major hindrances in hands-on learning of cell culture techniques. Online learning was initially necessitated for instructors by the unprecedented event of COVID-19 pandemic worldwide which led to the limitations in conducting practical and hands-on sessions. In this review, various teaching and learning methods which include blended learning, virtual laboratory, or massive online open course (MOOC), and assessment modalities related to online teaching of cell culture techniques are discussed. The benefits of these modalities to students and instructors such as increased motivation and more engaged learning are discussed. Even though the benefits of these modalities are substantial, we also discuss the limitations related to online learning such as less interpersonal communication and inability to nurture all the senses that usually happens in hands-on learning. Suggestions on the advancement and improvement of such modalities are also discussed in this review. The present review will aid educators and instructors in planning, designing modules and executing online teaching for cell culture techniques.

Keywords: Benefits, Cell culture, Online practical, Suggestions, Teaching modalities

INTRODUCTION

Traditionally, the methods of teaching and learning cellular function, molecular biology and cell cultures in science have always involved lecture series by the academic staff and the teaching session is followed by practical sessions in the laboratory settings. The presence of an instructor to facilitate the practical session with students has been the standard practice by all universities around the world. In the past, a practical session without the presence of instructors during face-to-face sessions was unimaginable. Specific teaching on practical skills such as using scientific equipment, technology, instrumentation, physical laboratory techniques are regarded as almost impossible to be taught outside traditional laboratory settings (Huang et al., 2015).

However, in the last decade, the recent advancement of technology has contributed to the innovation in practical session teaching at higher education level. The lecturers who are the content experts have embraced the technology in an innovative way by developing online distance learning materials or e-learning platform suitable for practical sessions. Online distance learning can be defined as conducting a learning session face-to-face, but the physical gap is bridged by the technology (Rahman et al., 2015). The use of e-learning or web-based learning has been seen as a solution to certain universities who have difficulties to conduct practical sessions effectively due to the large cohorts of students but limited numbers of academic staff and instructors (Peña-Fernández et al., 2020). The use of e-learning in medical sciences provides an interesting learning experience with flexibility of time and space. The e-learning resources have been seen as relevant platforms especially in medical related knowledge as they require constant updates and adaptation with the recent findings (Strube et al., 2018). Besides that, as suggested by the World Health Organization (WHO) and United Nations (UN), e-learning has high potential to be used as a learning method to address the shortage of health professionals in future (Al-Shorbaji et al., 2015).

The COVID-19 pandemic has caused a huge implication to the academic world, particularly critical courses involving practical sessions or hands-on sessions at tertiary level of education. The global pandemic has certainly raised concerns amongst the academicians, as the prolonged lock-downs in many countries have resulted in many universities and laboratories to be closed hence, compromising the exposure to practical skills and hands-on experience in the laboratory. The inadequate exposure to hands-on sessions may implicate lack of proficiency in laboratory techniques, procedures, and protocols which could jeopardize their performance and career later (Bhattacharjee et al., 2021). In light of the global pandemic that has affected the entire world, educators and academicians were compelled to adapt to the situation and rise to the challenge of finding alternative approaches as effective solutions for teaching and learning. Online distance learning has been adapted by many universities during the pandemic. The pandemic has made the teachers realize that their role is mainly as manager of various knowledge resources instead of the sole source of knowledge, hence expediting the growth of innovations in teaching and learning, as described in the literature since early 2020. Inter-faculty collaborations in producing a new way of online learning have been established in several universities around the world. Efforts such as collaboration with the faculty of computer science to develop virtual biomedical laboratory modules for medical students has been developed by one of the universities in the United Kingdom for effective parasitology learning (Fernandez et al., 2020). Academicians who are the content experts utilize the technology as a tool for the development of teaching and learning materials according to their learning objectives and creativity.

Teaching cell culture techniques at tertiary levels for undergraduate and postgraduate students during the COVID-19 pandemic era has imposed a great challenge to the academic staff who are supervising their students (Bhattacharjee et al., 2021). The global COVID-19 pandemic has certainly forced many instructors to venture into newer teaching modalities and at the same time, retain the student learning outcomes. As practical sessions are a core competency in science subjects, learning by doing is seen as an essential learning strategy to ensure competency (Pisano, 1996). The inappropriate learning strategies will impose a huge implication to the

research and development in biotechnology as well as manufacturing companies which contribute to the economic growth of the country (Pisano, 1996). The role of content experts is mainly constructing learning objectives, selecting the most appropriate mode of teaching, and utilizing all possible modalities to ensure that the learning session takes place, and the learning objectives are achieved. Based on this idea, many campuses have made the necessary transition of cell culture labs from campus to online, as their new approach (Peña-Fernández et al., 2019; Sabel et al., 2021). During the current pandemic, many companies and institutions have also taken their initiative in developing simulation labs or virtual labs, as this could be used as supplemental to online learning provided by educators.

This review was built from the conclusions of small and descriptive studies. In this review, various teaching and learning methods, assessment modalities, advantages and disadvantages of online distance learning related to online teaching of cell culture techniques are discussed in further detail in the next section.

TEACHING AND ASSESSMENT MODALITIES

Online learning has been gaining momentum with the advancement of the internet as it is more accessible to all and considerably more affordable. A search in the relevant literature will give rise to a plethora of terms associated with online learning. The terms 'online learning', 'open learning' and 'blended learning' among others, are referring to the usage of a computer or electronic device which is connected to a network that offers the delivery of knowledge from anywhere and at any time (Dhawan, 2020). In online learning, students may not feel isolated from their peers or teachers as learning may be held synchronously. In synchronous learning, students and instructors need to follow a predetermined timetable; students listen to live lectures and are able to discuss the topics in real-time with their peers and instructors (Dhawan, 2020). Meanwhile in asynchronous learning, students are given pre-recorded lectures, quizzes, videos, and assignments online and the students need to retrieve this information and learn (Rehman & Fatima, 2021). Some online learning modalities are incorporating synchronous and asynchronous learning; and this is exemplified by blended learning or hybrid learning; which refers to the combination of face-to-face and online learning (Hrastinski, 2019).

The online platform has been used extensively in various levels of learning and institutes, from secondary school to undergraduate and postgraduate levels encompassing various topics and subjects. For this review, we are focusing on the various modalities of online teaching of cell culture techniques applied at a higher institutional level for our undergraduate and postgraduate students. The cell culture techniques here refer to the basic techniques such as aseptic technique, usage of biosafety cabinets, preparation of culture media, the changing of culture media and others.

In teaching cell culture techniques, various online learning modalities have been incorporated by different laboratories and institutes of higher learning such as blended learning and virtual laboratories. The way these modalities are delivered also changes during the pandemic. Some of the modules also include assessments to aid students in understanding the topics better.

Most of the institutes incorporate blended learning in online teaching of cell culture techniques in which there is a face-to-face teaching component and the retrieval of information from an online source. Huang et al. (2015) incorporated blended learning to undergraduate and graduate students of biochemical engineering courses. They produced videos on fundamental biological concepts, demonstrations of experiments and safety and basic skill training. The videos were accessed by students before the lecture or laboratory sessions to enhance their knowledge. During the actual session, students had more time to conduct the experiments and they were also able to refer to the videos for the proper protocols and techniques. Quizzes were incorporated at the end of the videos and students were given three attempts to answer all questions. A perfect score was needed by the students in making sure that they were allowed to start their research work in the laboratory. Once they started their research, students were given hands-on safety tours and demonstrations on protocols.

Similar blended learning was done by Peña-Fernández et al. (2020) with focus on teaching human cell culture in the field of parasitology. He created an online package which contained resources and materials such as videos, pictures of specimens and clinical case studies that can be assessed at any time and place. The contents of the online package were divided into sections, with one section dedicated to a virtual laboratory module which addressed cell culture techniques and quizzes for formative assessment.

This package was used as an adjunct in learning parasitology and students agreed that this module aided them in learning and understanding the subject. Blended learning was also undertaken by David et al. (2021) for the teaching of cell culture techniques to undergraduate students in bioengineering courses. This move towards blended learning was due to the effects of the COVID-19 pandemic which forced the closure of institutes of higher learning. The theoretical part of the programme was done face-to-face - however the practical aspect of the course which constituted the assessment of the course could not be conducted face-to-face. To overcome this, David et al. (2021) had designed a virtual laboratory practical to assess the hands-on cell culture techniques. The design of this assessment was to have students critique videos of improper cell culture techniques, analysis of data (images and calculations) and test their understanding by answering multiple-choice questions. Even though the design of this virtual laboratory practical did not test the students' hands-on practical skills, it required the students to think critically when appraising the techniques in the video.

The wave of pandemic that hit the world also changed the way blended learning in cell culture technique was carried out. Yap et al. (2021) reported the change in the usage of virtual laboratory simulation in undergraduate students in a biotechnology course. Prior to this, students utilized the Labster virtual simulation as a supplementary learning activity before entering the laboratory for practical sessions. The virtual simulation laboratory enabled them to perform animal cell culture experiments virtually with various multiple-choice questions to enhance their understanding. During the pandemic, the virtual simulation laboratory was the mainstay teaching modality for cell culture techniques. For the purpose of assessment, the virtual simulation laboratory was taken as the summative assessment of the practical segment from the fourth week of the semester.

The change in learning for cell culture techniques was also reported by Sabel et al. (2021). The authors reported the changes in three types of learning institutions; community college, liberal arts institutions, and regional state universities. Prior to the pandemic, the cell biology courses were conducted face-to-face; with the practical sessions taking place in the laboratory. The unprecedented wave of the pandemic forced the usage and application of online learning. As they had not had existing online learning materials before, various methods were employed to make sure that students met

the learning objectives of the course such as editing and finalizing videos of plant tissue culture techniques. Another institution utilized free online learning materials developed by other institutions and materials from the previous batch of students. Following this, the students were required to perform data analysis and partake in synchronous laboratory sessions where the materials were sent to the students earlier. Some students presented their data analysis as poster presentations in academic conferences. In terms of assessments, quizzes attempted by the students served as a formative assessment of the process of peer-reviewing of posters.

Bhattacharjee et al. (2021) also reported changes in delivery of cell culture techniques in second year bioengineering major students. To accommodate teaching and learning during the pandemic, their institution offered two options to students: face-to-face teaching or online. For online students, they were required to complete the online safety training prior, and an online course on laboratory introduction. Students also received at-home laboratory kits which consisted of micropipettes, consumables, and others which they would use during synchronous sessions with the instructor. In this sessions, students were able to observe videos on proper techniques with the demonstration and guidance from the instructors. Students were also required to produce their own videos demonstrating aseptic technique and completed virtual cell culture simulation, using commercially available online resources.

An interesting method of online teaching of cell culture techniques was reported by Furtney (2020). This method was utilized by the undergraduate students enrolled in Cellular Engineering Laboratory at the author's institution. This method incorporated the element of gamification in teaching the technical aspects in the form of First-Person Shooter (FPS). The instructor was the FPS and students were able to experience the laboratory techniques from the eyes of the instructor. The FPS would use a recording device equipped with a microphone during demonstration of cell culture techniques. The recording was streamed live to a group of students in the laboratory discussion area. The session was interactive; with students and instructors asking questions and discussing the techniques performed. The summary of the type of online learning is shown in Table 1.

1st author (year)	Academic course of students	Type of online learning	Description	Assessment of student (if any)
Bhattacharjee, (2021)	2nd year bioengineering major students	Blended learning offered both face-to-face and online learning	- Online laboratory introduction (both face-to-face and online students) - Cell culture kits are delivered to online students - Online synchronous session (video with explanation) on protocols and usage of kits. - Virtual cell culture simulation	- No assessment
Huang, Z. J. (2015)	Undergraduate and graduate students of biochemical engineering course	Blended learning - online videos followed by hands-on session	- Online video on protocols and techniques (viewed before the practical session) - Hands-on laboratory session	- Quiz after completion of video. Three attempts.
Peña-Fernández, A. (2020)	Undergraduate pharmacy students	Blended learning - website for reference and addition to theoretical class	- Website is created containing theoretical knowledge, pictures, videos of various laboratory techniques (including cell culture), and quizzes	- Formative assessment (short quizzes, games, exercise). - Unlimited attempt, instant feedback
Furtney, S. C. R. (2020)	Undergraduate students enrolled in 'Cellular Engineering Laboratory'	Gamification element, using First-person shooting/seeding (FPS)	- Instructor uses recording device to record cell culture techniques and live streams to a large screen - Q&A session done in real time	- One-on-one assessment of protocol

David, B. (2021)	Undergraduate students in bioengineering course	Blended learning - In-person laboratory training followed by virtual laboratory practical	- Blended learning with three phases of assessment; using short video clips, randomly generated hypothetical image and a set of multiple-choice questions	- Creates learning management system-based assessment (Canvas), consists of critiquing instructor's technique, data analysis and multiple-choice questions
Sabel, J. L. (2021)	Students from different institutions; community college, liberal arts institutions, and regional state universities	Blended learning – in-person training followed by online practical or substitution of practical Online – synchronous	- Students edit and finalize their video protocols of cell culture. - Students assess free learning materials online, followed by data analysis and synchronous laboratory session with materials sent to students - Perform data analysis and virtually present as poster	- Quizzes, peer review
Yap, W. H. (2021)	Undergraduate students in biotechnology course	Blended learning - Virtual laboratory simulation (Labster) as a supplement	- Students use the virtual laboratory prior to entering the lab - Used as the main method of learning during pandemic	- Multiple-choice questions for formative assessment during the course - As a summative assessment from fourth week of the semester

Table 1. Type of online cell culture learning

3. IMPACT OF ONLINE LEARNING IN CELL CULTURE TRAINING

Cell culture users, especially the beginners, have been exposed for many years to online learning of cell culture techniques through websites of several well-known life sciences brands or manufacturers. Cell culture beginners can watch the YouTube videos provided by the manufacturers to get general information on cell culturing techniques.

Currently, cell culture training has also been part of several institutions' online course offerings. Rapid advancement in the internet, computer software and other technologies have made it feasible to incorporate the teaching materials into online teaching and learning platforms. Similar to other courses, cell culture training courses or module's learning resources are delivered via the institution's online learning environment or platform. The learning platform varies depending on the software used, but it usually consists of a central online platform that students can access from their personal desktop computer, mobile phone or tablet.

The degree to which students can properly use scientific equipment, technology, and instrumentation, follow technical and professional protocols, and/or demonstrate proficiency in physical laboratory techniques, procedures, and measurements are often regarded as challenging to teach outside a traditional laboratory setting. However, few studies have shown that students learn well through active learning that involves visual engagement. In this section, the impact of online learning in cell culture training is discussed based on the benefits of online learning on cell culture training as well as its limitations.

3.1 BENEFITS

In a virtual biomedical laboratory module constructed by Human Cell Culture e-Learning Unit (HCCU), 25 students in the second year of the Bachelor of Science (Biomedicine) programme have been exposed to the virtual laboratory module. The module covers how to work in the cell culture lab, consumables/equipment needed, video on steps and procedures in human cell culture as well as formative assessment and mini quiz to test student's understanding. Prior to practical training,

students were given a task to watch and complete the virtual module. At the end of the practical training, opinions from students were obtained from validated questionnaires with Likert scale and open questions. Fifty six percent agreed that the overall design was appropriate and interactive with 87% having enjoyed using, and being satisfied, with the module. The video on steps to do cell culture facilitated their learning, showing that application of blended learning is potentially an effective strategy to learn cell culture (Peña-Fernández et al., 2019).

In another cell culture module, which is known as Mammalian Cell Culture Module, students were able to practise cell culture techniques using lab kits provided by the instructors. Subsequently, the students were required to create a video demonstrating aseptic technique to assess their progress. Students who studied via an online platform were required to complete a virtual cell culture simulation. Although the practical activity was performed outside of a biosafety cabinet, the students were able to practise the aseptic technique and met the learning objective of this practical section, which was to become competent with aseptic technique and basic techniques in culturing mammalian cells (Huang et al., 2015).

The virtual laboratory environment is useful for the technicians and students across the world as it serves as a medium to experience the working environment in a biomedical laboratory as well as allowing for the performing of laboratory techniques virtually. As traditionally teaching cell culture technique using the biosafety cabinets require the students to sit or stand around the trainers, this is only feasible if the number of students is low. However, despite the low number of students, there is still intermittent visual obstruction and space limitation. Thus, some techniques may not be observed appropriately by the students. Having virtual teaching also has been seen as a means to solve teaching students in large crowds at a time. Not only that, virtual teaching has also been the solution to shortage of skilled personnel as instructors, teaching in limited resources and time constraint (Peña-Fernández et al., 2020). Besides promoting self-learning, overcoming barriers of time, space, equipment, and resources, virtual teaching has been seen to increase student engagement, facilitate essential work skills, and function as a useful source for academic teaching relevant to medical aspects.

In a separate study, a virtual cell culture lab was designed due to the COVID-19 pandemic to train students to practise cell culture independently. The virtual lab enabled the students to incorporate multisensory learning tools to recall information, while providing the opportunity for students to learn and make mistakes before using the equipment, as well as an enhancement to a hands-on lab. The online learning material allows students to pause and replay whenever they feel a need. Results showed that the virtual lab enhances students' understanding of the materials used in cell culture. The software used for designing the online learning materials also allows instructors or e-content developers to monitor the students' learning progress by acknowledging who had watched the video and to what degree they interacted with the materials (Gerstenhaber & Har-El, 2021).

Gamification was developed as one of the pedagogical tools (Furtney et al., 2020). Gamification motivates students into learning as some courses of action during the game offer reward. The application of game design elements in non-gaming environments increases motivation, engagement and attaining course outcome. Studies have shown that use of gamified laboratory simulations and active learning increase student interest, motivation, learning effectiveness, and self-efficacy. Furthermore, active learning decreases learning gaps, thus increasing student achievement (Theobald et al., 2020). Advantages to virtual laboratory simulations include cost-effectiveness, eliminates biosafety concerns, and increases engagement of digital aged students (Furtney et al., 2020).

In an Animal Biotechnology module for Biotechnology course in Taylor's University, Malaysia, Labster virtual simulations have been used as part of their blended learning activities. However, due to the COVID-19 pandemic, the role of virtual laboratory simulation has been transitioned from being a supplementary learning activity prior to entering physical labs, to primary learning tools. Instructors were able to monitor progress through assessments. Comparable to the traditional way; during assessment it is shown that a virtual simulation lab increases knowledge and understanding, facilitates active, inquiry-based learning, is low cost and enables students to learn at any time and pace. From their survey, students have responded that the virtual

simulation lab is extremely helpful. Increasing trend in students answering 'extremely confident' in their aseptic technique was also observed. Students like the quizzes in between, with theoretical explanations to help their understanding. The virtual simulation is a personalized learning experience to the students where they can repeat experiments until they can grasp the concepts. Students are also able to practise steps multiple times and perform at their own pace. Virtual simulation labs also increase study intensity and motivation. To apply virtual simulation laboratory in teaching, increased simulation realism and repeated simulations are needed. Structured lab simulations with realistic cases and animations, with theoretical explanation would be helpful (Yap et al., 2021).

There is equal or even increased learning outcome achievements when using virtual labs compared to traditional labs. However, in online teaching, it is not possible to test for the physical technique of the practical. But the students are tested on critical thinking such as thinking about the steps during practical and data interpretation. Multimedia examination is widely accepted by students if it mimics prior instruction. In the practical session for undergraduate biomedical engineering students during the COVID-19 pandemic, in-person lab training was conducted and then the assessment was done virtually. The assessments consist of students giving a critique on wrong techniques shown on videos, completing exercises on data analysis such as cell counting and answering multiple choice questions to assess their knowledge. Grades following assessment were analysed and the results were comparable between in-person and online cell culture laboratory. The findings may decrease the perceived subjectivity by instructors during live assessments (David, Masood & Jensen, 2021).

In another study where the cell culture courses had to be switched into online learning, which was also due to the pandemic, students were able to create their own experiments. Increased engagements and assessment scores among students were also observed. Online demonstrations, videos, quizzes, and mock data were used to improve students' techniques. While the online or virtual environment develops different types of skills than the traditional on-the-ground lab, these skills are equally important to student maturation into a scientist. (Sabel et al., 2021).

3.2 LIMITATION

The demand for online distance learning is increasingly spreading in education, especially in higher education levels. Online distance learning or e-learning is when the teacher and the student do not connect in the traditional way which is face-to-face during the educational process, and the physical gap between them is bridged by the technology (Rahman, Karim & Byramjee, 2015). The use of virtual worlds has irreversibly changed the traditional teaching and learning habits. They can provide appropriate conditions for a novice student while they have more advantages such as good quality, low costs, safety, and remote access - however, undoubtedly, it is a challenge to teach practical skills used in the lab such as using scientific equipment, technology and instrumentations outside of the laboratory setting.
There are concerns among instructors about online teaching of cell culture techniques whether the quality of teaching and learning materials have been peer-reviewed (Peña-Fernández et al., 2020). This is supported by Veselinovska, Gudeva & Djokic (2011) where content reviewers are crucial as an initial team consisting of medical researchers to provide overall insight, feedback, and accuracy check of the content disseminated in the modules.

There is also a decline in students who 'completely agree' for more simulations in teaching. Students also said it is not as interesting as normal methods and some students even preferred hands-on lab (Yap et al., 2021).

In another study that has been explained in the earlier section, although results showed that the virtual lab enhances students' understanding of the material used in cell culture, lack of social interaction, lack of student motivation as well as difficulties in conducting question and answer sessions were also observed. More importantly, students feel that the time for communication with lecturers for question-and-answer sessions was limited (Gerstenhaber & Har-El, 2021).

Online platform is not the ideal way to teach, but it can still engage students. Although students were comfortable with aseptic techniques and learned about culturing mammalian cells, some traditional aspects in hands-on teaching do not translate well in online platforms. Based on students' feedback, the live lectures that included technique demonstrations were helpful and students further suggested that additional sessions for online students to get instructor feedback on their techniques would be beneficial. The assessing of a student's ability to perform hands-on experiments is particularly challenging especially when the classes are conducted online, as the students are only assessed based on their conceptual knowledge. For future classes, it could be useful to compare the data between the written exams scores of online students and in-person students. The results of this work can be used to adopt similar at-home instructional lab models at other institutions as well as guide the implementation of future online lab course offerings or supplemental activities for in-person lab course offerings (Huang et al., 2015).

Another study also supported live lectures whereby the students mentioned that they preferred live lectures so they can ask questions immediately. Some comments include making instruction in a virtual lab to be clearer for students to understand (Gerstenhaber & Har-El, 2021).

Online labs do require different considerations in student engagement. A researcher pointed out that "getting the students to share data in a group is difficult remotely," and recommends "getting the students comfortable with speaking up and participating in an online system has to be the first priority." Another researcher also recommends being very purposeful in scaffolding the projects. "Meaningful data analysis projects can be accomplished in an online environment in which they just need to be planned that way" (Sabel et al., 2021).

4. SUGGESTION ON IMPROVING AN ONLINE TEACHING MATERIAL

The COVID-19 pandemic has certainly forced academicians and laboratory instructors to step out of their comfort zone and venture into new teaching and learning modalities. After more than a year in the pandemic era, we have transitioned into an endemic phase and it is remarkable to witness students showing their adaptation and improvement with the online distance learning provided by the instructors and academic staff who are the e-content developers. Continuous engagement between the academic staff and the students using online distance learning platforms has shown some benefits on both sides - the academic staff, and the learners. Students who have continuous engagement with the instructors are more likely to share their views and give suggestions and recommendations to the e-content developers. These inputs are considered valuable for the e-content developers for further improvement of the learning content. Designing the e-content module is the focus for academic staff who are the content experts. There are several aspects that the academic staff who are the e-content developers should be aware of when designing the learning module. The online course or the e-content and materials should be designed based on the learners' objective, basic knowledge attained by the learners, skills, and habits of learners. Having this information will help the e-content developers who are the content experts in their field to design modules suitable for learners better.

As teaching practical techniques such as cell culture techniques normally require the face-to-face mode, producing a good quality video is considered crucial. A good quality video for teaching and learning purposes contributes to the establishment of student engagement during the learning process. Addition of subtitles in the video can be an advantage to help the students stay focused when watching the video of practical steps. The use of high-quality equipment during video-shooting and good software are helpful in producing a good quality teaching video, apart from being time and energy saving for academic staff to do the editing. Using good software will not only help developers in creating high-quality photographs of specimens and video for teaching and learning purposes but also save time for the developers. Apart from the visual aspect, application of audio by using

different voice tones during video or voice recording may make video more interesting. Using all sensory information during learning has shown to be more effective for students (Goudsouzian et al., 2018).

With the current advancement in technology, incorporating impactful artworks, illustrations and graphic designs in learning materials is the new approach and thought to be essential to facilitate the understanding, enhancing of knowledge transfer and retention, enhancing of student engagement, application of visual model-based reasoning and simplifying a complex concept to a more understandable way. Based on this concept, some faculties such as from medical science, applied science and microbiology have commenced a network and collaboration with the faculty of arts apart from the faculty of computer science in developing a more impactful and high-quality e-learning module (Gomes & Bogosyan, 2009). Incorporating artists' art touch has shown to give an impact on society by producing visually high impact images and artwork (Peña-Fernández et al., 2020). The interesting design may enhance student engagement towards e-learning modules.

Teaching practical skills is thought to be challenging and almost impossible in a traditional learning method. The idea of developing a virtual lab for online learning is seen as beneficial for students. As some experts view the online learning module may not be the substitute for the whole course content, the use of online learning materials such as virtual lab can be used as a supplemental aid in learning. To create a more effective learning environment, the learning objective and instructions of online learning particularly the virtual lab for practical skill, must be clear for students to understand. The virtual interphase plays an important role as good quality and artistic interphase will be more likely to encourage active learning. To make the learning more realistic, the content of the simulation must be based on real life problems, for example identifying the source of contamination in cell culture (whether it is caused by fungus or bacteria) and the next steps to be taken by the operator. Steps in aseptic technique before starting cell culture can also be simulated to ensure student competency. By identifying the cause of the problem, students may be able to apply the knowledge learnt from videos or content provided by the instructors. This learning process can be an initial step to be learned before commencing real cell culture experiments later during real practical sessions.

As some learners thought that virtual lab learning lacks physical interaction and inhibits social interaction as most of the time students will have to perform the virtual lab session on their own, introducing game approaches which involve multiplayers could be a way to solve this matter. By creating games, other users from any country can use the platform. This platform can serve as a social network for communication with other students through text-based, voice-based, or other interactions. Apart from that, this platform can also be used for learners to interact with their peers and teachers. At the same time, the teachers have the direct medium to observe the students' progress while they are on online distance learning mode.

CONCLUSION

Based on the review, it is concluded that teaching basic cell culture techniques via online distance learning platforms is possible in this current era. Determining the learning objectives and designing the e-learning content materials is crucial to ensure the suitability of the content to the learners. However, the online learning of cell culturing must also be accompanied by face-to-face sessions to ensure better understanding among students, and this can be done by blended or hybrid learning. In this case, collaborations between students, e-content developers or instructors, and the faculty or institution's involvement are deemed important in realising the plan to embark into blended learning for cell culture techniques for our undergraduates and postgraduate students.

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