

Development and initial testing of e-learning stroke care modules for low- and middle-income settings: a user-centered co-design project

Louise Johnson

University Hospitals Dorset

Monica Appiah

Korle Bu Teaching Hospital

Farouk Ndeegu Abuud

Tamale Teaching Hospital

Julius Ambor

Ho Teaching Hospital

Josephine Attoh

Korle Bu Teaching Hospital

Luci Blight

Great Western Hospitals NHS Foundation Trust

Deborah Broadbent

University Hospitals Dorset

Rachel Chila Mubanga

Chipata Level One Hospital

Liz Cullen

Kent and Medway Health NHS Trust

Yohanna Gebreyohannis

Yale University

Malango Goma

University Teaching Hospital

Cynthia Osei Yeboah

Korle Bu Teaching Hospital

Clare Gordon

Lancashire Teaching Hospitals NHS Foundation Trust

Claire Fullbrook-Scanlon

University of the West of England

Doreen Kawelenga

University Teaching Hospital

Amelia Shaw

Hampshire Hospitals NHS Foundation Trust

Frank Sisali

Chipata Level One Hospital

Lucy Sykes

Hampshire Hospitals NHS Foundation Trust

Claire Spice

Portsmouth Hospitals NHS Trust

Katherine Watson-Short

University Hospitals Dorset

Albert Akpalu

a_akpalu@yahoo.com

University of Ghana Medical School & Korle Bu Teaching Hospital

Deanna Saylor

University of North Carolina

Research Article

Keywords: stroke, workforce, learning, training, elearning, low-income, Ghana, Zambia

Posted Date: August 6th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9427140/v1>

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Additional Declarations: Competing interest reported. AA is an author and an editor in the special edition to which this manuscript has been submitted.

Abstract

Background

Stroke is a leading cause of death and disability worldwide. The greatest burden of stroke occurs in low- and middle-income countries (LMICs), where access to organised stroke care and trained multidisciplinary stroke teams remains limited. Sustainable workforce development is essential to improving stroke care, yet traditional in-person training approaches are resource-intensive and difficult to scale. This project aimed to develop and undertake initial user-testing of culturally and contextually relevant asynchronous e-learning modules to support core stroke skills training for multiprofessional health workers in Ghana and Zambia.

Methods

A user-centred co-design approach was undertaken with healthcare professionals in Ghana and Zambia. Eight e-learning modules, covering core stroke care skills, were developed from established face-to-face training materials and adapted for online delivery. The first two module prototypes underwent user feedback in Ghana, and the final six in Zambia. Feedback was sought from health workers, who were recruited using convenience sampling, with efforts to include diverse professional roles and experience levels. Think-aloud “interviews” were conducted as health workers completed modules to capture real-time feedback on usability, content clarity, and contextual relevance. Comprehensive field notes were recorded, and findings were reviewed through regular team discussions to identify recurring themes. Insights were used iteratively refine content and platform design, resulting in a final suite of 8 published (and freely available) online modules.

Results:

A total of 79 health workers participated (Ghana $n = 34$; Zambia $n = 45$), including physicians, nurses, and physiotherapists. Feedback clustered into three key themes: training structure and user experience, training content, and assessment methods. Participants valued the interactive, case-based design and multidisciplinary relevance of content. Identified challenges included navigation, account registration, and quiz functionality, which were addressed through iterative modifications. The co-design process also fostered interdisciplinary collaboration and leadership development within participating teams.

Conclusions:

This project demonstrates the feasibility of collaboratively developing contextually relevant e-learning modules for stroke workforce development in LMIC settings. Think-aloud methods supported pragmatic

refinement of content and usability. Further research is required to evaluate implementation, scalability, and impact on clinical practice and patient outcomes.

Trial Registration

not applicable

Background

Stroke is the second leading cause of death worldwide, with the majority of global stroke burden residing in lower-income and lower-middle-income countries (1). In sub-Saharan Africa, stroke care faces significant challenges due to limited resources, infrastructure deficits, and a shortage of trained healthcare professionals. Despite these obstacles, several countries are striving to improve stroke care through strategic advocacy, capacity building, and partnership working. Over the past decade, this has seen the introduction of organised stroke unit care in a number of African nations (2). However, many countries still lack comprehensive stroke policies, face challenges in implementing effective stroke care programmes (3), and lack ministry level support.

Integral to delivering effective stroke care is access to a stroke skilled, multiprofessional workforce (4). Where dedicated stroke units are not available, coordinated multidisciplinary teams can contribute to improved outcomes (4). To achieve improvements in the coordination and specialism of care, sustainable workforce capacity building is required. Considering the (often) transient nature of the healthcare workforce, implementation strategies must ensure systematic and ongoing access to training and continuous professional development.

Whilst training health workers (HW) in low- and middle-income countries (LMICs) is essential for improving healthcare delivery, traditional in-person training methods often face limitations. For example, resource constraints and geographical barriers can limit scalability. Online training methods have emerged as solutions to address these challenges, with growing evidence in relation to their effectiveness, accessibility, implementation, and cost-efficiency (5). Whilst barriers relating to a lack of information technology infrastructure may exist, the rapid global increase in both internet/computer access and digital literacy means these obstacles are reducing (6). Thus, online training is one important way in which flexible access to professional development can be optimised in LMIC settings.

Wessex Global Stroke Partnerships (WGSP) is an established collaboration between UK healthcare professionals and partners in Ghana, The Gambia, and Zambia. The partnership takes a multi-faceted approach to supporting sustainable stroke care development, using a 'train the trainer' model for clinical skills development, complemented by initiatives to develop broader skills in multidisciplinary working, leadership, and implementation. Since inception in 2009, WGSP has supported workforce capacity building with a particular focus on *core* stroke skills; increasing HW knowledge and skill alongside facilitating operational systems where these skills can be translated into routine practice (7). To date,

this training has been delivered in-person by UK and local trainers, a successful but resource-heavy and costly method, with limited scope for scale up. In this current phase of work, our aim was to support the professional development of LMIC HW through the development and deployment of culturally and contextually relevant e-learning modules focused on core stroke care skills. Here, we describe the development and initial user-testing of an asynchronous e-learning platform, designed to teach core stroke skills to a multiprofessional workforce in in Ghana and Zambia.

Method

A user-centred co-design (8, 9) project, informed by insights collected using a think aloud approach (10). The project consisted of two phases corresponding to two funding grants. The first was from February 2024 to January 2025 with Ghana; the second from October 2024 to June 2025 with Zambia. This allowed early creation and pilot-testing of two modules in Ghana, followed by development and initial testing of a further six in Zambia. This was a service improvement project, for which ethical approval was not required; exemption was granted by the University of Zambia Research Ethics Council.

Development Principles

We applied co-design principles to support systematic and rigorous development. Through this approach, key development principles were jointly identified and described, ensuring cultural relevance and accessibility within the local contexts. Previous work has defined learner-centered features of online training for health workers in Nigeria (11), and we broadly adopted these features in this current work (Table 1).

Table 1

Design Features – minimally adapted to be relevant to this current project, from those described by Thomas et al (2022) (11).

Learners' context and challenges	Features to include in learning solutions
Mobile devices and connectivity: most users access internet with personal mobile devices using cellular data	Mobile-ready and low bandwidth: optimized for mobile devices and for use over 3G connections/ in areas of potentially low bandwidth
Lengthy registration processes: some platforms have multi-step registration processes or require download of an app	Minimal barriers to entry: does not require the download of new software, has a straightforward registration process and is offered free of charge
Complex user interfaces: some platforms have many different menus, screens, and pages that may have limited utility for learners and can interfere with learning	User-friendly and simple: has a single-screen and single-button navigation experience that does not require any orientation for learners to get started and is focused on learners' priorities and experience
Scheduling issues: HW work may conflict with synchronous events (webinars)	Self-paced and brief: can be accessed at any time and broken into short modules. Function to exit partially completed modules, with saved progress enabling easy return and completion.
Lack of utility: many courses focus on practices appropriate for tertiary care settings or emphasise non-clinical basic science content	Focused and applicable: learning is driven by brief 'vignettes' set in low resourced health care facilities, content focuses on the most fundamental concepts in stroke care, and certificates emphasize HW role-related course content
Passive learning: online courses often rely heavily on video and text, with limited opportunities for interactivity	Immersive learning: learning begins as quickly as possible and is driven by feedback and brief explanations embedded in formative assessment

Content Development

Module content focussed on foundational level stroke specific knowledge - applicable to the whole multidisciplinary team, with minimal requirement for specialist equipment. The intention was for training to create an underpinning knowledge across HW disciplines, applicable to limited resource settings, so that face-to-face training can focus on translation of knowledge to practice with progression of clinical reasoning and skills.

E-learning modules were developed in eight core skill areas (Table 2), based on well-established, existing face-to-face training materials developed by WGSP and previously identified by all partners as priority areas for clinical practice development (7). Initial content was adapted from these existing materials, by UK partners with input from stroke clinical leads for medicine, nursing and physiotherapy in Ghana and Zambia. Photographic materials used in the modules were obtained from hospital settings in Ghana and Zambia to increase relevance to learners.

Table 2
Core Skill Topics

Core Skills Area	Core Components
Positioning	• Importance of good positioning after stroke • Assessment of positioning • Positioning in bed and in a chair • How to transfer someone out of bed after stroke • Shoulder pain
Swallow	• Components of a normal swallow • Mouthcare importance and technique • Feeding strategies • Signs of aspiration and dysphagia • Compensatory strategies including diet modification
Communication Impairment	• Types of communication impairment after stroke, including: - o Aphasia - o Dysarthria - o Apraxia - o Cognitive communication impairments • Strategies to support people with communication impairments • How to support communication partners
Continence Care	• Normal continence • Types of incontinence • Incontinence assessment and management
Mood	• Factors contributing to low mood after stroke • Assessment of mood • Clinical depression • Strategies to support low mood

Core Skills Area	Core Components
Functional Independence	• Recovery of function after stroke • Strategies to support independence • Goal setting • Measuring function
Secondary Prevention	• Modifiable, non-modifiable, and treatable stroke risk factors • Medications and lifestyle adaptations to reduce stroke risk • Secondary prevention counselling
Discharge Planning	• How to support and educate families and carers after discharge • Multidisciplinary involvement in discharge planning • Areas to consider prior to discharge

Module Platform

An e-learning platform was built using the Content Management System (CMS) WordPress (12). The platform was built with registration and log in functionality to allow for future detailed user analytics. This allows HW to create a personal 'learner' profile and monitor/pace their own completion of the modules.

Sampling and Recruitment

Health workers at participating health facilities in Ghana and Zambia, who were available during the study period and willing to provide feedback, were invited to participate. Efforts were made to include individuals from a range of professional disciplines, roles, levels of experience and levels of digital literacy, in order to capture diverse perspectives on the usability and relevance of the e-learning modules. This pragmatic sampling strategy was considered appropriate for the quality improvement aims of the project, which focused on obtaining actionable user feedback to support iterative refinement of the modules rather than achieving thematic representativeness.

Data Collection

The 'think aloud' method (13) was used to facilitate user feedback. Within this method, participants verbalise their thoughts and decision-making as they perform a task or interact with a project. Here, we asked HW's to follow a think-aloud process as they completed an e-learning module. This allowed us to capture real-time feedback on platform usability, how individuals understood and interacted with the

content, and contextual relevance. Healthcare staff who volunteered to participate in module feedback discussions were briefed on the purpose of the activity and provided informed verbal consent.

The first two modules (positioning and swallow) were drafted and underwent a think aloud process in Ghana, conducted face-to-face and led jointly by UK and Ghanaian project leads. This allowed for a trial of the think aloud approach [Appendix 1], as well as review of module structure, content and style.

To introduce and rehearse the think aloud methodology, as a group, participants first completed an exercise making a paper aeroplane, during which they were asked to verbalise their thoughts and decisions. Following this, individual HW held a 1:1 think aloud conversation with a member of the project team. Each HW completed a module from start (logging into the system) to finish (completion of quiz and feedback), whilst verbalising their thoughts throughout. Different devices were used: laptop, tablet, and smart phone. The facilitator prompted only to encourage verbalisation of thoughts and to ensure correct interpretation and depth of information. They also took field notes, including direct quotes where possible. At the end of the session, the project lead summarised and confirmed key points with each HW, whilst also giving an opportunity to provide additional feedback on any points not raised.

Following this, content for the remaining six modules was developed, and these underwent a think aloud process with HW's in Zambia. In this phase, the UK team trained and supported project leads in Zambia (two nurses, two physiotherapists and one medical student) to conduct the think aloud process with their peers. Two virtual sessions, lasting approximately 1 hour each, were facilitated by members of the UK team. During these sessions, the five Zambian HW's underwent training on think aloud method and participated in an interview themselves on a specific module. The Zambian study team then replicated this process locally with colleagues, collecting insights to inform further development of the modules. Zambian HW's participating in a think aloud conversation were reimbursed for their time and provided with a mobile-data allowance to support engagement.

Analysis

As this work was undertaken as part of a pragmatic quality improvement process rather than a formal qualitative research study, conversations were not audio recorded. Instead, facilitators produced comprehensive field notes during and immediately following each session to capture HW comments, observed behaviours, and usability challenges. Field notes were reviewed by the facilitators and wider project team, who met regularly to discuss observations and identify emerging themes related to usability, comprehension, and relevance of module content. A pragmatic, iterative analytic approach was used, whereby recurring issues and suggestions were summarised and used to inform ongoing refinements to the modules. The e-learning content was iteratively modified between rounds of user feedback to address identified barriers and improve clarity, usability, and contextual relevance.

Results

Think-aloud conversations were completed with a total of 79 healthcare workers (HWs), including 34 in Ghana and 45 in Zambia. HW characteristics are summarised in Table 3; they represented a range of professional groups, including physicians (n = 10), nurses (n = 34), physiotherapists (n = 28), and other health professionals (n = 7), with representation from both genders (male n = 36; female n = 43).

Table 3
Participant
Characteristics

Gender (n)	36
Male	43
Female	
Profession (n)	10
Physician	34
Nurse	28
Physiotherapist	7
Other	
Country	34
Ghana	45
Zambia	

Qualitative feedback from think-aloud sessions generated themes across three main domains: (1) training structure and user experience; (2) training content; and (3) assessment methods. Feedback was broadly consistent across countries, professional groups, and module topics. Figure 1 illustrates representative examples of content-related and user interface feedback from the swallowing module desktop interface.

Training Structure and User Experience

Overall, participants responded positively to the structure and visual design of the platform and modules. The interactive format and use of multimedia elements were consistently described as enhancing engagement and facilitating learning. Participants reported that the single-screen navigation and stepwise progression supported ease of use across a range of devices.

Usability challenges primarily related to platform functionality rather than learning content. These included account registration processes, password complexity, and uncertainty regarding navigation between completed sections. For example, one participant queried whether complex password requirements might discourage course registration, while others requested the ability to revisit previously completed content.

These findings informed several refinements, including simplification of registration processes, clearer navigation prompts, and functionality enabling users to re-access completed material and resume partially completed modules

“If you make the password so complex, will it discourage people to continue with the registration?” Nurse specialist, Ghana [swallowing module]

“Can I re-access the content that has been marked complete?” Doctor, Ghana, [positioning module]

Training Content

Participants reported that the concise and practice-focused structure of the modules was positive. The emphasis on brief, clinically relevant content was viewed as appropriate for busy clinical environments, where time constraints limit opportunities for prolonged training engagement.

The use of case-based learning content was widely valued, with participants noting that patient vignettes increased engagement and supported clinical reasoning. Participants also highlighted the importance of providing foundational knowledge applicable across professional roles. Many noted that the multidisciplinary nature of the content promoted shared understanding and supported coordinated team-based care.

Feedback across modules suggested that the opportunity to review responses and revisit earlier content supported reflective learning. In addition, participants reported that the modules reinforced previously learned knowledge while introducing new concepts relevant to routine practice. Several participants described the content as directly applicable to patients encountered in daily clinical work.

Iterative feedback also led to targeted refinements to improve clarity, simplify terminology where required, and ensure contextual relevance to local clinical environments

“I think this summary is good, as it will make you think about your previous answers. You correlate it and see if you are on the right path. If you want to, you can go back and change your answers. For instance, I think I missed prevention of complications of immobility. I’d like to go back and correct”. Nurse specialist, Ghana [positioning module]

“The case study helped make the module more engaging as I was interested in the patient progress” Nurse, Ghana, [positioning module]

“It is interactive so this is good, not just reading and reading” Doctor, Ghana, [positioning module]

“It looks more comprehensive from the last time we reviewed it, so this is good” Physio Zambia, [communication module]

“I had to revise stroke continence management: good revision and relates to a lot of patients” Nurse, Zambia, continence module

Assessment Methods

Interactive quizzes were included within each module to reinforce learning and assess understanding. Participants reported that quizzes were generally motivating and supported active engagement with the content. The availability of a downloadable certificate following successful completion was perceived as an important incentive.

However, participants identified several limitations within the initial quiz design. In particular, the requirement to repeat entire quizzes following minor errors was reported as frustrating and potentially discouraging. Participants also highlighted the need for greater variation in assessment content and clearer instructions regarding progression through the modules.

In response to this feedback, quiz functionality was modified to allow correction of incorrect responses, reduce repetition burden, and improve clarity of instructions. Additional explanatory guidance was incorporated to support users in understanding course requirements and certification processes.

"Pillows, oh I missed an 's'! Oh! Now I need to complete to full quiz again for one typo!" Doctor, Ghana, [positioning module]

"Is the test only on the cranial nerves? This is very academic. We need to mix up the test." Nurse specialist, Ghana, [swallowing module]

"What are the specific rules of the course? Do I need to mark as complete before I move on? Do I get a certificate at the end?" Doctor, Ghana, [positioning module]

Wider Benefits

Beyond module development, the think-aloud process generated several unintended but valuable outcomes. Engagement of a broad range of healthcare workers supported interdisciplinary collaboration both within local teams and across international partners. Participants reported that involvement in module development fostered a sense of ownership and investment in the training materials.

In addition, the process created opportunities for local leadership development, particularly among Ghanaian and Zambian project leads who were trained to facilitate think-aloud sessions. Participants described this involvement as professionally rewarding and valued the opportunity to contribute to locally relevant educational resources

"Happy to be part of the team to develop modules to help with stroke patients. That was amazing just to be part of the team" Physio, Zambia

Iterative Refinement Outcomes

Feedback generated through the think-aloud process directly informed successive refinements to both platform functionality and educational content. These iterative modifications resulted in the finalisation

of eight e-learning modules addressing core stroke care skills. The completed modules are now available through a freely accessible online platform, supporting ongoing scalability and wider implementation

Discussion

The field of technology-enabled learning offers a flexible and sustainable approach to training and continuous learning, especially when it is part of a comprehensive capacity building strategy (6). While distinct challenges relating to infrastructure and digital literacy exist, blended learning approaches can mitigate these issues. Furthermore, e-learning offers the opportunity to train large numbers of healthcare workers in a range of clinical skills, with greater geographical reach than in-person training alone.

In this project, we deliberately focused on core stroke skills, raising awareness and knowledge of the fundamental aspects of care to benefit the majority of patients, and using a platform that allowed delivery with limited or no additional resources. This was deemed essential to ensure relevant training across a range of settings.

The think-aloud method proved effective for eliciting detailed feedback on the e-learning modules, enabling HW's to articulate their reasoning, reactions and experiences while engaging with the material. This approach facilitated the identification of both strengths and areas for improvement, allowing potential limitations of the modules to be addressed through iterative development cycles. Think-aloud techniques are widely used in usability and educational research because they provide insight into users' cognitive processes and interaction with learning materials (14, 15). Notably, the nature of feedback provided was broadly consistent across professional groups (including doctors, nurses and allied health professionals), study sites (Ghana and Zambia), and across different module topics. This consistency suggests that the modules address common learning needs and may have relevance across diverse professional roles and healthcare contexts. Taken together, these findings provide preliminary evidence that the modules may be applicable across a range of sub-Saharan African settings, although further evaluation in additional contexts would strengthen conclusions relating to broader generalisability.

Research has demonstrated that online training methods can be comparable to traditional methods in enhancing knowledge among HW (16). Future work must focus on broader effectiveness; particularly if/how the knowledge gained through e-learning methods translates into clinical delivery and overall professional competence, and whether knowledge acquired is retained long term. Blended approaches are likely to be required to optimise the translation of theoretical knowledge into real-world changes in behaviour. Future research must therefore consider this multifaceted approach to clinical skills training, and explore the long-term impact and scalability of e-learning interventions.

This study has several strengths. The e-learning modules were developed locally, ensuring that the content was contextually relevant to the healthcare systems and clinical realities of the settings in which they are intended to be used. Such locally informed development is important for improving the acceptability and relevance of digital learning interventions in global health contexts. A further strength is the use of think-aloud methods to evaluate the modules, which enabled in-depth exploration of

participants' experiences while interacting with the training materials. This approach provided detailed insight into usability, comprehension and perceived relevance, and allowed iterative refinement of the modules. In addition, the evaluation included participants from a range of professional groups and healthcare settings across two countries, supporting the potential transferability of the modules across different cadres of health workers and service contexts.

However, several limitations should be acknowledged. As this study focused on the development and early-stage evaluation of the modules, it was not designed to assess their effectiveness in real-world implementation. In particular, we were not able to examine outcomes such as training uptake, completion rates, or the extent to which knowledge gained through the modules translates into changes in clinical practice. Further research is therefore needed to evaluate the implementation and impact of these training modules in routine settings. Future work should focus on assessing the reach, engagement and effectiveness of the online training, including strategies for implementation that ensure reach and sustainability, and evaluation of whether improvements in knowledge and skills lead to measurable changes in healthcare delivery and patient outcomes.

Conclusions

Through this project, we have demonstrated that a collaborative development process led by identified local HW's, using think aloud methodology to gain user centred feedback, can lead to successful development of e-learning programmes that are contextually and culturally relevant, as well as potentially scalable. The process we used for module development ensured buy-in from all partners, and a demonstrable readiness to adopt online learning. The next phases of this work will focus on evaluation and impact of the e-learning modules, with a particular focus on how this form of training can be sustained and scaled, and how translation of knowledge to clinical practice can be optimised.

Abbreviations

HW
health worker
LMIC
low and middle income countries
WGSP
Wessex Global Stroke Partnerships

Declarations

Ethical Approvals

this was a service improvement project, for which ethical approval was not required; exemption was granted by the University of Zambia Research Ethics Council. The study was conducted in accordance

with relevant guidelines and regulations. Healthcare staff who volunteered to participate in module feedback discussions were briefed on the purpose of the activity and provided informed verbal consent.

Consent for Publication:

not applicable

Conflicts of Interest:

AA is an author and an editor in the special edition to which this manuscript has been submitted.

Declarations

Competing Interests

AA is an author and an editor in the special edition to which this manuscript has been submitted.

Funding:

this work was supported by two grants from Global Health Partnerships, UK [Global Capacity Building Programme SG.18 and Global Health Workforce Programme SG.04]

Author Contribution

LJ, LS, CFS, DS, AA conceptualised the project idea; LJ , CG, DS and AA developed the evaluation methods; LJ, MA, FA, JA, JA, LB, DB, RCM, LC, AS, LS, KWS, CFS contributed to the development of module content and materials, KWS led module platform development; DB, LC, YG, MG, CG, DK, FS supported data collection and interpretation. DS and AA provided local project management. LJ prepared the final manuscript; all authors discussed findings and contributed to the final manuscript version.

Acknowledgements:

not applicable

Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures



Figure 1

Examples of content and user interface feedback.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Appendix1DiscussionPrompts.docx](#)