One Health Outlook

BRIEF REPORT

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Developing digital learning to help reduce laboratory inequalities: a viral haemorrhagic fever case study

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Abstract
Countries with the highest potential exposure to viral haemorrhagic fever viruses are also those with low expenditure on health services, limiting the capacity for surveillance and detection of these viruses, and effective treatment and outbreak containment. The COVID-19 pandemic further limited travel and in-person collaborative training opportunities for researchers, laboratory and public health professionals. Digital learning offers the prospect of addressing some of the shortfall in training needs. In this short report, we describe our experiences in the development of effective laboratory training tools using digital learning methods. We describe the teaching methodology, list barriers to successful implementation and offer some potential solutions.

Keywords Ebola virus disease, Lassa fever, Crimean-Congo haemorrhagic fever, Rift Valley fever, One health, Zoonoses, Digital learning, Global health

Introduction

Global health is defined as "an area for study, research, and practice that places a priority on improving health and achieving health equity for all people worldwide" [1]. There are large inequalities in global health, particularly in the tropics and this has significant economic cost for lower-income countries [2]. In Africa, for example, most countries have health-care systems hindered by economic limitations, resulting in inadequate disease surveillance and laboratory capacity, and scarcity of public health human resources [2, 3]. Disease surveillance is a crucial element of the One Health approach to disease management, where wellbeing of humans, animals and ecosystems are treated as interrelated and interdependent [4] and strengthening of laboratory testing capabilities in low to middle income countries (LMICs) is essential for this. Training, however, can be expensive, time consuming and limited by access to resources.

The COVID-19 pandemic greatly reduced international travel, including for capacity building and international partnerships, but also led to increased use of digital learning techniques, including in health training [2, 3]. Virtual training sessions play an increasingly important role in strengthening laboratories in LMICs by providing accessible, cost-effective, and scalable opportunities for skill development in epidemiology, allowing professionals to stay up-to-date with global standards and enhance their diagnostic and research capabilities. There are increasing numbers of online learning methodologies for training, including from the World Health Organisation (WHO) for Ebola virus disease (EVD) [5, 6], but none designed to

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help with laboratory training. In this article, we explore how digital learning tools have the potential to address persistent barriers that perpetuate health disparities, focussing on laboratory training, while outlining the barriers and potential difficulties in doing so. We present a case study where laboratory training resources were created by researchers at Massey University, New Zealand and Leon Quist Ledlum Central Veterinary Diagnostic Laboratory, Republic of Liberia to enhance viral haemorrhagic fever virus surveillance. This initiative took place amidst the COVID-19 pandemic and formed part of a broader region-wide laboratory twinning program.

Viral haemorrhagic fevers in West Africa

Viral haemorrhagic fevers (VHFs) such as EVD, Marburg virus disease (MVD), Rift Valley fever (RVF), Crimean-Congo haemorrhagic fever (CCHF) and Lassa fever rank among the most serious threats to global health. This is in part due to the morbidity and mortality associated with these pathogens, but also because their geographical distribution is close to human populations without access to health services in many low-income tropical nations. All these viruses are classified as Risk Group 4 pathogens, requiring handling in a laboratory with an equivalent containment level (Biosafety Level 4—BSL-4), with the exception of RVF virus (which requires BSL-3 containment). BSL-3 laboratories are designed for handling infectious agents that can cause serious diseases but are not airborne, while BSL-4 laboratories are for handling highly dangerous pathogens that pose a high risk of aerosol transmission and require maximum containment. Preliminary viral detection can be carried out using molecular techniques (PCR and RT-PCR) as soon as the sample is inactivated in a BSL-3 or BSL-4 containment laboratory. Equally importantly here, working in lower BSL settings is easier for training basic skills, as well as sufficient for infections which pose lower risk to health.

Most novel and emerging infectious disease have their origins in wild or domestic animal species [7]. For example, CCHF virus infects numerous domestic and wild animal hosts [8]. Lassa fever is caused by a virus that circulates among rodents [9]. The largest outbreak of any VHF with human-to-human transmission was the West African EVD outbreak from 2013 to 2016, with 28,646 recorded infections and 11,323 human deaths [10]. However, in addition to having wildlife reservoir hosts, EVD has caused the death of great apes in Central Africa [11, 12]. For these reasons, a One Health approach to these infectious diseases is required [4].

The twinning partnership: Ebo-sursy in Liberia

To build surveillance and laboratory capacity in Africa, the Ebo-sursy project [13] was enacted by the World Organisation for Animal Health (WOAH), formerly the Office International des Epizooties (OIE), in 2016 with financial support from the European Union. Ebo-sursy aims to "strengthen early disease detection systems for wildlife in West and Central Africa to prevent outbreaks of EVD, and four other viral haemorrhagic fevers: MVD, RVF, CCHF and Lassa fever". Ebo-sursy was active in Cameroon, Central African Republic, Côte d'Ivoire, Democratic Republic of the Congo, Gabon, Guinea, Liberia, Republic of the Congo, Senegal and Sierra Leone. The initial plan was for course participants and tutors to travel between laboratories and complete in-person training over a two year period. However, a digital learning approach was implemented after international travel was limited during the COVID-19 pandemic.

This training was developed after initial (pre-pandemic) assessments of the capacity in Liberia in the twinning laboratory, aiming to provide the foundational knowledge and practical skills necessary to establish an effective wildlife health infectious disease surveillance program despite limited resources. The content was then structured to equip participants with essential epidemiological and disease surveillance principles to enable early infectious disease detection and response, whilst ensuring safe and efficient laboratory practices suited to Liberia's available facilities, along with strengthening data analysis and decision-making skills. The aim was to help the Liberian team develop their own, independent working practices, with the ultimate aim being to allow effective wildlife infectious disease surveillance for evidence-based policy development and resource allocation to mitigate disease risks.

The content was designed to cover the necessary theory and background knowledge and incorporate this into the appropriate laboratory workflow within the available time frame and budget, accounting for the available in-country physical infrastructure, utilities and support systems (e.g., electricity, clean water, internet, and temperature-controlled environments such as refrigeration for reagents and biological samples), equipment and supplies, human resources and logistics and supply chains. In the Liberian veterinary laboratory, the team of eight included technicians with certificates or diplomas as well as members with degrees. The focal areas were first identified by the WOAH, New Zealand and Liberian teams together, before the New Zealand team of scientists and learning curriculum team developed the content. These focal areas were developed following an assessment of the Liberian facility to ensure that the practical learning elements would not be limited by any local constraints. For example, the lab protocols used end point PCR rather than qPCR, as well as thermostable reagents and lab processes [14]. We decided to focus on in-lab procedures since adding downstream skills like DNA sequence analysis would introduce additional barriers to learning around computer literacy or access to licensed software.

Digital learning

Digital learning, also known as e-Learning, or "technology-enhanced learning", describes a set of technology-mediated methods that can be applied to support student learning. This can include elements of class-based or individual e-learning experiences carried out at a fixed time (synchronous learning) and content designed for self-paced learning community tasks available upon demand (asynchronous learning), along with student feedback and assessment [15, 16]. It is more focussed than simply making information available online. Effective digital learning aligns with broader pedagogical principles such as those long established by Chickering and Gamson [17]. Digital learning supports active learning, in which students are involved in the construction of knowledge and skills, rather than passively consuming them in static format; it fosters a supportive and collaborative environment in which connections with other learners and teachers form part of the learning process itself; it provides timely opportunities for feedback that support learners to monitor and direct their progress; and it provides flexibility and variety to accommodate the diverse needs of different learners. These elements are as important in a distance learning environment as they are in the classroom but cannot be achieved simply by moving classroom or laboratory materials online. Instead, they must be achieved through careful design that is tailored to the distance context.

Digital learning barriers

Many barriers exist for digital learning approaches in (LMICs), including sub-Saharan Africa. For example, having access to internet at home is a major factor in digital learning [18], but for many learners in this area of the world this is not possible, while great difficulties may exist even at the institutional level. Uninterrupted power supply, access to computing hardware (PC or laptop) and digital literacy cannot be guaranteed in many cases [19–21]. Reliable internet presents another major obstacle to engagement in digital learning. In Liberia just 17% (5/29) of health facilities had daily access to internet [19]. Internet supplier issues, unreliable power supply due to poor infrastructure, virus contamination, poor and unmaintained firewalls, and digital literacy all contribute to a lack of access to internet services, an essential element of communication during digital learning [22–24]. Digital literacy in particular is often a barrier and other virtual programs such as the Tunapanda Institute seek to develop these skills for youth from low-income backgrounds [25]. Combined, these issues make it difficult to know whether communication gaps are to do with existing understanding/knowledge, language barriers, or the realities of the laboratory environment, such as competing demands on staff time. These factors add complexity to the challenge of designing a learning experience that would enable students to form reciprocal relationships with teaching staff, located in very different laboratory environments on the other side of the world, and obtain meaningful feedback that they could apply to enhance further learning.

Developing the training tools

Overview

Taking these challenges into account, we designed a tailored approach to the digital learning environment to facilitate a training package and deliver our Ebo-sursy contract, titled 'Enhancing Capacity for Early Detection of Viral Haemorrhagic Fevers in Liberia through Epidemiological and Laboratory Training' during the COVID-19 pandemic. Our tool was designed around a challenge, solution, conclusion framework (see Table 1). To partly alleviate issues of access to computer or internet, in consultation with our Liberian co-authors, we designed course materials that were suitable for either hardcopy, digital or online use. We subsequently shared these with the Liberian course participants online as well as on USB drive to maximise accessibility. Workbooks and laboratory manuals were additionally provided in hardcopy form, for easy reference in the laboratory, with sufficient space for reflective and self-assessment activities to be completed.

The design of the package divided content into four modules (Fig. 1):

Table 1 Designing a tailored approach to digital epidemiological and laboratory training in LMICs

Challenge	Solution	Conclusion
The existence of several digital learning barriers, e.g. access to Internet, power supply, access to computing hardware, and digital literacy.	Offering a digital learning environment with content accessible online, through USB, or hardcopy. Using a pedagogical approach of preparation-actions-feedback.	Providing asynchronous foundational readiness education prepared individuals for immersive, hands-on, in person training.
Limitations of biocontainment conditions, equipment and infrastructure in the host laboratory environment.	Focusing the practical laboratory training around a customized set of controlled experimental procedures.	Practical elements can be effectively carried out in the host laboratory, minimising the requirement for ongoing support and travel while simultaneously addressing health disparities.

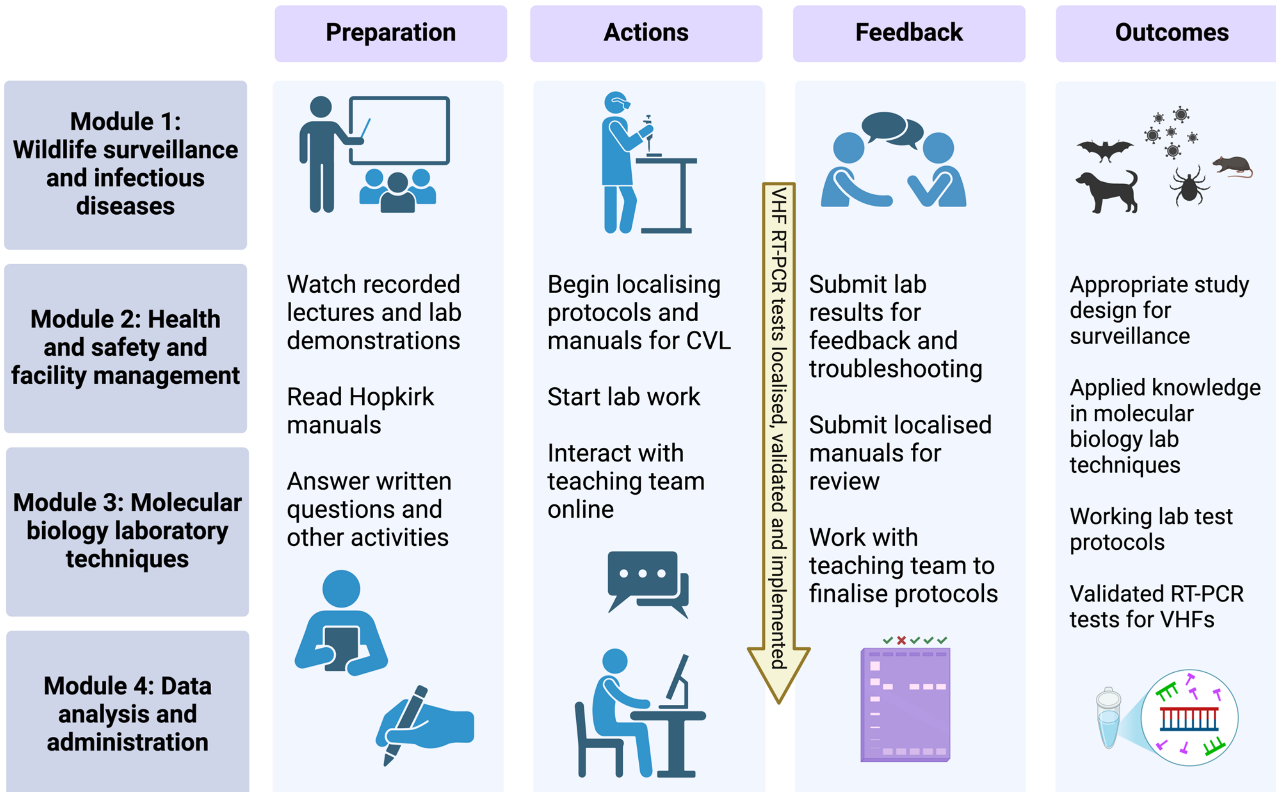

Fig. 1 Illustrated course structure and workflow

Module 1: Wildlife surveillance and infectious diseases. Basic epidemiology, disease surveillance and background on the specific pathogens.

Module 2: Health and safety and facility management. Standard laboratory practices, designed to assess practices and equipment in Liberia.

Module 3: Molecular biology. Background on general molecular biology theory with reference to the specific procedures used in detection of pathogens.

Module 4: Data analysis and administration. Information on the types of data and how this is used to inform decisions.

All four of the modules took the form of workbooks with accompanying videos and recorded PowerPoint presentations, and process manuals. The workload was structured around two different types of task: preparation and action. Preparation tasks could be done without feedback from the teaching team, for example, watching a video or presentation or reading a section of a manual and then answering questions or completing a table. An example training video and example manuals and workbooks are provided in Supplementary Material 1. Action tasks require an interaction with the teaching team by submitting questions, discussion topics, completed preparation tasks or sections of manuals. However, the training material is complete and available for users as standalone content that can be worked through in their own time.

Laboratory considerations

The New Zealand partners operate a BSL-2 and −3 facility only, so to overcome the imposed travel restrictions and for ease we used synthetic, non-infectious control material, mitigating the need for high containment facilities and simplifying training relating to the molecular steps themselves [14]. Specifically, we designed oligonucleotide primers complementary to the viral targets for use in conventional PCR and RT-(q)PCR. A synthetic control was created to act as a non-infectious positive control material, allowing for both direct PCR as an amplification control and the transcription of short, non-infectious RNA fragments for extraction controls. This was enabled by the use of a T7 RNA polymerase at the promoter sequence located either side of the target primer binding sites assays (see Knox et al. [14] for full details). These methods allow all steps of the training process, from RNA extraction through to DNA sequencing, to be performed correctly in a safe and efficient manner under less strict biocontainment conditions.

At Leon Quist Ledlum Central Veterinary Diagnostic Laboratory, donors have supplied essential diagnostic equipment, including PCR machines, some reagents, power generators, and upgraded infrastructure, including refrigeration systems, biosecurity measures, and waste management facilities. However, the facility still has to deal with poor infrastructure, such as unreliable electricity, outdated buildings with limited space, and limited capacity to maintain equipment which can affect workflow and result in delays or contamination. Furthermore, laboratory biosafety training was previously highlighted during the COVID-19 pandemic [26], highlighting the importance of further training.

Module development

The material began on all formats (online and in the hardcopies) with an introduction to the team and how to use the material.

Module 1 was an introduction to infectious disease surveillance and the infectious disease systems. Modules 1 and 2 functioned in lieu of the in-person training that would have taken place at the New Zealand facility (Hopkirk Research Institute, Massey University NZ) under non-COVID circumstances. Together the two modules provide a basis for undertaking molecular detection of viral haemorrhagic fevers in a BSL-2 level laboratory. The first module is intended to induct a new staff member or student into our group as though they were visiting in person and includes practical information on staffing, instrumentation, sample handling, health and safety procedures, stocks and supplies and quality control practices. The second module outlines in detail the methods for RNA extraction, RT-PCR and gel electrophoresis.

An important feature of the design was the integration of the Hopkirk process manuals within the wider learning package. For modules Two to Four, we provided both editable and non-editable versions of a Molecular Biology Test Procedure Manual and a General Laboratory Protocol Manual. The workbook materials for these modules support researchers to explore the learning content in a reflective way, identifying key similarities and differences in their own laboratory environment and resources. As learners progress through the material, they are asked to adjust the editable copy of the Hopkirk manuals in order to develop their own laboratory-specific version. These interactions and feedback are all conducted within Massey University Stream, a learning management system for the administration, documentation, tracking, reporting and delivery of educational programs. The aim is for the learner be able to use these manuals to design (or employ) equivalent quality molecular processes for use in their laboratory, in any country. By the time all modules are completed, working documents of both test protocol and general procedure manuals will be ready for local use.

Building in communication and feedback

The challenge presented by this design in an asynchronous learning context is to ensure learners can get timely and practical feedback as they progress through the learning. In particular, as they consider differences between their own laboratory environment and that of the Hopkirk laboratory, it is critical that learners are able to ask questions, explore challenges, and receive feedback on their proposed adjustments to the Hopkirk processes and resources. Originally the manuals were digital only, however we sent printed copies of manuals and all course notes to assist with the learning process based on feedback from the course participants. Synchronous feedback was ruled out due to the significant limitations in internet access. Instead, a feedback loop was created in two ways. Firstly, learners can be encouraged to email at any time they need to ask questions or seek feedback. Email was chosen simply because it was the easiest and most practical way for the learners to make contact given technology limitations. Secondly, at the end of Modules Two, Three, and Four, learners are asked to submit their edited version of the procedure or protocol manuals (as applicable). Here, Hopkirk staff can then review the changes made and ask follow-up questions as well as providing feedback when helpful. Learners are then able to adjust their approach and further refine their manuals before or during their progress onwards.

Key benefits of the material provided are linkages between steps theory, steps in the process, and training videos. For this project, videos were professionally filmed and recorded to a very high quality, with optimal angles used to show key processes in detail. The videos included all methodological steps, from the laboratory induction, through to receiving goods and dealing with laboratory incidents, to basic skills, such as using pipettes and running gel electrophoresis. A key benefit is that they can be watched repeatedly.

Challenges to digital learning success

The short, medium and long-term success of this project depends on multiple factors. The first of the challenges relates to transitioning to an online educational environment. Many learners unfamiliar with digital learning will automatically see it as less effective than the sort of in-person experiences they are used to. A clear, confident introduction to the learning design, the tasks and the interactions is essential to building trust in this approach, highlighting the learning opportunities it provides. It is important that the facilitators of training highlight that there are still opportunities to interact with tutor groups and peers through the design, while acknowledging this could be a culturally and socially unfamiliar learning experience. Tasks that encourage social learning interactions within a blended learning environment can be very valuable for building trust as learners negotiate the content within their specific and shared contexts. The more familiar one becomes with the cultural setting and previous educational experience of the participants may allow for a more tailored approach to the design of these tasks. Another consideration within the online educational environment is the level of digital literacy of the participants. Despite cultural settings, it is important to be aware of what we are asking of participants within the learning management system and the task design while also providing sustainable, reusable guidance and support as necessary within the course design itself.

A second set of challenges relate to the infrastructure and funding necessary for remote, technology-mediated training. While the barrier of travel and the associated costs may be avoided within a digital learning experience, there are still the considerations of access to devices and the wider domestic infrastructure challenges of connectivity related to both internet access and electricity stability. Along with the natural bias toward in person education and need for learner training, it is not as simple an educational solution as some might propose. However, this, like all training and development, requires a move from 'donor-supported' to self-supporting domestic models that will allow trainees to train other staff in the future without the need for externally driven input, which can be sporadically distributed. This transition is often challenging [27] and requires collective and coordinated action from global, bilateral and national partners. A One Health approach is a useful model for coordinating organisations and strengthening national core public health capacities [28]. With careful design of the blended digital learning experience, accounting for culture, learner training needs, as well as physical infrastructure, training courses like ours can be part of sustainable efforts addressing broader issues such as workforce education, funding, and retainment.

These have all been issues with our collaborations and similar issues have been faced by OIE in recent years [29]. However, while these barriers have been present in this current partnership project, the material from this course is now hosted on the German Online Platform for Biosecurity & Biosafety (GO4BSB), an e-learning platform for the projects of the German Biosecurity Programme launched in 2013 under the auspices of the G7 Global Partnership against the Spread of Weapons and Materials of Mass Destruction. This highlights how once material is developed, it can be distributed for the benefit of many, rather than just a few, and adopters of such material can later benefit from in-person training, having foundational knowledge available through such digital learning experiences. Further barriers exist, however, relating to those barriers already faced by laboratories from poorer nations, such as maintaining laboratory infrastructure and access to support services for thermal cycler maintenance and calibration, for example.

Conclusion

Our case study of a COVID-19 pandemic-led pivot to a digital learning experience could be the seed for much more intentional blended design of these training opportunities. Incorporating asynchronous foundational readiness education to prepare individuals for immersive hands-on experiences in person, followed by digital reflection and communities of practice upon returning to their respective environments has the potential to bring significant advantages. Such programs can effectively minimise the requirement for expensive and environmentally harmful travel while simultaneously addressing health disparities.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42522-025-00156-6.

Supplementary Material 1

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Author contributions

MK Co-led the design of the laboratory steps for viral detection and was a major contributor in writing the manuscript. CB Co-led the design of the laboratory steps for viral detection and contributed in writing the manuscript. WA Contributed to digital learning design. VK Co-led the project initiation, contributed to the digital learning design. CS Co-led the digital learning design and contributed in writing the manuscript. FCD Co-led the digital learning design and contributed in writing the manuscript. DH Led overall study, co-led the project initiation, secured funding and was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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