Learning Practical and Research Skills through Emergency Remote Learning (ERL): Insights from Life Science Programs in Malaysian universities during the Covid-19 pandemic

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Received: 10 August 2022; Accepted: 22 December 2022

Abstract
The COVID-19 pandemic has brought unprecedented disruptions to higher education by forcing campuses to close, thus shifting teaching and learning (T&L) activities to emergency remote learning (ERL). Higher learning institutions (HLI) in Malaysia were not spared, whereby ERL has become the dominant mode of T&L since March 2020. The field of life sciences faces additional challenges in ERL that remain underexplored, especially in the context of HLI in Malaysia, which is highly centralized and with limited institutional autonomy. Using equity theory as a framework and qualitative data gathered through interviews and focus group discussions, this paper aims to understand the impact of ERL by outlining the challenges faced and innovations devised to circumvent these in the development of practical skills and conducting research projects, which are seen as critical aspects of life sciences programs. Finally, we discuss ways to improve equity and quality of life science education by raising critical questions as the world continues to grapple with new waves of pandemic uncertainty.

Keywords: COVID-19, Emergency Remote Learning, Life Science, Outcomes-based Education, Equity

Introduction

In Southeast Asia, an upper-middle-income economy with a multi-ethnic and multi-lingual society, Malaysia's higher education system is fairly developed with 1.2 million students and 43% of gross enrolment across equally sizeable public and private higher learning institutions (HLI) in 2019 (*Higher Education Statistics 2019*, 2020). Unlike in most other countries, higher education in Malaysia is heavily centralized. The minister and ministry overseeing this portfolio have a substantial and direct influence on HLIs, and a slight change in the ruling government may significantly alter the governance of institutions (Sirat *et al.,* 2012; Wan, 2019). Parallel to this, all tertiary programs offered with accreditation from the Malaysian Qualifications Agency (MQA) follow the

Malaysian Qualifications Framework (MQF) and the Outcome-based Education (OBE) approach which is a rigidly implemented and auditable requirement (Kaliannan & Chandran, 2012).

When the coronavirus disease 2019 (COVID-19) pandemic slammed the globe in the first quarter of 2020 (Hu *et al.,* 2020), there were unprecedented disruptions to every facet of the economy, society, and education. But in addition to the COVID-19 pandemic, HLIs in Malaysia also grappled with the ramifications of a political crisis resulting in the collapse of the ruling coalition and a new government sworn in on 1 March 2020 (Saravanamuttu, 2021). Overnight, Malaysian HLIs migrated from being under the purview of the Ministry of Education (also covering primary and secondary education) to the re-established Ministry of Higher Education and a newly appointed minister. Arising from an emergency movement control order or 'lockdown,' campuses were forced to shut down, in part following Ministry directives abruptly, and a fundamental dilemma was how to proceed with teaching and learning (T&L) activities and meeting OBE requirements while grappling with uncertainties and changing restrictions related to the pandemic. The closure of campus and the logistical challenge of transporting students back to hometowns became a significant disruption on its own, as most larger public and private HLIs are concentrated in urban cities of Peninsular Malaysia, but students living on campus would often come from smaller or rural towns, including from remote areas in Sabah and Sarawak on the island of Borneo as reported by the Malay Mail ("MCO: Tertiary Students Grateful for Chance to Return Home," 2020; *Soalan Lazim (FAQ) Mengenai Perintah Kawalan Pergerakan Kementerian Pengajian Tinggi (KPT) Bilangan 5*, 2020).

Nonetheless, a 'simple' solution was to move activities online, as many universities had already established online platforms to enable 'blended' learning, i.e., a hybrid teaching methodology combining e-learning with traditional classroom methods (Nuruzzaman, 2016). Prior to the lockdown, many HLIs incorporated 'blended' learning, but uptake remained low and ambiguously characterized (Torrisi-Steele & Drew, 2013). Indeed, traditional delivery was replaced by unplanned and ad-hoc emergency remote learning (ERL) for more than two-thirds of HLIs worldwide (Hodges *et al.,* 2020; Marinoni *et al*., 2020). In true emergency fashion, all available resources were utilized. The migration of all T&L activities and communication online expanded beyond the established official university platforms to include Google Meet, Webex, Zoom, as well as communication via social media applications such as WhatsApp and Telegram. While the ability to transfer pedagogies overnight suggests flexibility that has long been absent in HLI, the sudden shift posed significant challenges related to technical infrastructure, competencies, pedagogies, and specific fields of study. Critically, while the transition to online learning appeared to have 'saved' the curriculum and academic calendars for many HLIs, the rapid, forced, and total technological reliance on T&L has undeniably widened existing digital gaps across university communities (García-Peñalvo, 2021). Importantly, where previously staff and students could rely on basic infrastructure and learning environments provided within the campus, varying access to stable and affordable internet and diverse home environments rapidly became sources of inequity for university education under ERL (Hamid & Khalidi, 2020; Salmi & Bassett, 2014).

The equity theory has several articulations, but of most relevance in the context of education are ideas related to fairness and inclusion (OECD (Oversea Economic Congress Development), 2012). Fairness in education inherently implies that personal or socio-economic circumstances do not only hamper individual learning experiences (Field *et al.*, 2007; Lynch & Baker, 2016). Still, it may further extend to perception of justice, such as a balance of input or effort (from the student, but also from the lecturers) versus output and outcomes, which can range from academic performance in specific courses to employment opportunities upon graduation, overall satisfaction and wellbeing (Lai *et al.*, 2014; Salmi & Bassett, 2014; Zeng *et al.*, 2019). More, as ERL became the default mode, new equity dimensions emerged, such as connectivity and access to gadgets to support this new form of learning. Inclusion, on the other hand, implies that all students that undergo the learning process would reach a common and basic level of skills relevant to the field of study (Field *et al.*, 2007). The COVID-19 pandemic and the ERL introduced to mitigate threats to public health have raised several pertinent questions regarding equity in higher education which have been extensively described. The literature includes discussions related to academic staff managerialism, de-professionalization, and overstretching labor and pedagogical responsibilities (Ma *et al.,* 2021), as well as student socio-economic circumstances, barriers from the language of instruction, and juggling of competing priorities (Ezra *et al.,* 2021), on top of inequities in infrastructure and digital connectivity for everyone involved in ERL (Díaz, 2021; Idris, 2021).

Regardless of general challenges across various disciplines, it remains unclear to what extent life science programs can adapt curriculum and pedagogy to ensure equity under the ERL context. Most life science programs, including those in Malaysia, require the development of practical skills through laboratory or fieldwork modules and the undertaking of a final year project that combines aspects of practical skills with guided independent scientific inquiry culminating in a thesis and *viva voce*, which confers an honors degree (Yousefi *et al.*, 2020). Due to the expected difficulties in adapting practical skills and research training to ERL platforms which primarily occurred in an ad hoc manner, life science programs in Malaysia entered unchartered territory where the onus and power of determining the pedagogy of these core elements were passed entirely to individual course coordinators and lecturers (Al-haimi *et al*., 2019), who also grappled with their circumstances and the diverse circumstances of their students. Thus, while pedagogical and learning variation occurred under in-person learning during pre-pandemic times, the sudden switch to ERL only increased variability in the T&L experience and consequently precipitated any existing inequities. More importantly, in what ways and to what extent practical skills and research training, which are essential components of life science programs, were developed under ERL circumstances?

With this question in mind, we document and explore in-depth pertinent nuances of the development of practical and research skills through ERL implementation in life science programs from the perspective of equity to learning. This discussion provides insights to inform and guide future educational practices to minimize inequity as higher education continues to resume under pandemic-related uncertainties in developing essential aspects of life science education programs.

Methodology

We conducted a qualitative analysis of evidence accrued from in-depth interviews and focus group discussions and guided by an overarching question, "What are the data telling us?" (Srivastava *et al.*, 2009), we take an interpretivist paradigm allowing students and academics through empirical evidence to illustrate and illuminate the challenges and practices (Corbin & Strauss, 2008). Using three case studies of biotechnology programs in a public research university, comprehensive public university, and a private university, framed to examine the relevance and currency of curriculum of biotechnology programs, specifically in terms of the content and syllabus, teaching practices and incorporation of recent research, technologies, and issues in the discipline of biotechnology (Stake, 2013). However, as the study coincided with the pandemic, ERL became a major topic of discussion. Using a purposive sampling method, we obtained verbal responses from 16 academics (including program coordinators and four policymakers) and 21 undergraduate students from selected private and public HLI with biotechnology programs, using semi-structured interviews lasting 1 to 1.5 hours in length via an online platform. All qualitative data were obtained between July 2020 and September 2021 with informed consent and institutional ethics approval (USM/JEPeM/19030171). Digitally recorded and transcribed interviews together with written responses were thematically coded to identify themes (Corbin & Strauss, 2008; Stake, 2013). While the interviews have a much broader focus on the relevance and currency of the curriculum, for the purpose of this paper, we zoomed specifically into the data bits related to practical skills and development of research capability project during the ERL for students in these life science programs. Guided by the principle of constant comparison method, data bits referred to similar aspect of ERL were grouped as a theme, but at the same time, allowing for subtle and nuanced differences across data bits within the same theme. Four themes emerged from the analysis concerning ERL with the participants: (i) the development of practical skills, including from routine laboratory sessions or fieldwork activities, (ii) the final year project as the epitome training of research skills in the program, (iii) issue of assessment of practical skills and research capability, and (iv) internship as an opportunity to develop real-life practical skills.

Results and Discussion

Based on analysis of interview transcripts and analysis, we elaborate thematic findings in the context of practical skills training and realization of the final year research project below.

Practical Skills Training: Laboratory and Fieldwork

Studying remotely was the most significant barrier in the delivery of otherwise routine laboratory or fieldwork activities. Although some aspects of the application, problem-solving, and scientific thinking could be introduced, there was consensus that psychomotor training or fieldwork experience for most courses appeared impossible to achieve through ERL. As one head of department noted:

> *"[No matter] how many YouTube videos or demonstration videos you watch, you simply cannot achieve that same level of outcome or learning outcome at the end of a practical [session]…. The best strategy is still to get the students back [on campus, but] in smaller batches."* (Academic A02)

Some instructors were able to arrange for an intensive short series of practical sessions for their courses, scheduled to accommodate small batches of students, which contrasted with pre-pandemic norms that often had up to 100 students per session, limited only by sheer space capacity. Thus, paradoxically, despite the pressures of compressed laboratory sessions, mask-wearing and social distancing requirements, several respondents found this situation more favorable than pre-pandemic laboratory sessions. Nevertheless, the variation in the implementation of small group sessions across different courses became a clear source of perceptions of inequity amongst students. On the one hand, some students lamented the heavy workload that came with undergoing compressed laboratory sessions as well as the cost of accommodation, travel and living expenses to return to campus for only a limited number of laboratory sessions; on the other hand, other students who were not provided such an arrangement expressed feeling short-changed with alternative assignments and missing crucial hands-on training.

In cases where it was not feasible for planned practical sessions to be conducted in person, students reported benefiting from performing 'hands-on' practical assignments designed by instructors, which could be feasibly completed at home. Some instructors went as far as mailing simple kits or foldscopes that enabled students to perform experiments at home or the dormitory, while others designed tasks that utilized everyday household items that could be conducted in a typical living environment. Where the hands-on activities were not able to be simplified or performed remotely, such as was the case with practical sessions that required the use of specialized apparatus or reagents, the use of instructive videos and step-by-step tutorials were found to be valuable learning resources to expose students with different laboratory/field techniques (Donkin *et al.,* 2019).

While pandemic restrictions hampered the delivery of standard laboratory and field-based practical training, it also encouraged some creativity in the interpretation and design of 'practical' assignments that may be beneficial to maintain post-pandemic. Examples included replacement assignments such as analyzing the movie 'Contagion' using concepts in microbial genetics and organizing an online fundraiser in collaboration with local NGOs (Non-Governmental Organizations) for a course in wildlife conservation. But while students often received these 'creative' assignments, instructors noted challenges in devising appropriate marking schemes that were fair yet flexible. As one lecturer for a course in microbial genetics pointed out:

> "*It was challenging for me to come up with a rubric for these different assignments to encourage creativity but be able to grade it in such a way that meets structured vetting requirements.*" (Academic AS02)

In addition, adeptness at using digital technologies became a source of disparity that significantly influenced pedagogy in ERL. As noted by one senior academic, the more 'creative' assignments and tasks that utilized different online or home-based resources to adapt to ERL delivery while trying to achieve intended outcomes of life science practical training often came from younger lecturers who were trained to use tools and techniques for blended learning as part of more recent training for new academics. In contrast, more senior lecturers who did not have such training and exposure tended to stick to more traditional tools and pedagogical methods that

may be less engaging when delivered through online platforms (Deslauriers *et al*., 2019; Rajesh Shah & Udgaonkar, 2018).

Despite innovative alternatives, the overwhelming response from both lecturers and students strongly suggested that there is no complete replacement of practical components in a course, especially for achieving essential psychomotor outcomes and laboratory-based skills. Notably, one academic raised concern over an apparent cohort-related inequity whereby:

> "…*the pandemic cohort would have less exposure in doing lab work, [and] they lose out there. Lab [training] is the core and backbone to the course.* "(Academic AS04)

This sentiment and perception of disadvantage at undertaking training in life sciences under ERL were echoed by students, such as one final year student in Biotechnology who expressed concerns about their employability in the future as:

> *"… the high-skill worker is sought after, and this online learning cannot enhance my technical skill*." (Student B07S01).

However, one of the ways suggested to mitigate this issue was for the provision of catch-up technique-based open laboratory sessions once safe to do so (e.g., PCR, gel electrophoresis, microbial culture) to provide second chances for students who missed on learning specific techniques in-person during the pandemic, especially those who would need such training to conduct their final year project.

Research Project: Final Year Project

The Final Year / Research Projects provide crucial exposure and training for students to conduct guided research during their undergraduate studies, with a dissertation/thesis as part of the fulfilment of their honors bachelor's degree. From initial contact with respective supervisors to the thesis defence, students engage in planning, literature review, proposal drafting, conducting experiments, collecting, organizing, and analyzing data, and communicating their findings in writing and through a presentation. Fittingly, when pandemic restrictions began to ease, the priority to return to campus was given to final year students undertaking research projects, particularly those who required access to laboratories. Nevertheless, despite permission to return to campus and perform experiments or fieldwork, disruptions to research progress were inevitable in the times of the COVID-19 pandemic. For instance, restrictions that limited in-person interactions and guidance between student and mentor/supervisor reduced the efficiency of the learning experience. At the same time, the unpredictable closure of laboratories forced timelines to be pushed back or even project titles to be changed. Besides constraints in access to laboratories, fieldwork was significantly affected due to interstate and inter-district travel limitations, travel distance, and several passengers in transport vehicles.

Before the COVID-19 pandemic, students conducting their final year project not only could rely on guidance from postgraduates or supervisors from their research group, but most students also working in a laboratory could rely on assistance from any other students or staff present in the laboratory. But with density limits and

scheduling requirements due to the COVID-19 restrictions, many students were left working alone and thus more susceptible to committing experimental errors, which posed additional setbacks to research progress. Nevertheless, while in-person interactions were limited, some postgraduate students or supervisors were able to set up online meetings while the student conducted their experiment and made themselves available via text messaging platforms during that time if any questions arose. For example, one student noted:

> *"…[they were able to be guided by a*] *senior who's doing research in a similar topic with mine, but he's in (a different campus), so he helped me by giving me (verbal guidance) when it comes to lab work so that I mess up less and waste less [sic] chemicals*." (Student SI01)

As barriers to access laboratory and fieldwork were expected, many final year students in the second cohort conducting projects amid the pandemic were encouraged to go for hybrid research topics, which allowed students to partially conduct their experiments at home or research topics that required more analytical and computational skills rather than laboratory or fieldwork. The latter also included surveys and questionnaires, as well as bioinformatics analysis of secondary data in which students were still able to learn analytical and computational skills that are crucial in any scientific research, albeit not necessarily of primary interest. Many students who experienced conducting research projects during the ERL were primarily dissatisfied with the quality and value of their experience, not necessarily related to the research outcomes but due to constant changes from challenging to foresee circumstances. As one final-year student noted:

> *"There were a lot of approvals needed to do the fieldwork. By the time it was March, there was no seagrass left for me to sample. So, I could not continue (with) the same project. (Instead,) my supervisor gave me a new topic which was easier (to conduct during the pandemic) but I had no interest in it."* (Student SI02)

Assessment

Typically, assessments for courses in a Malaysian science program comprised timed invigilated final examinations with up to 50-60% weightage, while the remaining 'continuous assessments' comprised laboratory reports, a variety of assignments, quizzes, and tests. Grading was the sole responsibility of the lecturer who assigned the assessment, even for classes that are 80 – 130 students in size. It was typical for written coursework such as laboratory reports to be assigned in groups to manage grading burden, and feedback on individual assignments were rarely provided.

With the pandemic preventing safe gathering of students in examination halls, many courses removed final examinations entirely, or replacing it with additional assignments or an open book examination or conducted timed exams online but with reduced weightage. This significantly increased course workload throughout the semester with poor understanding of the impact on lecturer preparation and student learning time. Additionally, due to a need for alternative assignments, lecturers were expected to devise a variety of grading rubrics which were not the norm previously.

> *It was challenging for me to produce a rubric for these different assignments to encourage creativity but be able to grade it in such a way that meets structured vetting requirements. I also opened office hours every week to discuss with students and get feedback on what they thought about the assessments. It encouraged them to read up more on topics related to the tests. Those sessions were always informal and a safe space.* (Academic AS02)

There were also several limitations when conducting timed examinations online as the structure and format were more rigid than previous paper-based exams. Internet connectivity and other technical issues added to anxiety to students, while the fact that invigilation was near impossible except using very rigid e-proctoring systems which also were susceptible to technical issues, meant that plagiarism or various forms of cheating could not be effectively addressed during the examination and instead had to be prevented through design of questions.

> *For finals...many things needed to be taken in consideration. I do not like questions where students must write a long answer. I like it when they draw something like the set-up of an experiment. But online we had to structure it a certain way which made the questions easier. I wish I would have been able to ask things differently. If we were to produce questions that were a bit simple, students may open the books and that is how they would answer the question. On a personal note, that does not matter to me because we open books to find an answer. But we ended up making it very applied for my questions. It is not something they can copy and paste from the slides.* (Academic AS02)

> *Many students have abused the 45 mins buffer time to continue writing their papers and lecturers have no way to trace these fraud activities [sic] ... This is extremely unfair to students who stopped writing when the scheduled time is up.* (Student S310)

Despite a heavier workload due to increased weightage of continuous assessments under emergency remote learning, students responded more positively when they received individual feedback on assignments. Due to large class sizes and tight timelines, this was not commonly practiced. However, the importance of receiving feedback was a common theme across several respondents (Ahea *et al.*, 2016), suggesting that additional resources to train and hire assistants to assist in grading for courses with large class sizes should be seriously considered.

> *She is also the only lecturer, by far, who is willing to give feedback on every one of us, where there was almost 80++ of us for our assignment. I felt so appreciated like never before…It is understandable that given with a large group of students, it is such a hassle to give detailed feedback [sic], yet she is willing to spend her time just to wrote us an individual feedbacks [sic], which really makes me feel so overwhelmed and happy.* (Student S31)

> *[Name redacted] will feedback to us [sic] regarding our test answers so that we can know what we did wrong. He also held a virtual class during our study week to teach us how to answer correctly in final exam. I really appreciate his effort. Marking schemes and correct answers being feedback to students are important for students to learn from mistakes.* (Student S61)

Students were more positive towards having open book online exams compared to proctored timed exams as was the pre-pandemic norm. They felt that the open book exams enhanced their understanding rather than relying on rote memorization (Green *et al.*, 2016; Williams & Wong, 2009).

> *I suggest the exams done online should be open book concept with limited time as it will allow the students to refer and make effort to understand the important lesson in a course through the examination. With the world we are living today, everything is on our fingertip [sic]. In future, if we want to know anything we will look out using the digital platform then trying to recall what we learned. Those days exams make sense because we have limited resources to refer if we need to do something. We had to have knowledge in our head. Now what needs to be emphasized is the experience. We need to be able to allow students to experience things more than memorising everything.* (Student S74)

> *The one positive aspect that I like that can be kept is the interesting way to carry out the final assessment [examination]. It is no longer just memorize everything and go into a 'verbal diarrhea.' The online assessments are more relevant to [future] work [settings] because it is based on case study. We are required to do a bit more analysis, a little research here and there. I like [online assessments] as compared to [written examination where we] sit down, 'eat the book' and 'throw into the paper' [sic] straight away.* (Student C801)

Internship

With the intention to increase employability after graduation, internship has increasingly become a major part of the undergraduate program. The structure of internships varied by program, with some placing the internship as a module during the long break between academic sessions, and others placing internship as industrial attachment for the entire final semester. Interestingly, in one of the three case studies, which the university adopts the principle of being a praxis university, students have three internship/industrial attachment stints throughout its program.

A major challenge to internship and industrial attachment during the pandemic situation was the restriction of movement and closure of economic sectors that were deemed as non-essentials. Early in the pandemic, where all economic sectors were closed, the internship and industrial attachment of students were severely affected. Equally affected for students who have planned to do their internship and industrial attachment abroad, as international travel was halted.

> *So, we have a lot of students who do industrial training outside of Malaysia, we have many of them in our program doing industrial training outside of Malaysia … they were affected.* (Academic A04)

While the disruption on internship and industrial attachment was unavoidable, the flexible structure of this component in the curriculum has shown to be a good practice. Instead of designing internship and industrial attachment as a mandatory component for graduation within a fixed duration in the curriculum, such as the final semester, the practice of allowing multiple internships and/or allowing students to

decide when to include this into their learning journey demonstrated the flexibility to support achieving this component of the curriculum amidst the emergency online learning.

> *We really emphasize on practical training and giving a lot of hands-on [experiences to our students]. Industrial experience prior to graduation, when our students graduate, their CV (Curriculum Vitae) would have at least three different working environments.* (Academic A01)

As the academic further explained, students in the programme can decide for themselves which industry they would be interested across the three different attachment stints. For instance, a student can choose to be attached to a pharmaceutical company, industrial laboratory, and an academic research institute as their end-of-year internship. Such flexible arrangement, particularly in the pandemic situation, is helpful and supportive for the students as there is much more room for them to adjust and change the internship attachment according to the situation and job nature of the attached entity.

Overall Findings Learning Practical and Research Skills through ERL

Using a thematic analytical approach of qualitative data from interview-based case studies, we attempted to formulate a better understanding of the impact of ERL implementation in life science programs from the perspective of equity to learning practical and research skills.

The laboratory and fieldwork components are seen as essential throughout the educational processes of life science programs as mentioned by Shana and Abulibdeh (2020) for three main reasons: 1) as hands-on skillset training to familiarize with the use of specific tools and techniques, 2) opportunity to apply theoretical knowledge by observing, recording, and analyzing 'real' data, and 3) development of problem-solving mindset using scientific methods. Subsequently, students are prepared for independent scientific inquiry, troubleshooting skills, and scientific communication through a written dissertation and an oral presentation through a research project conducted in the final year. The research project is seen as an opportunity to bridge the gap between theoretical knowledge and hands-on practical skills in a specific life science discipline. Still, more importantly, for accreditation purposes, it is often the only component capable of providing outcomes of higher-order cognitive, psychomotor, and affective skills in a program designed to align with the MQF and OBE (Mohayidin *et al.*, 2008).

Through discussion with academics and students undergoing life science programs in Malaysia during the COVID-19 pandemic, we documented widespread frustration and concern pertaining to the absence or modification of laboratory and fieldwork modules within limitations of ERL, as well as challenges in fulfilling a research project, which would otherwise be the 'pinnacle' of a four-year science degree with honors. In this regard, inequity emerges on multiple fronts, first, between cohorts of the same life science program; second, between different courses subjected to diverse ad hoc adaptations of the curriculum, limited by varying levels of course-specific adaptability to ERL; and third, between individuals in the T&L process who face varying circumstances after being removed from the security of a campus-based learning environment and infrastructure.

As in-person practical training sessions were not feasible due to pandemic-related restrictions, course instructors were forced to think and act beyond their comfort zone and often beyond their usual job scopes, becoming designers of virtual games or videographers for their online tutorials. Due to the slow uptake of online learning prior to the pandemic (Torrisi-Steele & Drew, 2013), there was a clear gap between the academics with proficiency to use and adopt various online resources and academics who struggled to fulfil ERL beyond primary usage of online platforms such as uploading slide decks. Consequently, inequity related to the use of technology as a T&L resource became omnipresent, and students are at the brunt of this pedagogical divide. The inequity is two-fold whereby students would perceive the presence or lack of innovative and 'quality' pedagogy when comparing one course to another or comparing with their peers, as well as experience limitations in their ability to participate in online activities devised due to costs and challenges in accessing stable internet connection and technological gadgets (Hamid & Khalidi, 2020; Journell, 2007).

Furthermore, lecturers grappled with determining a fair workload for assignments to replace the higher weighted laboratory-based assessment and ensuring proper yet flexible grading of some less conventional assignments. The workload for courses with significant laboratory or fieldwork components was notably significantly higher for the pandemic cohort, yet, both students and lecturers felt there was undertraining of various discipline-related skills, which may have affected future employability. Typically, laboratory and fieldwork components are considered means of achieving specific 'psychomotor' skills outlined as part of more considerable program outcomes promised under an OBE framework (Mohayidin *et al.*, 2008; Nasrallah, 2014) and often are tied to particular assessments to evaluate students' technical skills are trained in. For example, a typical medical microbiology laboratory practical requiring students to culture, isolate, and identify different pathogenic bacteria from a mixed bacterial culture provides training in aseptic techniques, use of personal protective equipment and tools such as micropipettes, preparation of various media and reagents, performing different microbiological methods, and interpreting these results using available references. While students often work in pairs or small groups following a set of protocols that should deliver expected results, no two experiments are ever the same. Different students may experience real-life challenges such as procedural errors or contamination, resulting in unexpected or unclear results. These deviations from expected results, which not only require repetition and troubleshooting but critical thinking in describing and explaining the obtained results, is the most instructive part of a laboratory practical (Haritani *et al.*, 2019).

Thus, one pertinent ramification of the ERL may be the realization that life science training in Malaysian HLIs has overemphasized graduate value as equivalent to their level of specific technical skills while ironically separating these practical aspects from the theory through a heavily examination-oriented curriculum. Students are typically taught in lectures on how to conduct a textbook experiment, but the variables of conditions that may affect the outcome are rarely discussed or addressed in detail. This leaves students jarringly disconnected from the realities of 'real-world' experimentation due to failure to cultivate critical thinking skills among students who feel painfully unprepared without experiencing laboratory or field practical training during ERL (Fadhlullah & Ahmad, 2017).

But the living world is full of errors and unpredictable changes. The textbook experiment is exactly that, the one experiment that finally succeeded to be immortalized in a book after the 99 previous iterations failed. But the failure is the learning opportunity. Our science teaching needs to evolve from imprinting what a successful experiment looks like to training students to develop a mindset on how to improve on failed experiments. The beauty of such an approach is that it may not even require stepping foot into a laboratory or going into a mangrove. It is interesting to reflect that a job that requires extremely high technical skills, such as airline aviation, is trained in simulators that give cadets exposure to the worst-case scenarios (Lateef, 2010). The hands-on training to fly the actual plane occurs as part of the job, with experience gauged in-flight hours accrued. Thus, rather than maintaining the status quo of developing theoretical and practical skills as separate albeit related arms of life science education, the findings of this study suggests that a simulation approach, which better represents the complex relationship between theory and practice (Lateef, 2010), may reduce the disadvantages and inequities that arise from ad hoc attempts to deliver traditional practical and research training under pandemic restrictions. Encouragingly, evidence from a recent meta-analysis of simulation-based learning in higher education suggests that this approach may not only be suitable for ERL but may be a positive evolution of life science education in general due to effectiveness in facilitating learning of complex skills and flexibility in supporting different types of learners through various technologies and scaffolding (Chernikova *et al.*, 2020; Díaz-Guio *et al.,* 2021). However, even within the scope of simulation literature for life science education, there appears to be more focus on using gamification and virtual tools for the development of practical and experimental skills (Bonde *et al.,* 2014; Stahre Wästberg *et al.,* 2019; Yap *et al.,* 2021), rather than the development of a scientific troubleshooting mindset akin to the decision-making simulations more commonly scene in medical education (Meguerdichian *et al.,* 2021).

Incidentally, inequity in ERL for life science programs in Malaysia appeared to be proportional to the extent to which the curriculum has been designed to require psychomotor training to achieve learning outcomes. On top of difficulty and unequal delivery of practical skills training, students' research projects that typically required wet laboratory access or field sampling and experimentation were more susceptible to disruptions and uncertainty related to rapidly evolving pandemic circumstances. Indeed, the final year students appeared most conflicted by their thwarted ambitions to experience scientific research (which typically takes place in a laboratory or field setting), and the struggles they faced to achieve research progress in a timely manner, in comparison to peers who had computer-based projects that could be done remotely with minimal disruptions. This unfortunate dilemma may be a product of how the educational process of life sciences in Malaysia and many other settings have been designed, whereby training is viewed primarily from a technical perspective rather than a worldview. Ironically, we often lament competition and potentially the loss of jobs from automation, and the evidence suggests that the competitive edge for graduates comes from their communication and creativity, yet the experience from ERL appears to focus on the negative impact on the development of technical skills of the affected cohorts.

Conclusion

COVID-19 has drastically shaken the world and halted conventional teaching methods in higher education since March 2020. It has created the most enormous disruption to education in modern history. Long before COVID-19, the existing technology has always been mature enough to adopt online learning systems fully. However, the digitalization of education worldwide stagnated and still primarily focused on face-to-face teaching methods until the pandemic hit. The pandemic has clearly sped up technology adoption in education by several years in Malaysia and elsewhere. Indeed, although the ERL posed many challenges and precipitated existing inequities, several pandemic limitations also forced or motivated educators to rise to the challenge and update their pedagogical methods and spurred re-thinking about what are the key' learning outcomes' that are most important to achieve and the different ways to achieve them. Additionally, despite high internet coverage in 2021, stable and affordable internet connectivity remains the most vital variable to address to ensure that enhanced practices spurred by ERL are capitalized in an equitable way and that no one is allowed to fall through the cracks of the existing or widening digital and educational divide. Moving forward where now there is a clear and stark difference in T&L experience of students and lecturers' pre-pandemic and the 'pandemic cohort,' with questions of a possible 'post-pandemic cohort,' we argue against returning to the pre-pandemic norms, but to redesign the learning processes for more equitable and inclusive future in life science education.

Admittedly, our discussion of findings presented earlier is limited by potential biases from a purposive sampling method and a small study population. However, the themes captured through this in-depth approach remain helpful to ponder, particularly to stimulate conversation not only about delivering life science education in Malaysia under pandemic uncertainties but where ERL has exposed painful deficiencies in how life science training has been designed. In summary, some of the real and perceived inequities of ERL for life science programs stems from staunch beliefs related to the value of technical skills, for example, that a graduate of biotechnology should be able to use a pipette and the fervent hope that laboratory or field training will return to 'normal' once the pandemic ends. To this, we end with three questions, especially in view of a future for which there does not seem to be a clear end to the pandemic insight: first, what does a graduate of life sciences need to be trained in? Second, how critical are practical skills and conducting research projects in life science training and can these be better delivered through simulation? Third, should degree programs be tasked with skills training (that tend to become rapidly obsolete and irrelevant in different industries) as articulated from frameworks such as OBE, or focus instead on discipline-specific fundamentals and worldview construction that can be better delivered beyond the confines of rigid infrastructure or requirements? By exploring these questions, we may be better positioned to deliver more equitable learning experiences not only under the paradigm of ERL but for life science education.

Acknowledgment

Acknowledgment to Ministry of Higher Education Malaysia for Fundamental Research Grant Scheme with Project Code: FRGS/1/2018/SSI09/USM/02/3. We also thank the input from participants which has shaped this paper immensely. The usual caveat remains.

References

Ahea, M. M.-A.-B., Ahea, M. R. K. and Rahman, I. (2016). The Value and Effectiveness of Feedback in Improving Students' Learning and Professionalizing Teaching in Higher Education. *Journal of Education and Practice*, *7*(16), 38–41. https://eric.ed.gov/?id=EJ1105282.

Al-haimi, B., Nasir Ibrahim, D. and MR, A. H. (2019). An Investigation of the Current Autonomy Status of the Malaysian Public and Private Universities: An Empirical Result. *KnE Social Sciences*, *2019*, 347–363. https://doi.org/10.18502/kss.v3i22.5060.

Bonde, M. T., Makransky, G., Wandall, J., Larsen, M. V., Morsing, M., Jarmer, H. and Sommer, M. O. A. (2014). Improving biotech education through gamified laboratory simulations. *Nature Biotechnology*, *32*(7), 694–697. https://doi.org/10.1038/NBT.2955.

Chernikova, O., Heitzmann, N., Stadler, M., Holzberger, D., Seidel, T. and Fischer, F. (2020). Simulation-Based Learning in Higher Education: A Meta-Analysis: *Https://Doi.Org/10.3102/0034654320933544*, *90*(4), 499–541. https://doi.org/10.3102/0034654320933544.

Corbin, J. and Strauss, A. (2008). Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory (3rd ed.). Thousand Oaks, CA: Sage: *Https://Doi.Org/10.1177/1094428108324514*, *12*(3), 614–617. https://doi.org/10.1177/1094428108324514.

Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K. and Kestin, G. (2019). Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(39), 19251–19257. https://doi.org/10.1073/PNAS.1821936116/-/DCSUPPLEMENTAL.

Díaz-Guio, D. A., Ríos-Barrientos, E., Santillán-Roldan, P. A., Mora-Martinez, S., Díaz-Gómez, A. S., Martínez-Elizondo, J. A., Barrientos-Aguiñaga, A., Arroyo-Romero, M. N., Ricardo-Zapata, A. and Rodríguez-Morales, A. J. (2021). Online-synchronized clinical simulation: an efficient teaching-learning option for the COVID-19 pandemic time and: beyond. *Advances in Simulation (London, England)*, *6*(1). https://doi.org/10.1186/S41077-021-00183-Z.

Díaz, M. J. S. (2021). Emergency Remote Education, Family Support and the Digital Divide in the Context of the COVID-19 Lockdown. *International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 7956*, *18*(15), 7956. https://doi.org/10.3390/IJERPH18157956.

Donkin, R., Askew, E. and Stevenson, H. (2019). Video feedback and e-Learning enhances laboratory skills and engagement in medical laboratory science students. *BMC Medical Education*, *19*(1), 1–12. https://doi.org/10.1186/S12909-019-1745-1/FIGURES/5.

Ezra, O., Cohen, A., Bronshtein, A., Gabbay, H. and Baruth, O. (2021). Equity factors during the COVID-19 pandemic: Difficulties in emergency remote teaching (ert) through online learning. *Education and Information Technologies*, *26*(6), 7657–7681. https://doi.org/10.1007/S10639-021-10632-X.

Fadhlullah, A. and Ahmad, N. (2017). Thinking outside of the box: Determining students' level of critical thinking skills in teaching and learning. *Asian Journal of University Education*, *13*(2), 51–70. https://ir.uitm.edu.my/id/eprint/21917/.

Field, S., Kuczera, M. and Pont, B. (2007). No more failures: ten steps to equity in education | VOCEDplus, the international tertiary education and research database. *OECD*, 155. https://www.oecd.org/education/school/45179151.pdf.

García-Peñalvo, F. J. (2021). Transformación digital en las universidades: Implicaciones de la pandemia de la COVID-19. *Education in the Knowledge Society (EKS)*, *22*, e25465–e25465. https://doi.org/10.14201/EKS.25465.

Green, S. G., Ferrante, C. J. and Heppard, K. A. (2016). Using Open-Book Exams to Enhance Student Learning, Performance, and Motivation. *Journal of Effective Teaching*, *16*(1), 19–35. https://eric.ed.gov/?id=EJ1092705.

Hamid, H. A. and Khalidi, J. R. (2020). Covid-19 and Unequal Learning. *Khazanah Research Institute*.

Haritani, H., Febriani, Y., Yuliana, T. P. and Ihsan, E. A. (2019). The correlation of undergraduate course research experience and critical thinking skills. *International Journal of Innovation, Creativity and Change*, *5*(6), 336–347. *Higher Education Statistics 2019*. (2020).

Hodges, C., Moore, S., Lockee, B., Trust, T. and Bond, A. (2020). The Difference between Emergency Remote Teaching and Online Learning. *Educause Review*. https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning.

Hu, B., Guo, H., Zhou, P. and Shi, Z. L. (2020). Characteristics of SARS-CoV-2 and COVID-19. *Nature Reviews Microbiology 2020 19:3*, *19*(3), 141–154. https://doi.org/10.1038/s41579-020-00459-7.

Idris, A. N. (2021). *MCMC: Malaysia's 4G coverage up at 93.51% as at March, on track to reach end-2021 target | The Edge Markets*. The Edge Markets. https://www.theedgemarkets.com/article/mcmc-malaysias-4g-coverage-9351-march-track-reach-end2021-target.

Journell, W. (2007). The Inequities of the Digital Divide: Is E-Learning a Solution? *E-Learning and Digital Media*, *4*(2), 138–149. https://doi.org/10.2304/ELEA.2007.4.2.138.

Kaliannan, M. and Chandran, S. D. (2012). Empowering Students through Outcome-Based Education (OBE): *Http://Dx.Doi.Org/10.7227/RIE.87.1.4*, *87*(1), 50–63. https://doi.org/10.7227/RIE.87.1.4.

Lai, D., Tian, Y. and Meng, D. (2014). Differences Between the Employment of Higher Education Students from the Cities and the Countryside and the Fairness of Higher Education. *Http://Dx.Doi.Org/10.2753/CED1061-1932440101*, *44*(1), 3–26. https://doi.org/10.2753/CED1061-1932440101.

Lateef, F. (2010). Simulation-based learning: Just like the real thing. *Journal of Emergencies, Trauma, and Shock*, *3*(4), 348–352. https://doi.org/10.4103/0974-2700.70743.

Lynch, K. and Baker, J. (2016). Equality in education: An equality of condition perspective. *Https://Doi.Org/10.1177/1477878505053298*, *3*(2), 131–164. https://doi.org/10.1177/1477878505053298.

Ma, G., Black, K., Blenkinsopp, J., Charlton, H., Hookham, C., Pok, W. F., Sia, B. C. and Alkarabsheh, O. H. M. (2021). Higher education under threat: China, Malaysia, and the UK respond to the COVID-19 pandemic. *Compare: A Journal of Comparative and International Education*, 1–17. https://doi.org/10.1080/03057925.2021.1879479.

Marinoni, G., Van't Land, H. and Jensen, T. (2020). *The impact of COVID-19 on higher education around the world: IAU global survey report*. IAU : International association of universities.

MCO: Tertiary students grateful for chance to return home. (2020). *Malay Mail*. https://www.malaymail.com/news/malaysia/2020/04/24/mco-tertiary-students-grateful-for-chance-to-return-home/1859942.

Meguerdichian, M. J., Bajaj, K. and Walker, K. (2021). Fundamental underpinnings of simulation education: describing a four-component instructional design approach to healthcare simulation fellowships. *Advances in Simulation 2021 6:1*, *6*(1), 1–8. https://doi.org/10.1186/S41077-021-00171-3.

Mohayidin, M. G., Suandi, T., Mustapha, G., Majid Konting, M., Kamaruddin, N., Man, A., Adam, A., Siti, and Abdullah, N. (2008). Implementation of Outcome-Based Education in Universiti Putra Malaysia: A Focus on Students' Learning Outcomes. *International Education Studies*, *1*(4), p147. https://doi.org/10.5539/IES.V1N4P147.

Nasrallah, R. (2014). Learning outcomes' role in higher education teaching. *Education, Business and Society: Contemporary Middle Eastern Issues*, *7*(4), 257–276. https://doi.org/10.1108/EBS-03-2014-0016.

Nuruzzaman, A. (2016). The Pedagogy of Blended Learning: A Brief Review. *IRA International Journal of Education and Multidisciplinary Studies*, *4*(1), 125–134. https://doi.org/10.21013/JEMS.V4.N1.P14.

OECD. (2012). Equity and quality in education: Supporting disadvantaged students and schools. *OECD Publishing*, 1–165. https://doi.org/10.1787/9789264130852-EN.

Rajesh Shah, S. and Udgaonkar, U. S. (2018). Influence of Gender and Age of Teachers on Teaching: Students Perspective. *International Journal of Current Microbiology and Applied Sciences*, *7*(1), 2436–2441. https://doi.org/10.20546/ijcmas.2018.701.293.

Salmi, J. and Bassett, R. M. (2014). The equity imperative in tertiary education: Promoting fairness and efficiency. *International Review of Education*, *60*(3), 361–377. https://doi.org/10.1007/s11159-013-9391-z.

Saravanamuttu, J. (2021). Southeast Asian Affairs 2021 (Malaysia in 2020: Political Fragmentation, Power Plays and Shifting Coalitions). In *Southeast Asian Affairs 2021* (pp. 169–184). ISEAS-Yusof Ishak Institute.

Shana, Z. and Abulibdeh, E. S. (2020). Science practical work and its impact on students' science achievement. *Journal of Technology and Science Education*, *10*(2), 199–215. https://doi.org/10.3926/JOTSE.888.

Sirat, M., Ahmad, A. R. and Azman, N. (2012). University leadership in crisis: The need for effective leadership positioning in Malaysia. *Higher Education Policy*, *25*(4), 511–529. https://doi.org/10.1057/HEP.2012.10.

Soalan Lazim (FAQ) Mengenai Perintah Kawalan Pergerakan Kementerian Pengajian Tinggi (KPT) Bilangan 5. (2020). https://www.mohe.gov.my/hebahan/soalan-lazim/soalan-lazim-berkenaan-perintah-kawalan-pergerakan-kementerian-pengajian-tinggi-bilangan-5.

Srivastava, P., Professor, A., Hopwood, N. and Fellow, R. (2009). A Practical Iterative Framework for Qualitative Data Analysis: *Http://Dx.Doi.Org/10.1177/160940690900800107*, *8*(1), 76–84. https://doi.org/10.1177/160940690900800107.

Stahre Wästberg, B., Eriksson, T., Karlsson, G., Sunnerstam, M., Axelsson, M. and Billger, M. (2019). Design considerations for virtual laboratories: A comparative study of two virtual laboratories for learning about gas solubility and colour appearance. *Education and Information Technologies*, *24*(3), 2059–2080. https://doi.org/10.1007/S10639-018-09857-0.

Stake, R. E. (2013). *Multiple Case Study Analysis*. Guilford Press.

Torrisi-Steele, G. and Drew, S. (2013). The literature landscape of blended learning in higher education: the need for better understanding of academic blended practice. *Http://Dx.Doi.Org/10.1080/1360144X.2013.786720*, *18*(4), 371–383. https://doi.org/10.1080/1360144X.2013.786720.

Wan, C. D. (2019). The Universities and University Colleges Act in Malaysia: History, contexts and development. *Kajian Malaysia*, *37*(2), 1–20. https://doi.org/10.21315/km2019.37.2.1.

Williams, J. B. and Wong, A. (2009). The efficacy of final examinations: A comparative study of closed-book, invigilated exams and open-book, open-web exams. *British Journal of Educational Technology*, *40*(2), 227–236. https://doi.org/10.1111/J.1467-8535.2008.00929.X.

Yap, W. H., Teoh, M. L., Tang, Y. Q. and Goh, B. H. (2021). Exploring the use of virtual laboratory simulations before, during, and post COVID-19 recovery phase: An Animal Biotechnology case study. *Biochemistry and Molecular Biology Education*, *49*(5), 685–691. https://doi.org/10.1002/BMB.21562.

Yousefi, M., Abdollahzadeh, M. and Moossavi, S. (2020). Equity in science education and disseminations: lessons learned during COVID-19 pandemics. *Authorea Preprints*. https://doi.org/10.22541/AU.159363375.57325180.

Zeng, G., Chen, X., Cheung, H. Y. and Peng, K. (2019). Teachers' growth mindset and work engagement in the Chinese educational context: Well-being and perseverance of effort as mediators. *Frontiers in Psychology*, *10*(MAR), 839. https://doi.org/10.3389/FPSYG.2019.00839/BIBTEX.