A pilot trial of internet-delivered mastery-based Ebola simulation education in Uganda

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Abstract

Ebola Virus Disease (EVD) poses a global health threat in Uganda where the disease is endemic, and resources are limited. We designed a curriculum to provide EVD education at the Masindi Kitara Medical Center (MKMC) and compare it to a group who took the same course at the Medical University of South Carolina (MUSC) in the United States. Demographic information, confidence and knowledge test scores, and video grading data was gathered. Three trainers and six trainees were enrolled at each site. Completion of the online curriculum improved knowledge test scores in trainees. Initial pre-training knowledge test scores were higher in the MUSC group than the MKMC group (p=0.04), but both sites had significant improvement in post-test scores. On the confidence survey, participants at MKMC were generally more confident pretraining than MUSC participants. MUSC participants improved more in confidence, although post-training confidence at MUSC (median=4.2; IQR=3.0-4.6) remained significantly (p=0.02) lower than at MKMC (median=4.9; IQR =4.4-5.0). We demonstrate the feasibility of utilizing our course with a train-the-trainer component designed to rapidly develop new trainers to provide EVD education in Uganda.

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Ethics approval and consent to participate: human subject use was approved by MUSC IRB and TASO Research Ethics Committee in Uganda. Nine paid HCW volunteers were recruited at both sites to pilot the curriculum. Informed consent was obtained.

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Introduction

Ebola Virus Disease (EVD) is a High-Consequence Pathogen (HCP) that poses a major global health threat. Uganda has been the site of five outbreaks since 2007, with the most recent outbreak ending in January of 2023 following the identification of 164 cases with 77 deaths.[1,2] Additionally, in Uganda, spill-over events are a considerable threat from outbreaks originating in the neighboring Democratic Republic of The Congo, which has experienced 7 EVD outbreaks in the last 5 years. EVD carries a high risk of nosocomial spread and causes significant morbidity and mortality in Healthcare Workers (HCWs). In settings where HCWs and resources are limited, communities are at risk of suffering exponentially in disease outbreaks.[3–6]

Simulation-based education in the use of Personal Protective Equipment (PPE) and infection control techniques during patient care have been shown to be useful to reduce the spread of disease and loss of HCWs to nosocomial infection and/or quarantine during disease outbreaks.[4,5,7,8] Intensive simulation education at the National Ebola Training Academy in Sierra Leone was successful in the 2014 Ebola outbreak.[8] However, time-consuming, potentially expensive, cost-prohibitive travel was required of attendees. As seen during the COVID-19 pandemic, international travel and in-person learning is limited during a pandemic. Previous studies evaluating the implementation of local simulation-based education in resource-limited Sub-Saharan Africa (SSA) have identified challenges to its implementation, including the high cost of equipment and lack of dedicated simulation centers and trained local personnel to lead simulation-education.[9–13] Remote, online training may offer a more cost-effective, efficient strategy for rural healthcare institutions. In this pilot trial, we describe the development of a Medical Unit Specialized Simulation Training (MUSST) curriculum, designed to provide simulation education to HCWs to manage patients with EVD and lessons learned at a site in the rural region of Masindi, Uganda.

The MUSST course, which combines online and simulation training to educate healthcare workers in Ebola patient care, was created to be adaptable and rapidly deployable to a wide breadth of healthcare institutions.[14] The curriculum contains a train-the-trainer component intended to make the training independently sustainable at any site it is instituted. The first iteration of the curriculum was successfully piloted in 2016 where it was developed at the Medical University of South Carolina (MUSC).

The MUSC Department of Emergency Medicine, Division of Global Health, has a long-standing relationship with the OneWorld Health (OWH), an 501(c)(3) non-governmental organization which operates the Masindi Kitara Hospital, formerly and at the time of this trial, the Masindi Kitara Medical Center (MKMC), a rural, private level-three medical center with 55 inpatient beds in Masindi, Uganda. Prior bidirectional educational exchanges between MUSC and MKMC included medical trainee clinical rotations at MKMC as well as the development of continuing medical education for medical staff in Uganda by MUSC fellows and faculty. It was recognized that Viral Hemorrhagic Fevers (VHFs) pose a significant threat after one case was identified at MKMC itself, and others occurred in the surrounding region.[15] VHF training was provided to HCWs at MKMC by the Uganda Ministry of Health, but did not include a simulation component. Prior to coordinated efforts to establish simulation training from MUSC, staff at MKMC had no previous experience in donning and doffing PPE for VHF management. At OWH's request, training for staff at MKMC in VHF management was established by MUSC faculty. In order to evaluate whether MUSST curriculum might offer a sustainable solution to provide ongoing Ebola training, we decided to adapt the MUSST curriculum and pilot it at MKMC. In March of 2021, an updated version of the MUSST curriculum, described in detail below was again piloted at MUSC, an 865-bed tertiary-care referral hospital in Charleston, South Carolina, U.S.A. to ensure functionality of the curriculum platform. Following successful completion in South Carolina, the MUSST updated curriculum was piloted at MKMC in Uganda in May 2021.

In this pilot trial we describe the development and adaptation of our curriculum to train HCWs at MKMC in Masindi, Uganda. In comparing the implementation of this training modality at MUSC versus MKMC, we review valuable lessons learned which may assist with future curriculum development to overcome some of the challenges related to Ebola-response simulation education in this region of SSA.

Materials and Methods

Curriculum development and design

Curriculum development was performed by a team of two anesthesiologists with extensive simulation education expertise, an Ebola-patient care expert with years of hands-on experience working in Ebola treatment centers in S.S.A., a Global Emergency Medicine specialized physician with tropical infectious disease expertise and prior on the ground experience at MKMC, and a human-factors engineer with decades of experience studying and improving safety and performance in acute care. Content was developed utilizing resources from the CDC, WHO, and the National Ebola Training and Education Center.

This course was developed to be performed in two parts: i) online education and ii) simulation of clinical care scenarios. The online component hosted on Moodle™, an open-sourced online course management software package, included disease-specific written curriculum, checklists, and video demonstrations of simulation scenarios being performed correctly. Simulation training occurred in person, utilizing scenarios involving a "provider" and "buddy" team with checklists to support high-reliability team functioning facilitated by a trainer see example in (Appendix A). The 10 simulation scenarios included the donning and doffing of 3 distinct types of PPE and common clinical tasks. They were organized into three stations such that each group would don a specific form of PPE, perform the simulation task skill(s) in that PPE and then doff that PPE before rotating to the next simulation station (Table 1). This rotating format for training was meant to allow groups to continually rotate through stations to increase efficiency and decrease the total number of training days. A digital grading tool was created to be used by trainers during simulation scenarios. The tool was designed to function on a tablet device to capture real-time team simulation performance, generate a debriefing report for trainers and digitally store performance data for future reference.

A train-the-trainer module was developed to ensure sustainability of the MUSST curriculum and is described in more detail in a previous publication by Tobin *et al.* (2020).[16] Participants in the train-the-trainer component completed the part I online training plus an additional online train-the- trainer module shown in Table 2. The updated online learning platform developed for use in Uganda included three pre-recorded videos of actors performing simulation scenarios with a total of six intentional critical errors executed. This was included to allow the newly trained trainers to practice using the grading tool to grade videos of individuals performing the clinical simulation scenarios.

After completing all online coursework, trainers-in-training would then perform all 10 simulation scenarios three times, rotating through each of the roles of trainer, provider, and buddy. Thus, by the completion of their curriculum, the newly trained trainers completed the entire simulation curriculum themselves, and prac-

Table 1. Clinical simulation scenarios included in the MUSST course.

Station	Donning Scenarios (number of steps in scenario)	Task Skill(s) Scenarios (number of steps in scenario)	Doffing Scenarios (number of steps in scenario)
1	N-95 with Gown Donning (16)	Lab Draw and Specimen Bagging (19)	N-95 with Gown Doffing (20)
2	N-95 with Coverall Donning (16)	Spill Clean-Up (14) Waste Disposal (28)	N-95 with Coverall Doffing (23)
3	PAPR with Coverall Donning (21)	Body Bagging (34)	PAPR with Coverall Doffing (29)

ticed facilitating the simulations, utilizing the grading tool, and performing debriefing (Figure 1). The "Logistics" component of the training for trainers included information on how to set up the simulation scenarios for trainees. Rudimentary designs of simulation environments were created in a way such that they could be used in any location, making the curriculum adaptable to both high fidelity simulation centers and our intended location in Uganda (Appendix B).

Pilot trial

Human subject use was approved by MUSC IRB and TASO Research Ethics Committee in Uganda. Nine paid HCW volunteers were recruited at both sites to pilot the curriculum. Informed consent was obtained.

Training took place in March 2021 at MUSC (USA) and in May 2021 at MKMC (Uganda). Three trainers at each site completed the train-the-trainer course (Figure 1A) and then each new trainer trained two participants using the MUSST curriculum (Figure 1B). Participants at MUSC performed the online "Part 1" remotely whereas in Uganda participants completed the online portion in the hospital library at MKMC due to lack of internet connectivity at participants' homes (Table 2; Figure 1).

Trainers used the grading tool on a Samsung Galaxy Tab A Android® electronic tablet with connected keyboard to capture trainee performance in real time (Figure 2). Performance data were automatically transmitted to a web-based database. Mastery-based learning was used; if a "critical error" occurred, defined as one that

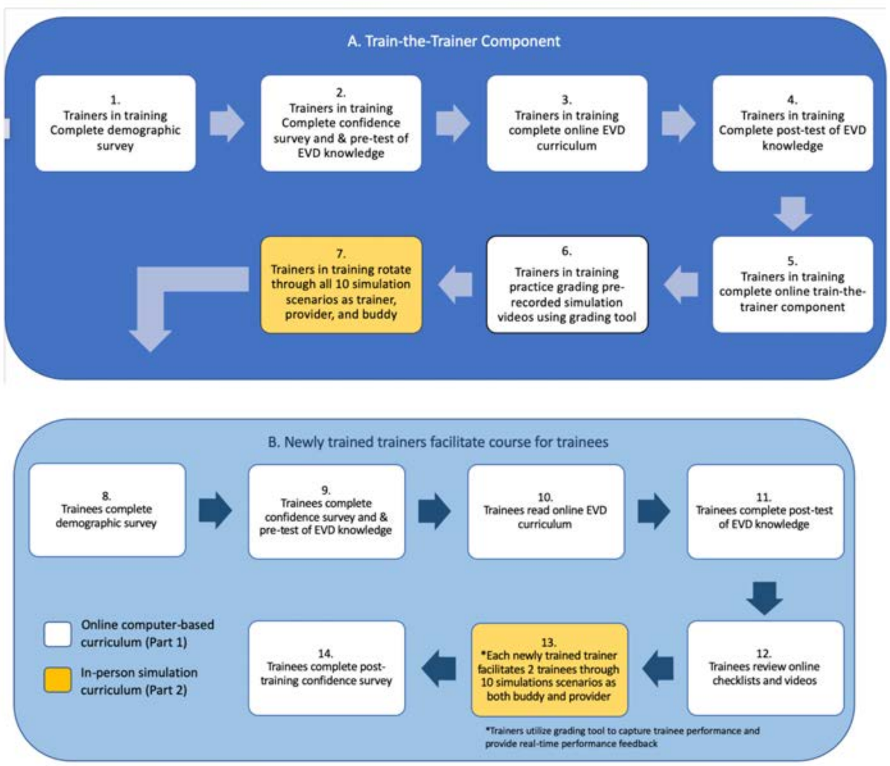

Figure 1. Pilot Trial design flow-chart.

Table 2. Train-the-trainer curriculum.

1.	Applicable infectious disease background information
2.	Review of protocols with train-the-trainer video demonstration of proper conduct
3.	Training goals
4.	Training space setup
5.	Logistic training ratio
6.	Safety considerations
7.	Scoring performance and providing feedback
8.	Learning to run simulation scenarios that measure performance
9.	Facilitating performance: debriefing
10.	Schedule and logistics of training
11.	Facilitator curriculum (to use the day of the course as a support aid for facilitators running the course).

could lead to infection or contamination, the step was mandatorily repeated until correct. If trainers selected "critical error specified" on the grading, the tool would signal trainers to comment on the critical action and would prompt trainers to have trainees repeat the step, until the trainer selected the "step completed" radio button (Figure 2). Trainers also had the option to utilize Rapid Cycle Deliberate Practice (RCDP) if desired, but only critical errors required repetition of the step. Upon completion of each simulation scenario, the grading tool generated a summary of performance with documentation of all checklist steps' time of completion, if the step required repetition and any comments regarding errors, positive or negative actions as documented by the trainer to be used by the trainer for debriefing following completion of the simulation.

Data collection and analysis

Information regarding the implementation of the curriculum in Masindi, Uganda, and how it compared to Charleston, South Carolina, was utilized with observations made by the study team along with quantitative data collected during the trials. This included a demographic survey and a 25-question multiple-choice knowledge test given both before and after the online coursework. Changes in pre- and post-knowledge test at each site and between the MKMC and the MUSC groups were evaluated using standard and paired t-tests, respectively. The Moodle™ platform also hosted a pre- and post-training confidence. The confidence survey consisted of 10 questions regarding participants' level of comfort caring for EVD patients using a five-point Likert scale.

Data was also collected from the grading tool reports generated from the practice videos at the end of the train-the-trainer online coursework and those from the simulation training of trainees. These reports, combined with observations made by the study team, were used to evaluate the functionality and effectiveness of the train-the-trainer curriculum. Observations made during the implementation of the curriculum in Masindi were compared to those made during the pilot trial in Charleston.

Results

Three trainers and six trainees were enrolled at each site. Table 3 gives demographic information at both sites. Educational background was the only demographic variable that was significantly (p=0.01) different between the two sites with MUSC participants having completed more degree programs, versus diploma and certificate programs at MKMC (Table 3)

Completion of the online curriculum improved knowledge test scores in trainees at both sites. Pre- and post-test results are shown in Table 4. Initial pre-training knowledge test scores were higher in the MUSC group than the MKMC group (p=0.04), but both sites had significant improvement in post-test scores with no significant difference in the change in test scores between sites.

Participants at MKMC were generally more confident pre-training than MUSC participants (Table 5). MUSC participants improved more in confidence, although post-training confidence at MUSC (median=4.2; IQR=3.0-4.6) remained significantly (p=0.02) lower than at MKMC (median=4.9; IQR =4.4-5.0).

Grading tool reports from the practice videos which contained six intentional critical errors generated by the three trainers-in-training in Uganda revealed one trainer correctly identified all six out of six critical errors. The second identified five of the six. The last grader noted five of the six critical errors, but incorrectly marked two of those five as non-critical.

Grading tool reports generated by the newly trained trainers

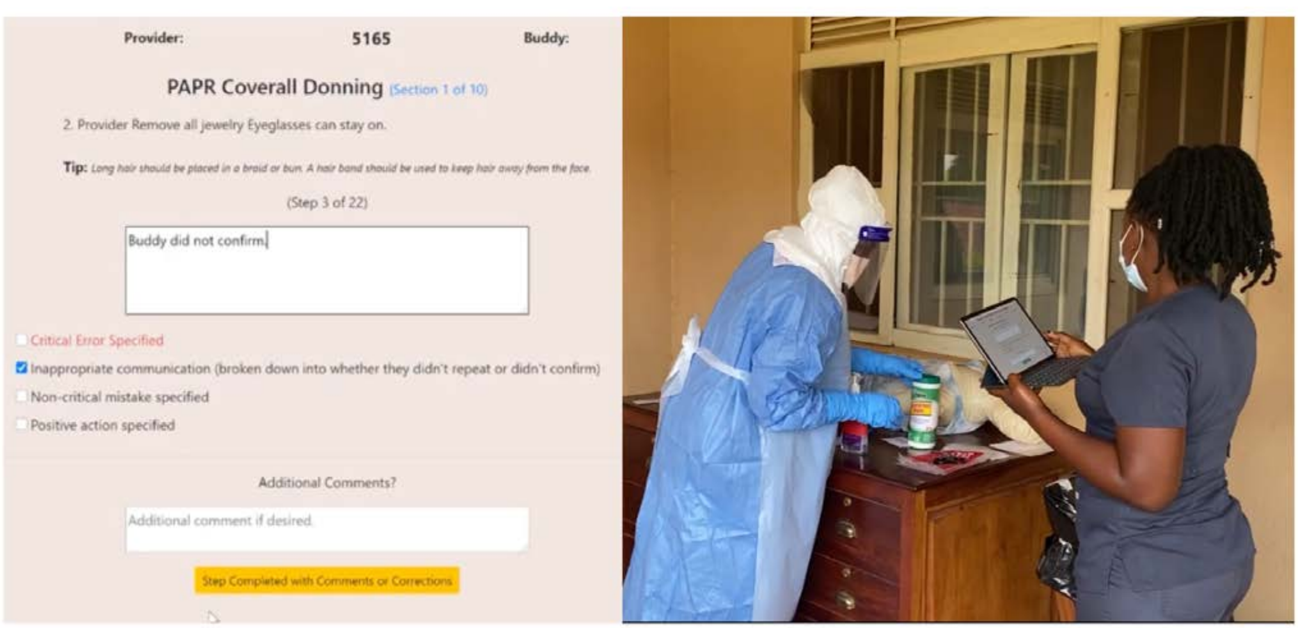

Figure 2. Screenshot of one step in the simulation scenario as it appears on the grading tool used by trainers during simulation training (left) and photo of a trainer using the grading tool on Samsung tablet device during simulation training at MKMC (right).

demonstrated a total of 20 critical errors were recorded at MUSC and five at MKMC. Trainers at MUSC recorded 89 comments on trainee performance (including 35 positive comments and 54 negative comments). MKMC trainers recorded 12 comments 11 of which were negative. The mean time to complete each scenario did not differ by site apart from one scenario, "Gown with N95 Donning" which had a mean time at MUSC of 7.7 minutes (SD 2.9) versus 13.7 minutes (SD 5.4) at MKMC (p=0.04) and all groups completed simulation training within the allotted one-day period.

Discussion

This pilot study demonstrates the feasibility of utilizing an internet-based course with a train-the-trainer component designed to rapidly develop new trainers to provide simulation education to HCWs in a lower-resource setting in Uganda.

Anticipated differences in resources resulted in pre-emptive adaptations to the course. Only five of the nine participants at MKMC reported having consistent or any internet access at their homes. Thus, the Part 1 "remote online study" portion at MKMC was done on the hospital campus using a Wi-Fi hotspot generated by a 4G mobile wireless router. This does expose a limitation of the internet educational modality in regions with no internet connectivity. However as mobile devices become more universally accessible, this trial shows that this modality can be utilized in settings similar MKMC where connectivity in the home is unavailable but access to internet on hospital campuses or through the use of mobile devices allows temporary connectivity for course access.

Significant improvements in post- test knowledge scores at MKMC suggest the online curriculum was effective despite online education being a less commonly used modality in Ugandan educational systems. When comparing the pre- and post-test knowledge scores in our MKMC cohort to our MUSC cohort, we found MUSC trainees had higher knowledge pre-test scores, which could reflect the higher educational and therefore knowledge level of the trainees or better test-taking skills. Nonetheless, both groups saw improvement in post-test scores.

Simulation training at both sites was low-fidelity using mannequins outside of a formal simulation center. The MUSC simulations occurred in a larger indoor building using Laerdal mannequins (~$2,800 USD) versus an outdoor pavilion used at MKMC using inflatable costume mannequins purchased online from

Table 3. Demographic characteristics of participants at MKMC and MUSC.

	MUSC trainers N=3		Uganda trainers N=3		MUSC trainees N=6		Uganda trainees N=3	
	n	(%)	n	(%)	n	(%)	n	(%)
Gender								
Female	3	(100.0)	2	(66.7)	3	(50.0)	4	(66.7)
Male	0	(0.0)	1	(33.3)	3	(50.0)	2	(33.3)
Education								
Baccalaureate	1	(33.3)	1	(33.3)	4	(66.7)	1	(16.7)
Masters	0	(0.0)	0	(0.0)	1	(16.7)	0	(0.0)
MD	0	(0.0)	0	(0.0)		(0.0)	0	(0.0)
Other	2	(66.7)	2	(66.7)	1	(16.7)	5	(83.3)
Current employment								
RNs	1	(33.3)	1	(33.3)	1	(16.7)	5	(83.3)
Med techs	2	(66.7)	1	(33.3)	2	(33.3)	1	(16.7)
Midlevel provider	0	(0.0)	1	(33.3)	0	(0.0)	0	(0.0)
Medical students	0	(0.0)	0	(0.0)	3	(50.0)	0	(0.0)

Table 4. Didactic learning scores at MKMC and MUSC.

	Pre-test Mean ± Std		P-value MKMC *vs* MUSC	Post-test Mean ± Std		P-value Pre and Post	P-value MKMC *vs* MUSC	Absolute change in score Mean ± Std		P-value MKMC *vs* MUSC
MKMC	17.2	±1.9	0.04	21	±4.4	0.04	0.22	3.8	±3.3	0.83
MUSC	20	±2.3		23.5	±1.4	0.005		3.5	±1.7	

Table 5. Confidence scores at MKMC and MUSC before and after training.

	MUSC (USA) Median (IQR)		MKMC (Uganda) Median (IQR)		P-value MKMC *vs* MUSC*
Confidence before training	3.2	(2.1-3.9)	4.6	(4.4-4.8)	0.01
Confidence after training	4.2	(3.9-4.6)	4.9	(4.4-5.0)	0.02
Change in confidence score	0.8	(0.4-1.5)	0.2	(0.1-0.2)	0.01
P-value Pre and Post**	0.06		0.03		

*Rank sum test. **Signed rank sum.

Amazon.com ($20 USD). Prior research has shown that high-cost, realistic simulators are not per se superior to low-cost simulations.[17–21] Psychological fidelity, or an individual's buy-in to the simulated scenario, can have a greater impact on education. MUSST simulations were designed to be implementable in any room with the addition of a small number of supplies. The supplies needed to run the MUSST curriculum cost a total of $7,857 USD in Charleston, USA, and a total of $2,246 USD in Masindi, Uganda. The MUSST model offers a solution to one of the major obstacles to simulation education in Sub-Saharan Africa: the high cost of simulation centers. It also avoids the use of clinical care spaces, which may be in short supply or dangerous during an actual Ebola outbreak.

Prior research demonstrates that mastery-based simulation education in high-resource settings improves confidence in performing clinical tasks.[14,22,23] We similarly found that both our cohorts experienced significant improvements in confidence levels following the MUSST training. This confidence in performance capability is important in the high-stress environments encountered during Ebola outbreaks, especially in settings with limited access to care. Lack of confidence in providing Ebola patient care has been associated with refusal to provide care to patients with EVD.[6] Additionally, HCW confidence can support HCW resilience during disease outbreaks. A review and meta-analysis of 59 studies by Kisely *et al.* (2020) found that lack of confidence in infection control, lower perceived personal-self efficiency and perceived lack of adequate training were all associated with an increased risk of adverse psychological outcomes in HCWs during emerging infectious disease outbreaks.[24] Inversely, self-perception of being adequately trained and supported was associated with a decreased risk of adverse psychological outcomes in HCWs.

Reports from the simulation training of trainees by the newly trained trainers show that the majority of critical errors occurred in PPE donning and doffing. These findings are consistent with past research which demonstrates that self-contamination is most likely to occur during the doffing process.[25-27] This emphasizes the need for high quality training in these particularly critical processes. MUSST's mastery learning technique with its competency-based structure and the utilization of checklists aligns well with existing donning and doffing guidelines supported by the WHO and CDC.[28] Future research is needed to determine how MUSST training affects PPE donning and doffing skills over time.

While our pilot trial proved the course could be completed within the allotted amount of time in the setting of a rural hospital in Uganda, we also noted areas for improvement, especially in the train-the-trainer aspect of the curriculum. In reviewing the performance of newly trained trainers, grading the example videos with 6 intentional critical actions, it was noted that while most errors were noted, some critical errors were missed by all trainers. This suggests that more robust practice is needed prior to trainers being prepared to run simulation scenarios. In hindsight, our curriculum should have included a review of the critical errors and how to document as part of the learning material provided for trainers.

Overall, the grading tool itself proved less utilized in the training at MKMC. Trainers at the MUSC site recorded a much higher number of both positive actions and errors in the grading tool than the trainers at the MKMC site (89 *vs* 12). One hypothesis for this relates to familiarity with using a tablet keyboard. All MUSC trainers had previous experience using a tablet device, whereas none of the MKMC trainers had previously used a similar device. Feedback from participants of prior research evaluating the use of technology for Ebola simulation training in West Africa indicated that participants were less familiar and less comfortable with using computers than they were with using smartphone technology with a touchscreen interface.[29] Our simulation grading tool allowed touchscreen capture of step-by-step performance (Figure 2). However, to record comments, the tablet keyboard was required. Future iterations of the grading tool software designed for use in SSA should consider utilizing a touchscreen keyboard for capturing comments.

Beyond the physical constraints of familiarity with the keyboard, we hypothesize that experience with the concepts of simulation education and debriefing was more foreign to our Ugandan trainers. While MUSC trainers recorded comments for both positive and negative actions, MKMC trainers primarily recorded negative comments. The purpose of debriefing is to recognize strengths alongside areas for improvement to promote learning and improve skills. The absence of positive comments used in debriefing sessions in the MKMC group as compared to the MUSC group suggests that more emphasis needs to be placed on this aspect of debriefing. It was noted by the research team that while MUSC trainees spent more time recording errors, MKMC trainees were more likely to verbalize praise or critiques without documenting comments in the grading tool. This may reflect differences in cultural teaching technique as well as possibly differences in English language written fluency. Despite all participants being fluent and literate in English, it is not the first language of the Ugandan trainers. Though anecdotal, our observations suggest that RCDP, with the ability to pause and provide immediate verbal feedback, occurred more naturally for Ugandan trainers as opposed to more traditional, end-of-simulation debriefing using recorded comments. Both RCDP and traditional debriefing techniques improve simulation education outcomes.[13,30] However, waiting until the end of simulation scenarios before providing debriefing allows trainees to reflect and explore experiential learning that occurred during the simulation. It provides trainers an opportunity to reinforce lessons learned. One strategy to improve education on the debriefing that has been successfully utilized in diverse and often resource-limited settings is the Vital Anaesthesia Simulation Training (VAST) program, which uses pre-recorded scenarios with examples of proper debriefing technique to teach debriefing to new facilitators.[12] Future iterations of the MUSST train-the-trainer curriculum intended for use in Uganda may want to utilize similar methods to implement more robust debriefing education.

A major limitation of this study is its small sample size. We demonstrate the feasibility of using the course in two vastly different settings, as may be encountered in an actual Ebola outbreak. While observations from this trial can be used to guide future curriculum design and implementation, further studies with larger study populations are needed to better evaluate its efficacy in a variety of environments.

Frontline HCWs can be trained using the internet and low-cost simulation to be trainers that satisfactorily and rapidly train others to safely use PPE and conduct routine clinical tasks in Ebola patient care. It bridges the gap between providing extensive cost-prohibitive in-person training and rapidly disseminated theoretical training without hands-on experience. Our simulation model is ideal for the training of HCWs in the management of novel or evolving disease outbreaks when improper task performance can be life-threatening. Through its train-the-trainer model, MUSST ensures sustainability by creating local simulation educators. This educational modality could be adapted to other HCPs. Future research is needed to determine whether this form of education leads to safe conditions during real Ebola outbreaks, and how this educational modality compares to traditional training models. The

COVID-19 pandemic brought to the forefront the profound burden of disease HCPs can cause in HCWs, emphasizing the value of just-in-time training.[5,13] With high consequence emerging infectious diseases on the rise, the continued development of rapidly deployable, effective training modalities to protect HCWs and safely care for patients should be a global health priority.

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Online supplementary materials

APPENDIX A: PAPR with coverall doffing scenario checklist
APPENDIX B: Body bagging in PAPR, coverall donning and doffing station. Spill clean-up & waste bag disposal in coverall with N-95.