A User-Centered Approach to the Development of E-Health Systems: A Case of Uganda

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Abstract. Over the years the quality of health service delivery has drastically improved through deliberate efforts that have been made to implement e-health systems in developing economies. In Uganda particularly, e-health systems have been introduced and implemented in both government and private-owned healthcare units. However, due to lack of a structured mechanism to guide the development of usable e-health systems there have been growing concerns related to usability challenges with the e-health systems. The challenges that include complexity of system user interfaces, limited interactivity of e-health systems, security and confidentiality concerns are attributed to ad-hoc design of system interfaces, limited involvement of users in the design process and misalignment of e-health interventions with user needs. In this research we examine the challenges of usability of e-health systems in Uganda. The research process was guided by the design science methodology that is premised on systems analysis, surveys and interactions with medical personnel and IT practitioners working with the health sector in the country. The overall goal was to identify the niches for the development of a user-centered approach to guide the development of e-health systems for enhanced and sustainable health services delivery in Uganda. The developed user-centered approach was evaluated by experts to ensure that it was fit for the development of usable e-health systems in Uganda.

Keywords: User-centered · E-health systems · Developing economies

1 Introduction

Over the years the quality of health service delivery and governance has drastically improved in developing economies through embracing internet and other technologies (Lau and Kuziemsky 2016; Pankomera and Greunen 2018). Deliberate efforts have been made to implement e-health systems that have the ability to greatly impact positively on health service efficiency in developing economies and also potentially reduce on treatment costs (Bedeley and Palvia 2014; Pankomera and Greunen 2018). In Uganda particularly, e-health systems have been introduced and implemented in both government and privately-owned healthcare units. The government systems have been implemented by the Ministry of Health with support from Development Partners

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(DPs) and donors and these include the electronic Health Management Information System (e-HMIS), Integrated Diseases Surveillance and Response System (IDSR), the open Medical Records System (open MRS), patient records management systems, and the drug monitoring and control systems used in numerous healthcare units (Namakula and Kituyi 2014; Ministry of Health 2016). Other initiatives implemented include EMR system at Reach out Mbuya clinic, m-Health initiatives such as u-reporting which is an SMS- based platform, and the mTrac SMS-based health management information tool (Kiberu et al. 2017).

Although various e-health initiatives have been implemented and reported (Fanta et al. 2016; Namakula and Kituyi 2014), there have been growing concerns related to usability challenges with e-health systems in developing economies (Nahurira et al. 2016). The challenges include complexity of system user interfaces, limited interactivity of e-Health systems, security and confidentiality concerns (Kubbo et al. 2016). Vélez et al. (2014) argue that the usability challenges are attributed to poor design interfaces of the systems, limited involvement of users in the design process and misalignment of e-heath interventions with user needs. In many cases this has resulted in e-health system failures and unsustainable systems in the long run yet significant resources are being invested in e-health development at all levels (Nahurira et al. 2016). A preliminary investigation and extensive literature review were done that revealed no evidence of a structured mechanism to guide the development of usable e-health systems in developing economies (Bogale et al. 2015). This motivated the researchers to examine the challenges of usability of e-health systems and determine an appropriate approach to guide the development of usable e-health systems in Uganda.

The rest of the paper is structured as follows: Sect. 2 provides an overview of the usability concepts and highlights the gaps of the existing approaches used to guide the development of systems; Sect. 3 is a discussion of the research methodology that guided the research; Sect. 4 discusses the results of the research that include field findings on the state of usability of e-health systems in Uganda, the efficacy of usable e-health systems for Uganda and the proposed approach for the development of usable e-health systems in Uganda; and Sect. 5 concludes the paper and points to further research directions.

2 Related Works

Usability, defined in terms of its attributes as the degree to which a system is easy to learn and use together with its safety, effectiveness and efficiency, is a technical factor that is fundamental in the sustainable development of e-health systems in developing countries (Goldberg et al. 2011). The ISO standard (ISO 9241-210, 2010) provided the most ideal and state of the art guidelines for user interface design for both hardware and software. For usability to be achieved, the ISO standard's definition includes three aspects namely; effectiveness, efficiency and user satisfaction (Vitanen 2009).

Abran et al. (2003) also describe learnability, memorability and low error rate and security as aspects of usability that are described below:

User satisfaction: is the extent to which users' expectations of the information system meet their informational requirements (Zawedde 2016).
Effectiveness: the ability of an e-Health system to enable users to accomplish certain goals with high accuracy and completeness and its measure is in terms of *error rates* (Mumford 2014).
Efficiency: the measure of how many clicks it will take to progress through the various steps so as to have a task completed and its measure is in terms of *task completion time* and *learning time* (Mumford 2014).
Learnability: is the potential of a system to enable ease of learning by its intended users so that they can rapidly get work done (Harrison et al. 2013).
Memorability: is the ability of a user to retain how to use an application effectively (Harrison et al. 2013).
Error: are actions that prevent a user from accomplishing the desired goal and its unit of measure are the *number of errors* made by a user during the standard user test (Zawedde 2016).
Security: is a set of software attributes that prevent unauthorized access to programs and data (Abran et al. 2003).

A critique of the existing usability approaches discloses that while some approaches were successfully implemented in the developed economies, they were not adaptable in the context of the developing economies. Table 1 presents a summary of the gap analysis of some of the approaches that were reviewed.

Table 1. Gap analysis of existing usability frameworks

Framework	Strengths	Weaknesses
• A usability framework for electronic health records in Nigerian healthcare sector (Taiwo et al. 2016)	• Designed for developing economies • Has parameter indicators for usability measurement	• Focuses on one domain of e-health (i.e. Electronic Health Records) • Context of use analysis is ignored • Missing guidelines for the design of e-health systems • No evaluation of designed system
• The ISO 9241-11 model (Bevan 2009; Scandurra et al. 2013)	• Analyses context of usage, design and evaluation of usability as well as usability measures/attributes	• Leaves out other important usability measures • No emphasis engagement of users in systems design
• A user-centered model for web site design: needs assessment, user interface design, and rapid prototyping (Kinzie et al. 2002)	• Articulates the steps involved in development of usable health related websites • Based on the UCD process which is argued to successfully guide the development of usable systems	• Designed for developed countries particularly USA • Does not emphasize the evaluation of the designed website • Training users of the developed website is not key • Collaboration among the key stakeholders of e-health systems is not emphasized

Given the relative strengths and deficiencies in the usability approaches, to successfully guide the development process of e-health systems in Uganda, an appropriate approach was developed guided by the methodology described in Sect. 3.

3 The Design Science Research Methodology

This research was guided by the design science research methodology (Peffers et al. 2007) to achieve the objectives of the research. Table 2 illustrates the alignment of the objectives and activities with the phases of the methodology.

Table 2. Alignment of the objectives with the methodology

Methodology	Objectives	Methods, techniques, & tools	Outcomes
1. Problem identification	To examine the challenges facing usability of e-health systems in developing economies	• Primary & secondary data collection • Surveys & desk reviews	Usability challenges and possible solutions
2. Defining the Objectives for a solution	To determine the requirements for achieving usability of e-health systems in developing economies	• Data analysis and reporting using SPSS tool	Requirements and corresponding design decisions for the user-centered framework
3. Design and development	To design a user centered framework in line with the requirements that will guide the development of e-health systems in developing economies	• Review of ISO model (Scandurra et al. 2013) on usability and user centered model for Web Site Design (Kinzie et al. 2002). • MS Visio 2016 for framework design	User-centered framework
4. Evaluation	To evaluate the designed framework in order to determine whether it fulfills the requirements for developing usable e-health systems in developing economies	• Analytical evaluation by IT experts and the potential end users • Structured walk-throughs	Revised user-centered framework based on evaluation

4 Results

4.1 State of Usability of E-Health Systems in Uganda

A survey was conducted to determine the state of usability of e-health systems in Uganda. Given the non-existent data on healthcare units using e-health systems in

Uganda, Cochran's (1963) formula was used to determine the sample size. The survey was carried out in Wakiso and Kampala which are some of the central districts of Uganda. The sample size was determined using non-probability purposive sampling. Validity and reliability tests of the research instruments were also conducted. Out of the 136 questionnaires distributed to the selected respondents in 68 sampled healthcare units, 127 valid responses were obtained from 65 IT practitioners and 62 medical personnel. This constituted a valid response rate of 93% which is an excellent representation of the actual situation (Mundy 2002). Analysis of the two categories of data collected (IT practitioners and medical personnel) was processed using SPSS to obtain an understanding of the results on all the study variables.

Respondents reported on the usability attributes of e-health systems in their healthcare units. From the findings, 70% of the respondents agreed that their e-health systems are memorable given that they recalled how to use the e-health system. However, 70.2% of the respondents argued that the e-health systems were not efficient and effective given that they accomplish their tasks with much effort and more time. Furthermore, 82.2% of the respondents argued that the e-health systems in their healthcare units were not learnable, had high error rates (68%), limited and weak security measures (74.2%) and were not satisfactory (67.1%). These results confirmed the challenges of usability of e-heath system for healthcare service delivery in Uganda.

4.2 Efficacy of Usable E-Health Systems for Uganda

To address the challenges identified from literature and the field studies, requirements were determined for the appropriate approach that should guide the development of usable e-health systems in Uganda. The findings from the field data informed the choice of usability requirements and the corresponding design decisions for the proposed approach as summarized in Table 3.

Table 3. Challenges facing usability vs. requirements vs. design decisions

Usability challenges	Usability requirements	Framework design decisions
• Complexity of user interfaces (UI)	– Consider needs of a broad spectrum of users, including general public, specialized audiences, people with disabilities, those without access to advanced technologies, and those with limited English proficiency and ICT skills – Localization of UIs and online help	– UI design favourable to a range of audiences such as persons with disabilities, low technology users, and those with limited ICT skills – Localized UIs and online help at key stages

(*continued*)

Table 3. (*continued*)

Usability challenges	Usability requirements	Framework design decisions
• System limitations	– Need to engage users in systems design – Undertake business process analysis/re-engineering to assess system value to the business	– Engage users throughout the design of the e-health system
• Resistance to change from traditional paper-based systems	– Engage users in systems design and communicate the benefits of the system to user roles	– Engage users throughout the design of the e-health system and indicate system benefits
• System delays in task execution	– Funds for acquisition of computer hardware and reliable connectivity for faster execution of e-health system tasks – Use efficient design patterns and architecture for faster execution	– Avail funds for acquisition of state of the art computer infrastructure and reliable connectivity
• Poor security measures	– Implement stronger e-health systems security measures to enhance user confidence – Design and conduct security awareness programs for staff	– Identify and select appropriate security and privacy measures – Security awareness training in line with security requirements and application security components
• Poor system design and display	– Need to design e-health systems within the context of use analysis and usability performance objectives	– Conduct context based use analysis of e-health systems and determine usability performance objectives
• Uncoordinated stakeholder collaboration in e-health systems development	– Government, IT practitioners, Development Partners/donors, academia and private health service providers to co-operate and champion the development of usable e-health systems	– Collaboration between government policy makers, IT practitioners, Development Partners/donors, academia and private healthcare service providers
• Multiple data entry in related systems	– Integration of processes, data and applications	– Integrated systems

4.3 Proposed Framework for Development of Usable E-Health Systems in Uganda

Guided by the design phases from the sustainable architecture model (Kim and Rigdon 1998), the design decisions in Table 3 were adapted into the frameworks of the

ISO 9241-11 model on usability (Scandurra et al. 2013; Bevan 2009) and the user centered model for Web Site Design (Kinzie et al. 2002). The developed user-centered approach in this study is therefore an improvement of the selected frameworks aimed at overcoming the usability challenges of e-health systems in developing economies like Uganda.

The framework that advocates for engagement of users throughout the entire process of e-health systems development, is iterative and constitutes three phases: the pre-design, design and post design phases as illustrated in Fig. 1. At each one of the phases, there are various actors with roles to play and activities to execute with an aim of following a structured approach to developing a usable e-health system for developing economies. In the **pre-design phase**, financial support is solicited by top management of healthcare units and the responsible sectors of the Government to fund the development of usable e-health systems. A context of use analysis is also done to establish the requirements of the system. In the **design phase**, the design and testing of the e-heath system prototype is done while engaging all users to ensure that the designed system meets the user requirements and the set usability performance objectives. This requirement is derived from Kinzie et al. (2002) model. In the **post design phase**, testing and evaluating of the designed e-health system is done to ensure that the system is secure, memorable, learnable, efficient, effective and has lower error rates.

Table 4. Evaluation results of the developed user-centered approach

Functionality	Mean	Std. Deviation
Outlines key usability attributes required of an e-health system	4.55	.522
Addresses key challenges of usability of e-health systems	4.27	.647
Simplifies the process of developing usable e-health systems by providing guidelines	4.55	.688
Applicable in guiding development of usable e-health systems	4.45	.522
Ease of use	Mean	Std. Deviation
The framework is easy to learn and understand	4.27	.467
The framework requires little or no training to be used	4.09	.302
The phases in the framework are logically arranged	4.27	.467
The various components of the framework are well explained	4.27	.647
Traceability	Mean	Std. Deviation
The framework phases are interdependent with each other	4.09	.831
The framework components are interdependent with each other	3.82	.982
The guidelines/principles of the framework are interrelated	3.82	.874
The guidelines/principles in the framework are interdependent.	3.82	.874
No of respondents	11	

The designed framework was tested and evaluated to determine the efficacy of the research and to ascertain that the framework achieves the purpose for which it was developed (Peffers et al. 2012). Evaluation of the framework was conducted based on the parameters of functionality, ease of use and traceability of the designed user-centered approach (Hevner et al. 2008). The structured walkthroughs method (Buonodono 2014) was used in evaluation of the designed framework. The procedure for the method included first determining the purpose of the walkthrough, secondly, determining the inputs of the walkthrough (the designed framework and the evaluation questionnaire); thirdly, selecting participants in the walkthrough (eleven (11) skilled IT experts); and finally, outputs of the structured walkthrough (in form of feedback related to the designed framework).

Pre-testing of the evaluation questionnaire was conducted using validity (content validity index (CVI)) and reliability (Cronbach alfa coefficient (CAC)) tests. Results from pre-testing confirmed that the evaluation questionnaire was valid with a CVI = 0.80 and reliable with CAC = 0.75 (Polit et al. 2007; George 2011). From the results, we conclude that the experts are in agreement with the usefulness and applicability of the approach in guiding the development of usable e-health systems in Uganda. This conclusion was based on the assumption that a mean statistic in the range of 3.5 to 5 is a representation of positive perception (George 2011). The results in Table 4 indicate a positive perception of the respondents regarding the functionality, ease of use and traceability of the framework.

The experts also made recommendations for improvement on the developed approach. In order of their importance, these include the need:

- To clearly state the high-level roles of Government, IT practitioners/vendors and the healthcare units in development of usable e-health systems,
- To enact e-health inter-operability policies and standards during the design of e-health systems, so as to achieve integrated & interoperable systems and
- To engage all categories of users such as the visually impaired persons, users with limited skills.
- To involve top management of healthcare units as champions of e-health systems usability.
- To include change management in addition to training of healthcare staff as one of the components/guidelines in the post design phase of e-health systems,
- To conduct business process analysis during the design and development of e-health systems.
- To review software architecture and measure execution times as per business requirements.
- To design Localized User interfaces (UIs) and online help at key stages.

The researchers revised the approach based on the concerns raised by the experts and the final designed approach is illustrated in Fig. 1.

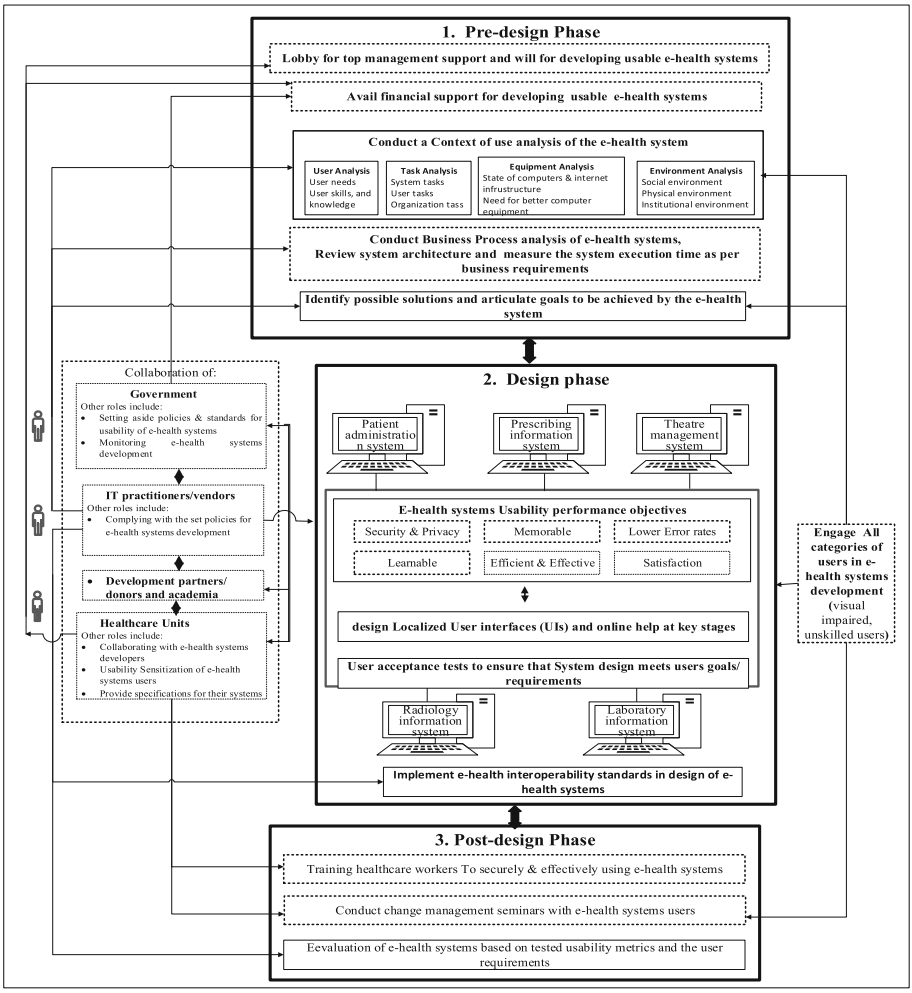

Fig. 1. Evaluated framework for development of usable e-health systems in Uganda

5 Conclusion and Future Work

This study examined the concept of usability of e-health systems and how it can be attained based on the paradigm of user-centered design so as to ensure that usable e-health systems are developed for staff of healthcare units in developing economies. To this end a framework was developed to guide the development of usable e-health systems in Uganda. The findings of the study indicated that there are a number of challenges hindering usability of e-health systems in Uganda. The challenges identified informed the requirements for the framework. The framework was evaluated by selected IT experts in the field of e-health, e-health policy experts and the end users of e-health systems in selected healthcare units.

Although the framework was found fit for the purpose of guiding the development of usable e-health systems in Uganda, further research can be done to explore the generalizability of the framework to healthcare units in developing economies Uganda that could have differences in e-health usability requirements.

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