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Health Worker Focused Distributed Simulation for Improving Capability of Health Systems in Liberia

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Abstract

Introduction: The main goal of this project was to produce an adaptable learning platform using virtual learning and distributed simulation, which can be used to train healthcare workers, across a wide geographical area, key safety messages regarding infection prevention control (IPC).

Methods: A situationally responsive agile methodology, Scrum, was utilised to develop a distributed simulation module using short one week iterations and continuous synchronous plus asynchronous communication including end users and IPC experts. The module contained content related to standard IPC precautions (including hand washing techniques) and was structured into three distinct sections related to donning, doffing and hazard perception training.

Outcome: Utilizing Scrum methodology, we were able to link concepts applied to best practice in simulation based medical education (deliberate practice, continuous feedback, self-assessment and exposure to uncommon events), pedagogic principles related to adult learning (clear goals, contextual awareness, motivational features), and key learning outcomes regarding IPC, as a rapid response initiative to the Ebola outbreak in West Africa. Gamification approach has been used to map learning mechanics in order to enhance user engagement.

Conclusion: The developed IPC module demonstrates how high frequency, low fidelity simulations can be rapidly designed using scrum based agile methodology. Analytics incorporated into the tool can help to demonstrate improved confidence and competence of healthcare workers who are treating patients within an Ebola Virus Disease outbreak region. These concepts could be used in a range of evolving disasters where rapid development and communication of key learning messages is required.

Introduction

Already *'fragile health systems'* in West Africa have been damaged further by significant reduction in numbers of health care workers due Ebola Virus Disease – efforts to recruit and train local workers have been highlighted as an extremely important measure to help fight the outbreak, build up trust in the local community, and improve the health system so that sustainable improvements in health care can be made.[1]

Effectiveness of traditional training in the Ebola outbreak is constrained by affordability, the number and location of experts and the logistical difficulty of accessing workers in daily contact with patients in remote regions. It is extremely difficult to sustain the learning required and spread best practice using traditional training techniques, especially in areas with low literacy levels.

Immersive simulation using virtual reality (VR) has been shown to enhance learning outcomes through both the learning experience and the interactive experience. Interaction during VR simulations allows participants an element of control where instructional choices can be made which promote active learning and reflective thinking.[2] VR provides an adaptable learning platform which can be widely distributed to workers from varied educational backgrounds in order to convey important safety principles regarding infection prevention control (IPC). Benefits of using virtual environments for learning allows 'acting on the world' in experiential spaces, where participants 'learn by doing' and observe the outcomes of their actions.[3]

Kneebone et al. have recognized the need to provide low cost, portable facilities to improve accessibility of simulation and provide *'just in time training'* when and where it is needed through the concept of the "distributed simulation" model.[4] Combining distributed simulation and VR on a conventional laptop or tablet could provide simulation training which is standardized, more affordable to the whole community and widely accessible with *'just in time training'* within reach of all.

The main aim of this project was to produce an adaptable learning platform using VR and distributed simulation which could be used to train healthcare workers, across a wide geographical area in Liberia, key safety messages regarding IPC.

Methods

The prototype module for IPC training was developed over a 3-month process as part of a rapid response initiative to the Ebola crisis in West Africa.

Design of distributed simulation[4] involves three main stages:

1. Identification of key elements from real clinical settings
2. Presentation of these elements in a lightweight, inexpensive & portable environment, and
3. The ability to recreate & replay clinical scenarios

The development team comprised Infection control experts and key stakeholders in Liberia tasked with building capacity of the health service and implementing IPC training. These members were responsible for identifying key content for the training such as IPC guidelines and sourcing authentic elements from the clinical environment which could be incorporated into the tool. Simulation and technology enhanced learning specialists were responsible for presenting these elements in the virtual reality platform and for designing the tool so that engaging and immersive clinical simulations were created for the participants.

The heterogeneity of end-users and the prospect of constantly changing needs in Liberia required an evolutionary development process that relied on incrementally adding and testing new features on an iterative basis to ensure that the clinical scenarios provided in the tool were acceptable and appropriate for healthcare workers in Liberia. Agile development methodologies were of particular interest for the purpose of the project since these involve; building products by empowering and trusting people, acknowledging change as a norm, and promoting constant feedback.[5] Key principles which influenced the conduct of this development phase were:

- End-user satisfaction

- Open to changing requirements

- Harmonious involvement of end-users and developers

- Sustainable development

- Self-organizing teams

- Regular feedback and reflection

A number of agile methodologies were available e.g. Agile Unified Process (AUP), Dynamic Systems Development Method (DSDM), Essential Unified Process (EssUP), Extreme Programming (XP), Feature Driven Development (FDD), Open Unified Process (OpenUP), and Scrum.[5] Among these approaches Scrum was chosen to fit best within the context of our project. The key differentiators that made Scrum the preferred choice as compared to other approaches were:

- Only what is needed gets developed
- Stringent quality mechanism through iterative and incremental process
- Very flexible to change (as situation changes on a daily basis in Ebola affected countries)
- A highly transparent process for all stakeholders

Founded on the concept of empirical process control, Scrum is a lightweight agile methodology, which enables delivery of software in small iterative cycles without prescribing stringent processes.[6] Such an approach is ideal for a project where there is an environment of high changeability with conflicting and competing multiple stakeholder interests requiring an open and flexible development process. A combination of software platforms was chosen for the development; 'Unity 3D' was utilized for the game engine, 'Blender' for 3D modeling and animations, 'Mixamo' library for 3D models, and 'Adobe audition' for audio management.

Figure 1 displays a typical scrum project, which was adapted slightly in terms of the iteration cycle lasting 1 week rather than 2-4 weeks. Daily meetings were scheduled with the development team and sprint retrospective every week. Due to the volatile nature of the continually changing requirements based on outbreak situation on the ground, it was decided to convene videoconferences three times per week during the development phase that contributed towards the sprint retrospective. Table 1 shows how features of Scrum methodology were incorporated into the project design and Table 2 highlights key terms and definitions utilised.

Table 1 Features of Scrum methodology which were implemented within the project

Scrum Features	Project Implementation
Small development teams co-ordinated by Scrum master	The lead developer co-ordinated two small animation teams and integrated 3D models, animations and audio to the core Unity 3D game engine
Product owner controls the development process	The product owner managed the whole requirements prioritisation for each iteration and planned future iterations based on continuous stakeholder feedback. Ensured that priorities were aligned to the overall goal.
Iterative, time-boxed sprint (iteration) driven incremental development	12 iterative development phases were conducted, with each iteration lasting one week. Each phase included improvement in aspects from earlier iterations, fixes and one or more new features.
Flexible sprint goals adjustable by developers and agreed by product owner during Sprint Planning (SP)	At the start of each week/iteration the product owner and scrum master planned/re-planned the required work for the next iteration based on feedback from all stakeholders.
Daily Scrum meeting including the product owner	Daily (15 minute) lunchtime meeting with product owner, Scrum master and other team members (as and when required) via Skype
At the end of each sprint the outcomes are demonstrated and evaluated along with feedback to the development team known as Sprint Retrospective (SR)	Every Friday an online demonstration session was organised for the whole team using Zoon/VSee and the session recorded for stakeholders who could not attend. Feedback informed the next iteration planning process. This session was used for assessing accuracy of content, flow of process, utility of gaming mechanics and local feedback from stakeholders on the ground in Liberia.

<p align="center">**Table 2 Key terms and definitions utilised in the project**</p>

Terms	Definitions
Agile Methodologies	A group of software development methods in which the problem specification and resulting solution collaboratively evolve through self-organizing and cross-functional teams. Key principles include adaptive planning, early delivery and continuous improvement which encourages rapid and flexible response to change. (Read more: http://agilemanifesto.org/)
Evolutionary Development	Agile methodologies enable evolutionary development in the sense that the final product is an outcome of multiple iterations and continuous stakeholder engagement and feedback. The final product may be completely different from what was originally conceived but will better meet the needs of the stakeholder group.
Virtual Reality	Virtual reality provides a safe computer-generated environment with realistic images, sounds and animations that offer a simulated experience of the real world minimising or eliminating risks for patients and healthcare workers.
3D Immersive Technologies	3D Immersive Virtual Reality (3D IVR) is a technology which provides the user a sense of presence and immersion in a virtual environment. Presence is achieved through coherently understanding and accepting the virtual simulation while immersion is established through having the ability to navigate around and interact with the objects in the virtual scene[7]

Outcome

The IPC module was developed into four sections which were each aligned with specific adult learning principles (Table 3).[8]

1. Introduction to the Ebola virus and importance of effective Personal Protective Equipment (PPE) use
2. Training in putting on PPE
3. Identification of risks and hazards in the clinical environment
4. Training in taking off PPE

Table 3 Adult learning principles embedded within the module

Adult Learning Principles[8]	Developed Sections
Adult Learners need to know why are they learning	Section 1: Introduction to the Ebola virus and importance of effective PPE use
Adult learners need to actively involved in the process	Section 2: Training in putting on PPE Section 4: Training in taking off PPE
Adult learners are motivated by the need to solve problems.	Section 3: Identification of risks and hazards in the clinical environment
The previous experiences of adult learners must be respected and built upon.	Section 2: Training in putting on PPE (Selection of locally available equipment) Section 3: Identification of risks and hazards in the clinical environment (Risk and Hazards encountered in Liberia)
The educational approach should match the diversity and background of adult learners.	All Sections: In Liberian English augmenting face-to-face training.

Content was aligned with World Health Organisation guidelines[9] and the Ministry of Health (Liberia) priorities for building capacity in the health system. PPE protocols were focused on use by healthcare workers in Primary Health Facilities rather than Ebola Treatment Centres. In this regard the study group had to differentiate between *basic PPE* (for use in Triage of patients), *Enhanced PPE* (for high risk patients at PHUs) and *Full PPE* (for use in Ebola Treatment Centres). The first prototype module was built around the need to build capacity in Primary Health Units and is based on the use of *Enhanced PPE*. The module was developed to effectively facilitate learning by introducing appropriate simulation learning features[10] demonstrated in Table 4.

Table 4 Simulation features implemented within the module

Simulation Features[10]	Implementation
Repetitive practice	The learners are required to identify the correct sequence of putting on (donning) and taking off (doffing) PPE twice before they can proceed. If they get the sequence wrong they start again.
Continuous feedback	If the learner makes a mistake, instant feedback is provided via a visual checklist before repetitive practice is allowed. Feedback on appropriate ways for donning and doffing PPE is given at each step.
Self-assessment through near peer teaching	An on-screen avatar plays the role of a "buddy" healthcare worker to train the participant at each stage of the simulation. The teaching phase is then followed each time with a testing phase (which is supervised by the buddy). During the testing phase each participant is allowed to make their own choices for:

	• Selection of equipment • Sequence of steps for donning • Choice of critical actions for each step in the sequence • Identification of risks and hazards in the clinical environment • Sequence of steps for doffing Continuous feedback through prompts, visual checklists and verbal feedback from "buddy".
Curriculum integration	Learning outcomes in the module was mapped to the Ministry of Health Liberia "Keep Safe Keep Serving" Guidelines and World Health Organisation guidelines for infection prevention control.
Exposure to uncommon events	Exposure of critical risks and hazards in the clinical environment through a dedicated risk and hazard section.

The content of the module was delivered with minimal amount of text and the incorporation of voiceovers in local dialect. Individual steps for putting on and taking off PPE were identified through international consensus guidelines from the Centers for Disease Control and World Health Organisation.[9] These steps were reviewed by stakeholders in Liberia, plus infection control experts within the project team. Each step was merged into an interactive learning sequence which participants could explore as an on-screen avatar in conjunction with a virtual buddy to provide; key learning points, commentary and instruction throughout the process. The virtual buddy was incorporated into the simulations in order to promote the use of safety checklists when putting on and taking off PPE, plus to emphasize the importance that observers should take part in checking correct procedures. In order to add educational and professional context to the simulations and facilitate the 'near peer teaching' concept, the buddy was animated to look like a Liberian healthcare worker and voiceovers sourced from Liberia for both English and Liberian English versions of the script.

Gamification was incorporated into the digital components, as a mechanism to engage users during the module, through the isolation of active ingredients (time constraints, challenge, leader boards, clear goals, badges, number of turns etc.) that make games addictive, engaging and fun.[11][12] Various gaming mechanics that enable user engagement were mapped to appropriate learning mechanics (including key simulation features) as shown in Table 5. Instructional learning was incorporated into the tool with the use of an on-screen avatar (Figure 2) providing near peer teaching through the use of short tutorials demonstrating the correct sequence of donning and doffing PPE, plus key critical actions for each step (see slide 7, Supplemental Digital Content 1, which demonstrates a mix of videos and animations used for critical steps). Discovery based learning was embedded through the use of interactive choices throughout the module; participants were required to choose the correct equipment (Figure 3) and make decisions regarding sequence of steps and specific actions to progress to the next stage of the training. Incorrect decisions were highlighted immediately and prompts provided with the use of visual checklists to provide feedback during training (Figure 4).

Participants who successfully completed specific stages of training were rewarded and allowed to progress to higher levels of the module providing motivational learning within the tool (Figure 5). A hazard perception section was designed as a higher stage level, where participants would be able to immerse themselves in a clinical area and identify risks and hazards (Figure 6). Feedback was provided visually regarding the number of hazards identified and verbally by the on-screen avatar reinforcing key learning messages related to each hazard (Figure 7). Please also refer to Slides 5-10 in the Supplemental Digital Content 1, which further demonstrates these attributes.

Table 5 Gaming and learning mechanics usage

Game Mechanics	Learning Mechanics	Implementation	Usage
Storyline / Cut Scene	Instructional	Pre-rendered videos	Ebola Virus explanation, hand washing, using the module
Cascading Information	Guided Tutorials	Donning Doffing	Buddy Guiding trainee with WHO approved steps
Selecting	Discovery	Equipment selection Scene	Trainee selects equipment based on availability and required protection
Movement	Activity/Action/Task	3D environment, interactional control	Immersion, reacting to hazards etc.
Capture/Elimination	Activity/problem solving	Identify risks and respond to hazards	Dedicated risk and hazard scenes highlighting dangers
Protégé Effect	Motivation Responsibility	Donning and Doffing	Show a colleague about PPE steps
Feedback	Feedback	Checklist Prompts	Correct/incorrect selection of PPE for required protection Risk/Hazard prompts
Behavioral momentum	Repetition Reflection	Attempts Progression Restart on fail	No progression if adequate gear not selected prompting reflection; 2 incorrect equipment selection forces back to guided scene.

Discussion

Agile development using Scrum methodology has been used in this project to link; concepts applied to best practice in simulation based medical education, pedagogic principles related to adult learning, and key learning outcomes regarding IPC, as a rapid response initiative to the Ebola outbreak in West Africa. Our approach utilizes 3D simulation and graphics with an interactive experience to enhance learner engagement, on a platform that can be accessed in a conventional laptop browser or tablet (with minor alterations). No active Internet connection is required for running the simulation and results are logged locally on the device. The results are reported to our server whenever Internet connection is detected and as a backup could also be copied and emailed by the trainer. Virtual reality and distributed simulation have been combined to remind, refresh and reinforce key learning messages acting as enablers to improve knowledge retention and reach a dispersed workforce.

Stakeholder engagement in the development process has been instrumental in utilising expert input and end-user feedback to address these priorities and provide a simulated environment which can be distributed widely. Best evidence in the use of simulation based medical education (SBME) includes the integration of simulation within an overall curriculum, choosing appropriate fidelity for interventions, participants playing their own roles in the correct educational and professional context, and allowing opportunities for repetitive practice and feedback.[13] We have attempted to include all these principles in the IPC module through the use of internationally agreed protocols for PPE, near peer teaching, on screen avatars, realistic clinical environments, gamification and self-assessment.

Kneebone et al.'s original model of distributed simulation involved an inflatable igloo and other lightweight props, to replicate a clinical environment where surgeons can practice psychomotor skills without the need to attend a high fidelity simulation training centre.[4] Our interpretation of the distributed simulation model is physically different since we have incorporated VR into the solution but theoretical specifications of distributed simulation have been embedded in the tool:

- An immersive virtual clinical environment has been created, where participants can interact as an on-screen avatar in a clinical area which closely resembles their own healthcare facilities.
- All cues are incorporated within the learning tool without the need for additional cues or clinical equipment.
- The tool incorporates deliberate practice of key critical steps with in-built feedback mechanisms to facilitate feedback / "observation" from an on-screen buddy. (See Slide 8, Supplemental Digital Content 1, which shows repetition pattern and checklist based feedback)
- The laptops / tablets are practical, lightweight and easily transportable
- A wide range of clinical settings can be recreated easily according to individual needs and changing circumstances, without the need for costly manikins / additional equipment

In a recent editorial, Geoff Norman emphasised the fact that simulation should not be part of a standalone simulation program but combined with other educational methods within the notion of *simulation augmented medical education* (SAME) rather than SBME.[14] Norman argues that simulation should be more easily accessible for all and that faculty should abandon the requirement

for "authenticity at any cost". In this respect, the use of high frequency, low fidelity simulation could be more effective than high fidelity simulation, especially if combined with other educational methods as part of an overall program. High frequency, low fidelity simulation has been shown to make major differences to morbidity and mortality in situations with resource-limited circumstances such as the Helping Babies Breathe Program.[15] Rapid distribution of the IPC module through improved accessibility to laptop devices and tablets could potentially make marked changes to disease transmission rates in West Africa through high frequency, low fidelity simulations designed to increase the number of workers who are confident and competent to treat patients at risk of Ebola.

Combining immersive simulation, local hands on training, and assessments of understanding and skills would be able to accurately mimic *'the critical cognitive and motor elements in the criterion task'* which are prerequisites for appropriate fidelity of simulations.[14 16]

There are an increasing amount of academic publications advocating the need to rethink the "traditional in-class, lecture-based course model" and to use the "flipped classroom" format which allows the learner to cover educational coursework by themselves on-line, prior to face to face training time.[17] Contact time with expert faculty can then focus on difficult concepts during student centred activities. The use of VR and distributed simulation for responding to crises situations has great potential to save limited resources if the training is worked into a "flipped classroom" format. Contact time with expert trainers could be used more efficiently when protective equipment and clothing is made available during workshops. Participants could then focus on practising key critical actions highlighted by the module and reinforce key learning messages from national and international curricula, which have been previously experienced through simulation training.

Bill Gates, philanthropist, has identified the use of simulation for building stronger health systems in developing countries as being crucial in global preparation for future epidemics, as well as providing significant benefits in terms of improving primary health care in these countries.[18] Our project is committed to implementing and evaluating VR and distributed simulation across West Africa to build capacity, resilience and sustainability of the healthcare system. Further studies are required to evaluate how learners engage with various conceptual elements incorporated within the virtual reality and distributed simulation model and how they complement other educational interventions.

Acknowledgments

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Figures

Figure 1 Typical Scrum project. Overview showing development sprints (iterations) and feedback loops.
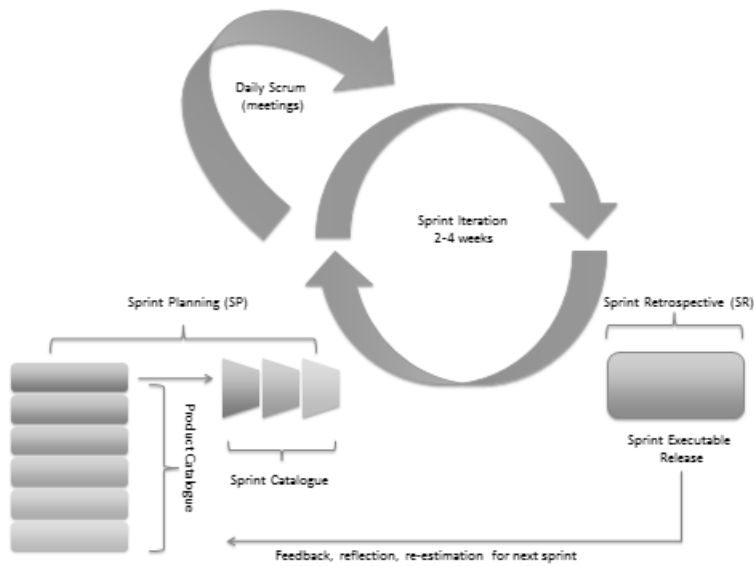

Figure 2 Instructional learning utilised in the module. Near peer teaching embedded within the module through the use of an avatar buddy. The buddy explains key learning messages regarding Ebola and PPE throughout the module.

Figure 3 Learner enabled selection fostering discovery process. Learners select equipment for the module based on locally available resources.

Figure 4 Repetitive self-assessment / feedback through the use of visual checklists and audio feedback from virtual buddy. Learner enabled interaction to make choices regarding correct PPE donning and doffing steps.
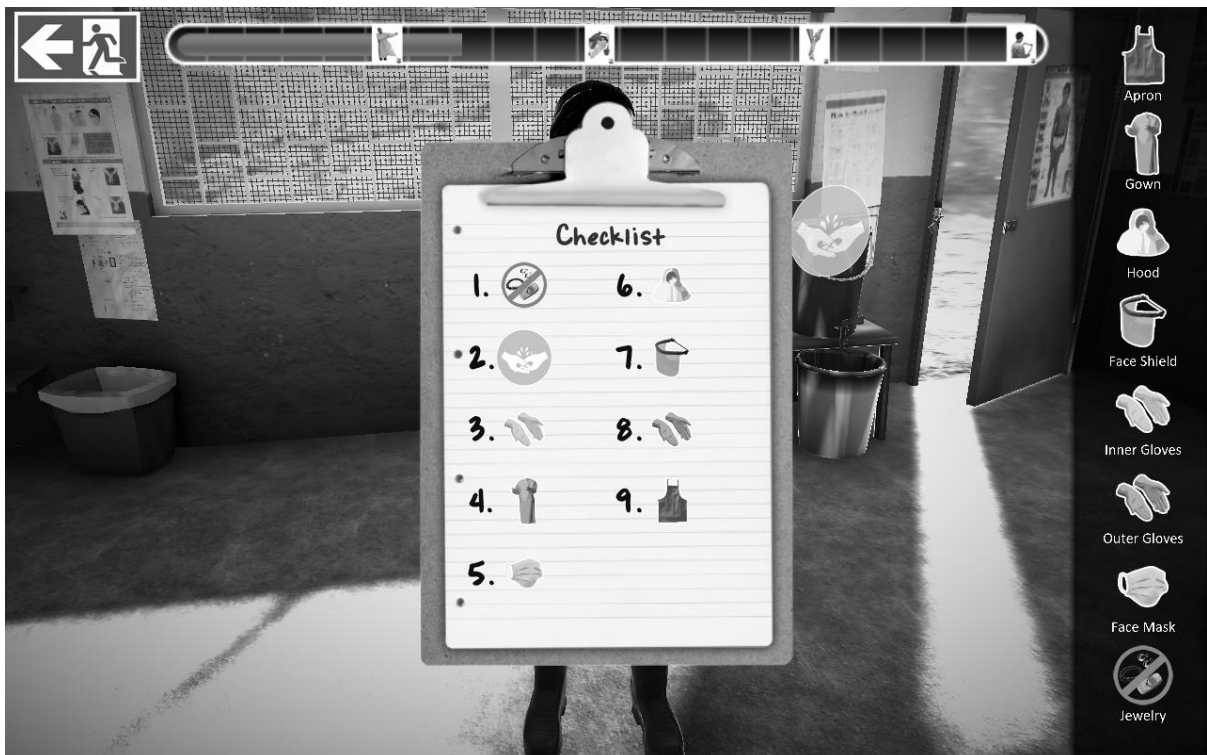
Figure 5 Continuous encouragements throughout the module. Learner moves to higher levels of the module once each stage is complete to provide motivation.

Figure 6 Risk assessment and hazard perception scene. Identification of hazards required before progression to next scene.

Figure 7 Visual feedback provided regarding the number of hazards identified in the hazard section. Feedback also provided verbally by the on-screen avatar reinforcing key learning messages.