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Exploring the use of virtual laboratory simulations before, during, and post COVID-19 recovery phase: An Animal Biotechnology case study

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Abstract

This study presents an evaluation of integrating virtual laboratory simulations in assessment design of a biotechnology course at Taylor's University in Malaysia before, during and post-COVID recovery phases. The purpose was to investigate how virtual laboratory simulations were integrated as part of the assessments of a practical-embedded course—the aim being to evaluate students' acceptance and perception of using virtual simulation. A total of 46 students, across three different study cohorts (August 2019, March 2020, and August 2020) were evaluated different educational aspects of using virtual laboratory cases in a 4-week course within Animal Biotechnology. Overall, students regarded virtual laboratory simulation useful as part of their learning, and there is a significant increase in the level of acceptance before, during and post-COVID recovery phases. The study showed that across the different study cohorts, students perceived their confidence level in laboratory skills have been enhanced and that they can apply the skills in real-life situation. Interestingly, students (March and August 2020 cohort) who have not been exposed to the related laboratory session still perceived that the simulated activity provides clear explanation and realistic experience. Furthermore, it had been highlighted across the study cohorts that the quiz questions helped to enhance their understanding on the underlying principles of the laboratory techniques. The overall conclusion of this study was that structured simulation-based activities which provide clear instructions and explanation would support significant improvements in students learning.

KEYWORDS

biotechnology, COVID-19, virtual laboratory simulation

1 | INTRODUCTION

Competency in a range of practical skills is an essential component for Biosciences students. Over the past few years, there has been an increased adoption of virtual simulations in teaching biology laboratory courses. Arizona State University (ASU) offered fully online biology degree course that uses virtual lab simulations instead of actual lab work. The Danish company Labster collaborated with Google Daydream to provide three-dimensional (3D) lab simulations for the course in ASU. There are increasing number of companies and institutions that develop lab-based virtual learning tools to supplement traditional practical sessions and provide a different kind of hands-on training for future scientists. Studies and literature have shown that virtual laboratory

tools were equally effective as traditional laboratories in increasing student knowledge and understanding, when evaluated by student performance in examinations.[1] They facilitate active, enquiry-based learning rather than the passive, protocol driven learning normally found in traditional laboratories, are low cost and enable students to learn in their own time and pace. Many studies have found little difference in learning outcomes between students who perform virtual lab experiments and those who have done the real lab work.[2,3] There are substantial educational benefits to be realized when high-quality virtual laboratory tools are fully integrated alongside traditional laboratory sessions within curricula, each complementing, reinforcing, and enhancing the learning from the other.[4] However, some studies have claimed that they do not provide hands-on experience of individual techniques or training in the use of individual items of equipment, health, and safety or promote awareness of ethical issues.[1]

Biotechnology undergraduates at Taylor's University Malaysia have been using Labster virtual simulations as part of their blended learning activities in 2019.[5] Aseptic cell culture and maintenance is an essential laboratory skill for students undertaking the Animal Biotechnology module where students are required to demonstrate competency in seeding and subculturing human cell lines. Labster virtual laboratory simulations on "Cell Culture Basics" was used as a supplementary learning activity for Animal Biotechnology module where it serves to prepare students for the lab, teaching them the techniques, skills, processes, protocols, and underlying principles. Students can learn from trial and error before reaching the physical lab. The COVID-19 pandemic and nationwide lockdown toward the middle of March 2020 however had significantly impacted students access to physical wet lab classes. In this instance, the role of virtual laboratory simulation had been transitioned from being a supplementary learning activity prior entering physical labs to one that was used as a replacement learning tool for the year 2020 study cohorts. Hence, this study aimed to evaluate the acceptance and perception of students across different study cohorts before (August 2019), during (March 2020), and post-COVID recovery (August 2020) phases for the use of Labster virtual laboratory simulation in the Animal Biotechnology module.

2 | METHODS

2.1 | Samples and module information

The study was conducted using three cohorts of students (August 2019, March 2020, and August 2020 semesters) that have undertaken the module "Animal Biotechnology." Comparison was made between 16 students in August 2019 cohort, 18 students in March 2020 cohort, and 12 students in August 2020 cohort. The module "Animal Biotechnology" is offered to second year Biotechnology undergraduates which introduce animal cell culture technique. Students taking this module will be prepared for future careers in cell tissue culture. Upon completing the module, students are expected to demonstrate techniques in animal cell culture including cell culture maintenance, primary culture, cells cytotoxicity testing as well as the ability to discuss principles and applications of animal cell culture.

2.2 | Design & development

At Taylor's University, assessments were designed in constructive alignment to the module and program learning outcomes—Taylor's Curriculum Framework (Figure 1). The Taylor's Curriculum Framework entails the focus on whole of program design, with specific emphasis on the modular level design and assessment, to ensure students develop and exhibit the Taylor's Graduate Capabilities. Due to COVID-19 and implementation of Movement Control Order (MCO) by the Malaysian government, all higher education campuses within the country were closed toward the mid of March 2020. Campuses were re-opened for essential teaching and learning activities in August 2020, before they were closed again in mid-October due to increasing number of COVID-19 cases and new infection clusters in the nation. In response to the pandemic and lockdown, the University and School have prepared a contingency framework which was used as a baseline for designing Teaching and learning delivery strategies and assessment plans. Hence, the assessment design for the module "Animal Biotechnology" have been revised for the 2020 study cohort (Figure 2). The lab skill assessment was replaced with a draft experimental design while the preparation of full laboratory report and completion of Labster virtual laboratory simulation remained.

2.3 | Implementation

The Labster "Cell Culture Basics" virtual lab simulation is an activity where students perform animal cell culture experiments in a virtual lab environment, and it incorporates multiple choice questions in between the activity for assessing students understanding on

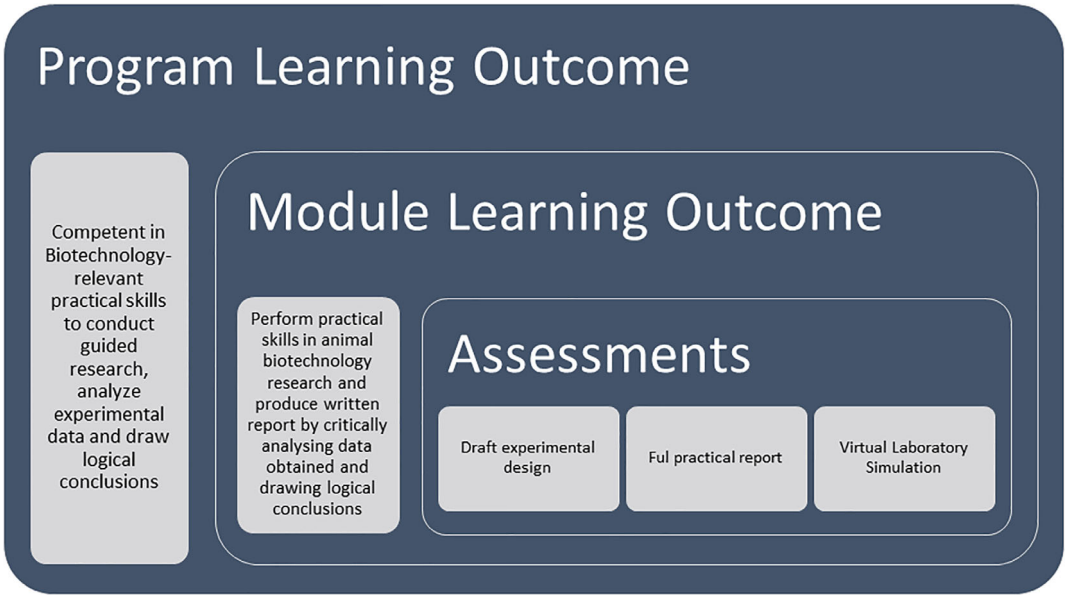

FIGURE 1 Constructive alignment of assessment design with module and program learning outcomes. In the Animal Biotechnology module, assessments were designed in alignment with the module learning outcomes that relate directly to the attainment of the desired learning outcomes

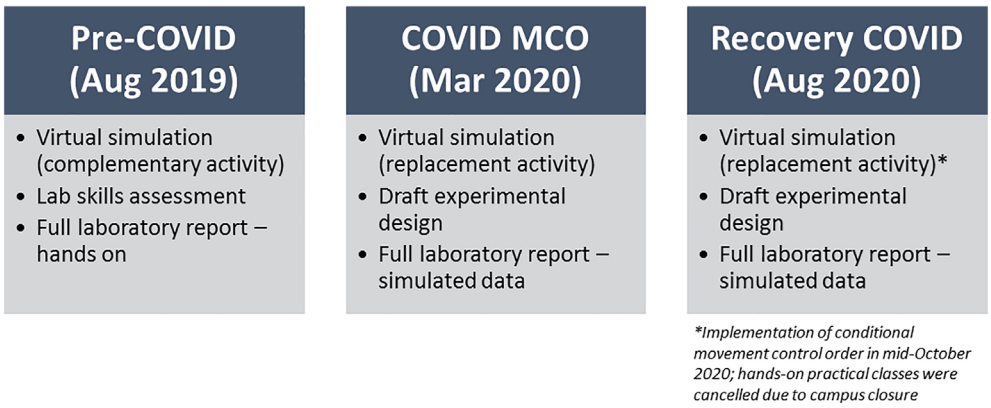

FIGURE 2 Animal Biotechnology module practical assessment design before, during and post COVID-19 recovery phase. Labster virtual simulation "Cell Culture Basics" was included as part of the module practical assessment components in August 2019, March, and August 2020 semesters. The role of virtual simulation transitioned from being a supplementary activity before hands-on practical session to a replacement activity which provides exposure of simulated laboratory environment in the 2020 study semesters. Scheduled practical sessions for the August 2020 semester was canceled due to implementation of conditional movement control order resulting from the second wave COVID-19 infections

the basic concepts and principles of animal cell culture. The virtual simulation was implemented as part of the summative assessment of practical component for the module in the fourth week of the semester. Students were required to complete a post-Labster survey after attempting the virtual simulation. Toward the tenth week of the semester, students would complete a teaching engagement survey for evaluating effectiveness of the overall module delivery.

2.4 | Data collection procedure

Data collection for both Labster and teaching engagement surveys were conducted throughout three semesters (August 2019, March 2020, and August 2020). Students were encouraged to fill out a questionnaire (Google form) evaluating their perception and acceptance from using lab simulation. Meanwhile, the teaching engagement survey was conducted through an online platform (tes.taylors.edu.my) evaluating module delivery.

3 | RESULTS

3.1 | Virtual laboratory simulation is beneficial—Enhances students' confidence level to apply the technical skills in real-life situation

Overall, students regarded the use of virtual laboratory simulation helpful as part of their learning. There is an increasing percentage of students (August 2019—56.3%; March 2020—61.1%; August 2020—66.7%) who have answered "Extremely Helpful" across the three study cohorts (see Supporting Information for details). The overall score for this question showed a rising trend from 2019 to 2020 (Figure 3). The positive perception on the use of virtual simulation may stem from three other questions: "How confident are you in your laboratory skills (cell culture aseptic technique) after completing the virtual lab simulation activity?," "How helpful were the quiz questions in the simulation activity in deepening your understanding about the topic?," and "I feel like I can apply what I learnt in the simulation to real life situation," which also showed an upward trend across the three study cohorts. Specifically, there is a significant increase in the percentage of students (August 2019—25%; March 2020—27.8%; August 2020—50%) who have indicated "Extremely confident" in their aseptic techniques.

3.2 | Interest for having more virtual simulation in teaching declined in early lockdown—Preference for hands-on practical

It is interesting to note that even though the 2020 cohorts have regarded the use of virtual simulation positively, there is a significant decline in the percentage of students who have answered "Completely Agree" to see more simulations to be used in teaching (August 2019—62.5%; March 2020—33.3%; August 2020—50%). Similar observation was noted for the question on "The gamified virtual lab simulation made me enjoy the learning process," where a plummeted score was recorded in the 2020 cohort compared to the previous year. The observation is notable especially during the early lockdown period in the March 2020 semester. In a follow-up interview, a student (March 2020) stated, "It is not as interesting as the normal methods" while another (August 2020) had indicated preference for hands-on laboratory experience.

3.3 | Valuable features of virtual laboratory simulation—Personalized, realistic animations, quizzes, and theoretical explanation

For the open-ended question on "Which aspects of Labster did you like?," three key themes were identified

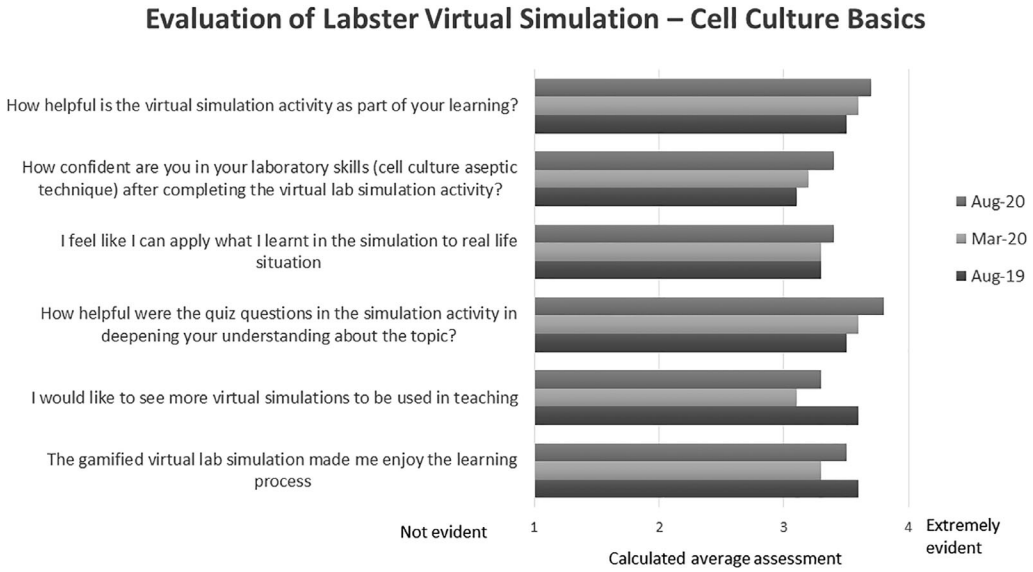

FIGURE 3 Analysis of students' perspectives on the use of virtual lab simulations before, during and post COVID-19 recovery phase. Students undertaking the Animal Biotechnology module completed a questionnaire survey (on a scale of 1–4) in relation to their perception and acceptance after completing the virtual simulation activity. Total student evaluation respondent rate was 84% (16/19), 100% (18/18), and 80% (12/15) for August 2019, March 2020, and August 2020 cohorts, respectively

from the students' responses, as outlined in Table 1. Overall, students have regarded the use of using virtual laboratory simulations as a personalized learning experience. Majority have expressed comments such as the ability to repeat the experiments until they fully understood the concepts, practicing specific steps for multiple times, and performing the experiments at their own pace. In addition, many have commented that the graphics and animations were realistic, gamified, and depicted as real-life scenario cases. More notably, students have commended on the advantages of having quizzes that are embedded within the simulation, coupled with the theoretical explanation which helped to deepen their understanding about the topic on aseptic cell culture.

3.4 | Achievement of module learning outcomes (teaching engagement survey)

Overall students in separate cohorts across the study semesters (August 2019, March 2020, and August 2020) have regarded that the learning outcomes for the module have been achieved, and that they are able to monitor their learning progress through assessments (Figure 4). The evaluation indicated the allocated assessments were in line with the module learning outcomes, and that students learning progress was not impacted despite of the pandemic and lockdown.

TABLE 1 Themes emerged from the free text comments

Themes emerged from the free text comments
Ability to repeat experiments (own place)
Realistic simulation (graphics)
Quizzes and theoretical explanation

4 | DISCUSSION

Due to the COVID-19 pandemic and nationwide lockdown, academic institutions had to close their doors and move their academic offerings online. The rapidly evolving situation was challenging for the faculty to plan and adapt for courses with laboratory practical classes. Virtual laboratory simulations became exceptionally useful during the pandemic lockdown as the simulations enabled laboratory courses to move online. In fact, virtual laboratory simulations have been used in many instances before COVID-19. Many research findings evaluated the roles of virtual laboratory simulation for educational use. There are studies indicating that the use of virtual laboratory simulation for chemical and biotechnical science students contributed to increased study intensity and motivation.[6] Others have shown that virtual simulation increased simulation realism in the radiology and laboratory departments.[7] Meanwhile, some research highlighted the essential need for hands-on lab exposure. It was shown that virtual activities are not as effective as hands-on practical, but they are successful strategies in physiology learning that can be used in practical classes in a hybrid problem-based learning curriculum.[8]

At Taylor's University Malaysia, students in the School of Biosciences are exposed to Labster virtual simulations before COVID-19. The use of virtual simulations had taken center stage during this period as students and faculty have no access to laboratory facilities. This study evaluated the perception and acceptance of virtual

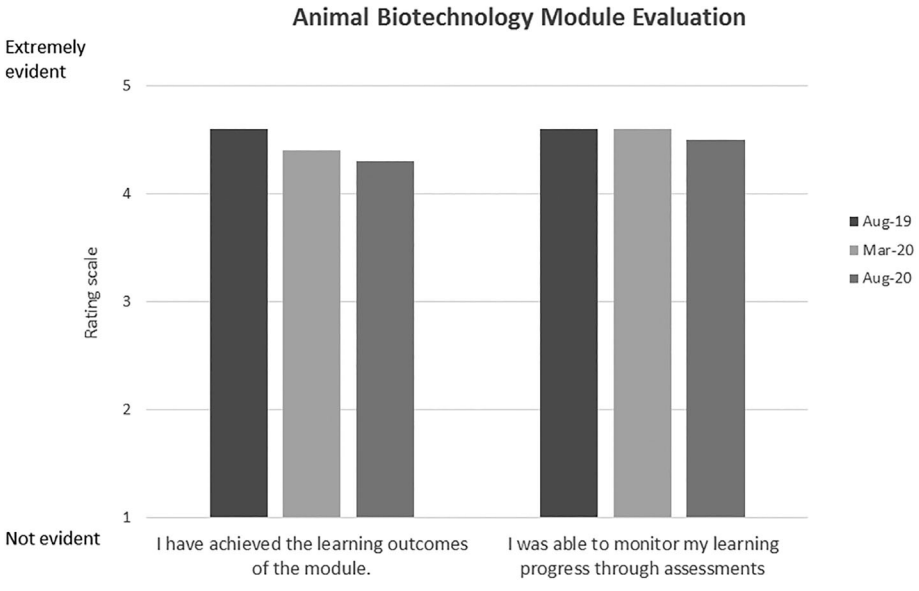

FIGURE 4 Overall students' evaluation on module assessments and learning outcomes attainment. Students completed a teaching engagement survey (TES) toward the end of the semester for evaluation about the teaching and learning as well as module core questions. Total student evaluation respondent rate was 95% (18/19), 67% (12/18), and 93% (14/15) for August 2019, March 2020, and August 2020 cohorts, respectively

laboratory simulation among Biotechnology undergraduate students across three different study cohorts before COVID (August 2019), during COVID lockdown (March 2020), and post COVID-recovery phase (August 2020) in the Animal Biotechnology module. The findings from this research showed that students regarded the use of virtual laboratory simulations—Labster Cell Culture Basics Simulation positively across the three study cohorts, despite some not being exposed to the real hands-on practical session (for March and August 2020 cohorts). The analysis showed that increasing percentage of students have enhanced confidence level in their techniques and they felt it can be applied in real-life situation. Similar observations were noted in other studies, indicating that repeated simulation experience enhances nurses and nursing students' self-confidence and competence.[9]

The main features that were highlighted to be valuable within the Labster Cell Culture Basic simulation include the ability to repeat experiments, realistic simulation, and quizzes with theoretical explanation. The virtual laboratory simulations use gamification and storytelling approaches to engage students in a case study-based scenario. It provides students a simulated version of the lab environment, teaching them the processes and underlying principles which allow them to engage in an active, visual learning context. Furthermore, students can learn at their own pace, and in their own time where they get to perform the experiments multiple times without constraints or restrictions for access to real facilities. The findings were in line with other studies evaluating the educational use of virtual laboratory simulations for biotechnical science students. They have shown that students can connect theory with practice and to visualize molecular processes as well as practical laboratory procedures and instrument techniques.[6]

It is interesting to note that even though students have positive perception toward the use of virtual simulations across the three study cohorts, there is significant decline in the interest for incorporating more virtual simulations as part of students learning. This phenomenon is particularly evident for the study cohort that have experienced the first lockdown in March 2020. The findings showed significantly lower enjoyable experience in the March 2020 cohorts compared to the August 2019 batch. The fully online learning environment in the 2020 cohorts may have resulted in an overwhelming experience for majority of the students who must cope with fear and anxiety during the pandemic. Studies have shown that university undergraduates are vulnerable as they face strict lockdown measures and have limited resources to cope with it.[10] It is notable that some students are living away from home the family home, some may have poor or limited housing conditions and some even have seen relatives become ill or die from COVID-19. The August 2020 cohort on the other hand have recorded a better score in terms of both the desire of incorporating more simulations and an enjoyable experience compared to March 2020, albeit lower than August 2019 cohort. It could be contributed by the more relaxed restrictions and re-opening of the campuses in August 2020.

In summary, students have regarded the use of Labster Cell Culture Basics simulation positively across the study cohorts, before and during the COVID-19 pandemic lockdown. The positive perception is in line with the achievement of module learning outcomes. Moving forward it is undeniable that virtual laboratory simulations will continue to play important roles in courses with laboratory classes owing to intermittent lockdowns and evolving infectious strains that may restrict full access to physical laboratory facilities. Our study indicated that structured laboratory simulations that contain realistic cases and animations, coupled with theoretical explanations are helpful in facilitating the acquisition of the techniques and underlying principles.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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