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KNOWLEDGE IN ACTION

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Charles Maina Mungai

DOCTORAL DISSERTATION

Mobile Learning as an Innovative Strategy for upgrading Technical Skills in Developing Countries: A case study of mobile learning for midwives in Uganda

D/2020/2451/53

Promoter: Prof. Dr Wim Vanhaverbeke | UHasselt

DECLARATION

I certify that this thesis is original and has not been submitted for examination to any university for the same award. Where the work of others has been cited, due recognition has been made, and lastly, errors and omissions herein are entirely my responsibility and humbly unintended.

Charles Maina Mungai

APPROVAL

We certify that Mr. Charles Maina Mungai carried out his PhD research under our supervision. We consent to the submission of this dissertation. Thus, this dissertation is submitted to the University of Hasselt with our due approval.

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DEDICATION

This work is dedicated to my dear beloved wife Doreen Kirungi Maina and our entire family.

ACKNOWLEDGEMENT

I would like first and foremost to thank God The almighty for having brought me this far. I am His and in His service will me and my lineage forever be.

Mwathani arogocwo! Nida cokeria mwathani gatho, ni kundathima na kuginyia haha ngiyete, theine wa maisha makwa. Nie, ndi wake na nie na nyumba yakwa yothe ni tukumugoca na tumutumikire tene na tene.

I am very grateful to my beloved wife, soon to be Dr. Doreen Kirungi Maina, PhD. I wouldn't have achieved this without your assistance, imperishable love, patience and invaluable contribution. Thank you and Congratulations, Babe!!

I would like to thank my entire family, more so my parents, for continued support, even when the candle was dim. Special thanks to my father, Alpha 1, for always having a pragmatic and spiritually discerning assessment of all facets of life.

Special thanks to Amref Health Africa and the entire team at Makerere University for the tremendous support over the years.

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On the journey to PhD, there are many people who have been of great support, I may not be able to mention you all, but together with the above mentioned, I do acknowledge, recognize and appreciate you, may God bless you all abundantly.

Hallelujah!!

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CHAPTER ONE

1.1 Introduction

A sudden, dramatic and rapid rise in the penetration rate of, access to, and use and ownership of personalized mobile devices since 2000 has immensely benefited many sectors of some developing countries in Sub-Saharan Africa. Arguably, innovations arising from these emerging technologies continue to swell. Access to the Internet via personal, wireless, portable and handheld devices also continues to grow. In the field of education, mobile technologies have given rise to an innovation commonly referred to as "mobile learning (mLearning)." mLearning enables learning on the go with the help of mobile devices such as mobile phones, smartphones, iPads and so on. Various subsectors in education are experimenting the use of mLearning. Outside the education sector, mobile applications continue to be developed; for example: the banking sector (mBanking), the commercial sector (mCommerce) and the health sector (mHealth). A common example in Uganda's health sector is the mTrac-mHealth system, which sees over 2,000 health facilities using mobile phones to submit weekly disease surveillance and medicine stock updates (Mattsson & Sabuni, 2013).

Soaring maternal mortality figures are synonymous with limited access to, and/or uptake of, maternal health interventions, but also a shortage of skilled workers (Kabayambi, 2014; WHO, 2015). To reduce the high burden of maternal deaths in Uganda, innovative and strategic approaches are required in the healthcare system skewed towards midwives, who are the frontline healthcare providers in ensuring good and timely high-quality maternal health care for obstetric emergencies in Uganda and other low-income countries.

In this thesis, the strategy is for different stakeholders to collaborate and support innovations that promote the co-creation and sharing of technical knowledge from different sources in the healthcare sphere.

By so doing, a mobile maternal healthcare knowledge repository can be built. With such a repository in place, Uganda will be able to improve the efficiency of midwives as they acquire new, and/or upgrade their current technical skills. This has the capacity to cause a substantial reduction in preventable maternal deaths as midwives use their smartphones with flexibility to obtain an easy-to-access, up-to-date and rich maternal healthcare knowledge repository. Notwithstanding this, explicit prescriptions for designing and using mLearning to improve the technical skills of midwives are still in their initial stages. In this thesis, exploratory research has been done to close this gap using the open innovation paradigm where an institution or individual can purposefully and viably use a rich technical knowledge base with drawings from several sources.

1.2 Problem statement

Whereas empirical evidence indicates that early and regular attendance of antenatal care by pregnant women, and delivery under the supervision of trained and skilled health workers is associated with both improved maternal outcomes and reduced deaths, there still exits an unfilled gap among trained and/skilled health personnel in Uganda (Villar et al., 2001; Wandera & Bulyaba, 2015). For instance, while almost all (95%) pregnant women receive some form of antenatal care from a skilled provider, only 57% of all births occur within health facilities, with 58% being assisted by a skilled health worker during delivery (UBOS, 2012).

Several initiatives/interventions are being introduced by Government and Non-Government Organizations to scale up the number, and upgrade the skills of health workers. Among these is Amref Health Africa's eLearning program for pre- and in-service nurses and midwives (Amref Health Africa, 2011). The program uses a tethered e-learning infrastructure to deliver learning/training content. However, an evaluation of this Amref Health Africa initiative seems to indicate a low uptake/impact of e-learning (Amref Health Africa, 2014).

Presumably, one of the possible reasons advanced for this low uptake could be the limited access to tethered e-learning facilities, leading to the need to support learning activities on easily accessible learning media such as personal, wireless, portable and handheld mobile devices (mLearning). The JIBU mLearning baseline survey showed that almost all pre- and in-service health workers owned a mobile phone (Amref Health Africa, 2014). Ministries of health and NGOs working in the health sector are now exploring ways of integrating mLearning into effective healthcare training systems (Amref Health Africa, 2014b; Jossey, 2012). One desirable approach is to provide midwives with real-time, up-to-date and rich maternal healthcare knowledge built through an open innovation approach by different maternal healthcare experts. This calls for research aimed at broadening the understanding of how to build such an easy-to-access, up-to-date and rich maternal healthcare knowledge repository using the open innovation paradigm. The open innovation model is a prerequisite for understanding, generating, preserving and sustainably using a rich mobile maternal healthcare knowledge repository.

1.3 General objective

The general objective of the research was to design and validate a mobile learning open innovation framework aimed at providing healthcare technical skills to midwives with the intention of reducing maternal mortality in Uganda.

1.3.1 Specific objectives

1. To identify the technical knowledge artifacts that could be extended to midwives through mLearning using an open innovation approach [paper 1]
2. To establish the cost-benefit implications for delivering mLearning technical knowledge artifacts in (1) above [paper 2]
3. To establish and validate mobile learning framework for effectively harnessing knowledge artifacts from different stakeholders using an open innovative approach [paper 3]

1.4 Definition of Some Key Terms and Concepts

1.4.1 Midwives

These are persons (typically women) who are professionals and registered with the Uganda Nurses and Midwives Council to legally serve as attendants at childbirth in hospitals and health centers. Midwives specialize in pregnancy, childbirth, postpartum, women's sexual and reproductive health (including annual gynecological exams, family planning and menopausal care), and newborn care (Royal College of Midwives, 2017; WHO, 2015, 2017a).

1.4.2 Mobile learning

In the context of this research report, mobile learning (mLearning) is looked at in terms of the use of mobile phone technology to provide better access to learning/training as a means of imparting technical skills to health practitioners working as midwives in Uganda. As such, mobile learning (mLearning) is any form of learning mediated through a mobile handheld device (Pegrum et al., 2013). According to Rikala (2015), mLearning sustains high levels of student engagement with rich connections to other people and resources across different contexts. Today, mLearning is slowly becoming prominent and a critical factor in addressing persistence and attrition in higher institutions of learning as learners interact amongst themselves and faculty (Greenfield, 2011).

The growth of mobile technology users and advancements (in terms of increased functionality, processing power and applications) is exponential (Fardoun et al., 2010). It is indisputable that right mobile technologies can suitably complement conventional educational approaches since such mobile technologies are now an integral part of people's daily lives and are used for communication and entertainment and education (Jeng et al., 2010; Ngambi et al., 2010). As a corollary, the influence of mobile devices in Uganda is undeniable, with many of these mobile devices becoming more sophisticated and allowing users to perform a wide variety of tasks (Flood et al., 2012).

In the school setting, today's students use mobile technologies such as smartphones everywhere they go, including in their classrooms (Hamann, 2015). Therefore, mLearning offers a prolific opportunity for effectively, efficiently and satisfactorily designing and developing healthcare instructional activities and tools that can support innovative educational processes for midwives.

1.4.3 Technical skills

These refer to a particular set of abilities or proficiencies acquired through learning and practice that are required to perform specific tasks. In this thesis, technical skills are the set of "up-to-date" and "real-time" technical abilities that midwives need to acquire through a mobile phone in order to assist with child deliveries.

1.4.4 Open innovation theory

The open innovation theory derives its being from the abundance of knowledge and the ability of such knowledge to freely provide value added from within and/or outside an institution (Chesbrough, 2003). Open innovation endeavors to reflect on how ideas flow across boundaries (Chesbrough & Bogers, 2014).

As such, to draw more general theories underpinning the understanding of existing open innovation theories, the following canonical definition was put forward by Chesbrough, Vanhaverbeke, and West (2014, p. 17):

> '…open innovation [is] a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model…'.

Open innovation denotes partnerships, external and internal, for co-creation of innovative artifacts and has been applied in various fields to innovatively seek solutions to different problems. Particularly in the health sector, various knowledge sources (with clear boundaries) can benefit midwives wishing to improve on their technical skills. Such knowledge support can be drawn from: doctors, nurses, traditional birth attendants, nurse and midwife councils, and ministries of health, NGOs, among others. A rich learning experience for improving the efficiency of midwives can be attained in this networking environment by a number of both internal and external stakeholders, vital for saving mothers, the unborn and new-born babies. With their mobile devices, midwives can access technical knowledge artifacts in repositories contributed to by different healthcare professionals in an open innovation way, a phenomenon that can be referred to as "mLearning."

1.4.5 Knowledge artifacts

In the context of the current investigation, knowledge artifacts refer to tangible and intangible forms of information regarding a specific topic or area of interest. A book, video, email, audio recording etc. are all tangible knowledge artifacts while thoughts, ideas, conversations and stories refer to intangible knowledge artifacts.

1.4.6 The JIBU Application (JIBU App)

This is an educational and knowledge application with potential to offer professional development opportunities to healthcare providers as well as keeping their medical knowledge up-to-date by means of a mobile phone. The App provides access to real-time learning among disparately located healthcare providers. In so doing, healthcare providers no longer act alone in their responsibility and can therefore provide better quality care. The App design is around Amref Health Africa's strategic desire to find ways of linking health services to the people (that need them the most) by focusing more on people, and less on diseases. The App design maps the training and practice of healthcare providers on the process of access to quality health services by disadvantaged communities. All was in the spirit of the 3-pronged roles of healthcare providers as:

(i) independents (working in their own),

(ii) dependent (working in collaboration with doctors and other specialists), and

(iii) interdependent (working in teams to provide quality health services).

The JIBU App creates and deploys content, creates user profiles (such as administrators, authors, tutors, and students), creates cohorts and tracks usage of app. On the next page, a visual impression of the App is provided.

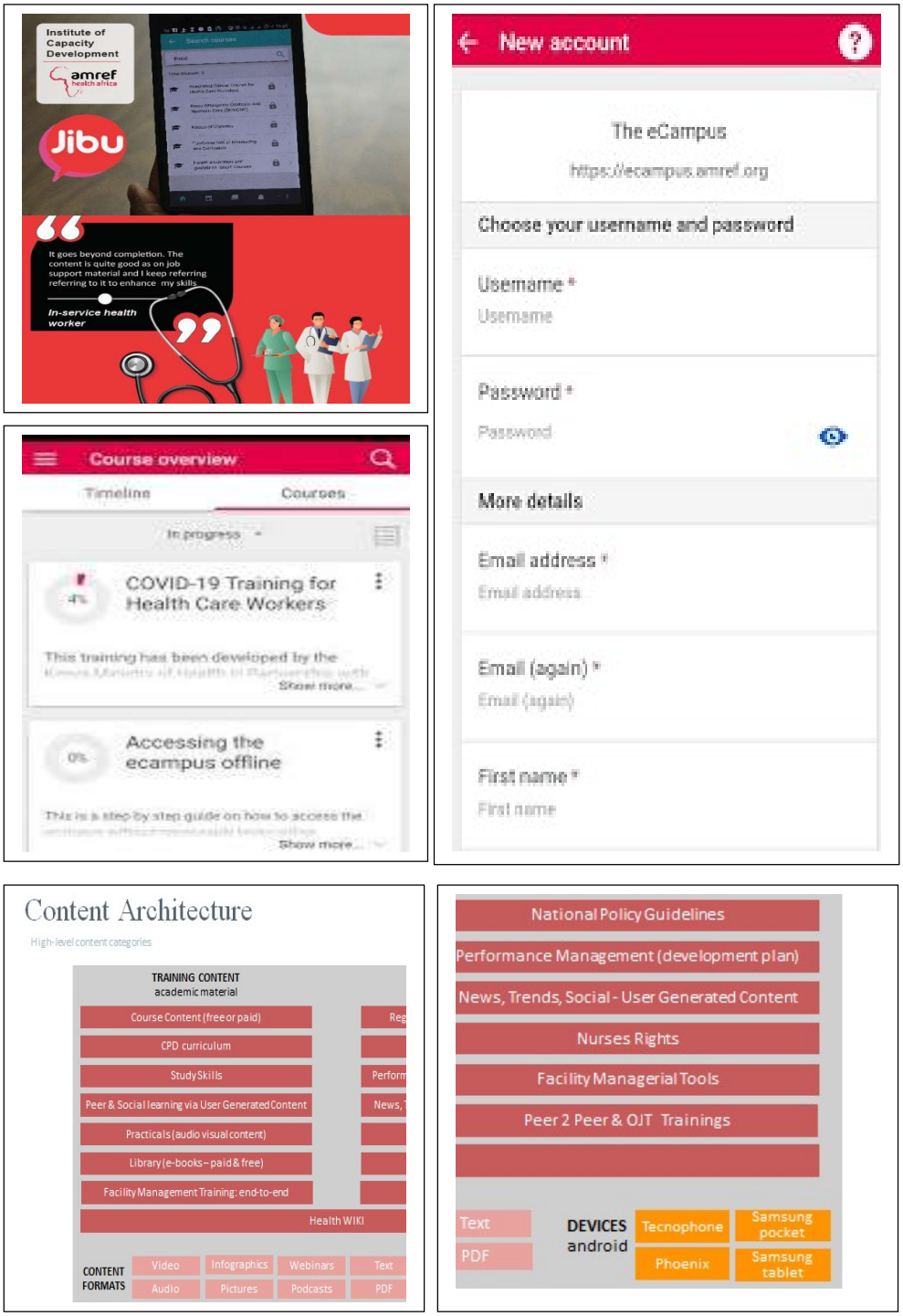

***Figure 1*: Related screen shots on the JIBU App**

1.5 Mobile learning and Learning

It is undeniable that a mobile phone is part and parcel of our daily lives, a companionship which presents a mobile phone at the center stage of informal and lifelong learning (Keegan & Mileva, 2010; P. B. Muyinda et al., 2015). Available literature suggests that existing learning theories can be amended to reinforce mLearning (Martin *et al*., 2010; Naismith *et al*., 2006). Adaptation to such theories is only meaningful by borrowing creeds that conform to mLearning (Sharples et al., 2005).

Notable learning theories singled out to support mLearning include but not limited to the constructivist, behaviorist, collaborative/conversational, situated, connectivism, activity, informal and lifelong, and the learning and teaching support (Naismith *et al*., 2006, Nie, 2007). The implications of the aforesaid learning theories in upgrading of technical skills of midwives are explained below.

The constructivist learning theory opines mLearning as an active individual process in which a learner constructs new ideas or concepts based on his/her current and past knowledge (Vygotsky, 1978). Whilst that is so, learning for midwives may necessarily not be individualistic and, therefore, requires the input of others. By and large, a social constructivist learning theory is advocated for to stress that knowledge creation is shared rather than an individual experience (Vygotsky, 1978). As such, for midwives to construct and/or co-create their own knowledge, they must actively participate in the learning process, collaborate/converse/interact with others, contextualize their learning and reflect on it (Fisher & Baird, 2006).

Tools and raw materials to create the social space can arise from emerging technologies that encourage interaction and collaboration, thereby presenting a mobile phone as one of such technologies.

According to (Skinner, 1968) , midwives can learn through the behaviorist learning theory by way of responding to a stimulus ignited on a human being. The theory derives it being from Skinner's work on operant conditioning and behaviorism. The existence of a force in the learning process reinforces the relationship between a stimulus and a response (Nie, 2007; Naismith et al., 2006). Conditioning midwives to a stimulus such as an SMS or call through their handheld devices (as a conveyor of educational/training related messages), can trigger a response to immediately respond. In this case, the mobile device that presents the message reinforces the relationship between the stimulus and the response.

The collaborative/conversational learning theory posits that collaboration and interaction present vast pedagogical benefits to a learner. As disparately co-located, located midwives share information (for the purpose of learning) with appropriate scaffolding from instructors; successful and continuous learning can occur through use of mobile phones (Naismith *et al*., 2006; Muyinda et al, 2015). This state of affairs is suitable when the learners are in charge of their learning. The fact that midwives own mobile phones implies that they are in control of their learning environment. Hence, midwives are able to virtually collaborate with each other in a seamless human-human interaction as opposed to online communication where human-human interaction may seemingly get lost.

The situated learning theory, founded by (Lave & Wenger, 1991) states, "learning is not merely the acquisition of knowledge by individuals, but instead a process of social participation" (Naismith *et al*., 2006, p.13). This presupposes that learning occurs in particular social contexts and communities of practice. Naismith and others (2006) further noted that situated learning is prominently evident in Problem-Based Learning (PBL), Case-Based Learning (CBL) and Context-Aware Learning (CAL). It is thus a good model for training practical oriented professionals such as health workers, doctors, nurses and midwives. Through use of a mobile phone, midwives in small groups can interact with each other and their teachers to arrive at a solution to a real-life problem. In this case, the teacher plays moderation roles as situations stimulate the midwives' higher order cognitive skills to inform learning. Similar to PBL is CBL, which aims at testing rather than developing skills of midwives in solving mainly wholly defined problems which may or may not be replicated at the midwives' place of work. CAL refers to gathering of information from the environment and comparing (contextualizing) it with what midwives actually learn. In the era of mLearning, mobile phones with a Global Positioning System (GPS) affordance can be helpful to midwives to receive learning activities and content relevant to them in their given work environments (Nie, 2007).

A similar learning theory closely underpinned by social learning though in a networked context is the Connectivism theory (Siemens, 2005). Siemens developed his learning theory for the digital age in a bid to criticize boundaries of the behaviorism, cognitivism, and constructivism learning theories.

The Connectivism learning theory supports cooperation amongst high-end and low-end learners and has the potential to increase knowledge and skills for those on the low end for particular individualized tasks (Siemens, 2005). As such, connectivism enables knowledge to be distributed across a variety of networks so as to help new generations collaborate to find solutions to the ever increasing number of questions (Downes, 2007). Further, the connectivism learning theory permits reflection on our rapidly changing, complex and socially connected globe mediated by increasing technological advancements (Duke, Harper & Johnston, 2013). An Internet connected mobile device has the potential to connect a midwife to her outside knowledge networks above her existing state of knowledge and skills (Duke et al., 2013)". The theory contends that one is as knowledgeable as the knowledge networks they belong to. This theory rhymes well with the open innovation theory which permits participants to collaborate and co-create and share knowledge without limits

The activity learning theory which derives its being from Vygotsky (1978) focuses on understanding human activity and work practices while integrating concepts of intentionality, mediation, history, collaboration and development. One of its key beliefs is that of activities being executed. Communities of practice and education are among the many fields where the theory is applicable (Eraut, 2000). Uden (2007) further attests that rules are a key component of the activity theory since there are joint activities, community and division of labor which indicate how activities are distributed. Rules regulate actions and interactions within communities and as such, learning occurs in situated contexts and is socially mediated as midwives help each other to learn.

This is done with the mediation by mobile technologies to underpin interaction and collaboration between midwives-midwives and midwives-tutor(s).

Under the informal and lifelong learning theory, activities that support learning outside a dedicated learning environment and formal curriculum are supported (Eraut, 2000). This grounds the informal and lifelong learning theory to the social constructivist and situated learning theories. Sustainable Development Goal (SDG) 4, "Ensure inclusive and equitable quality education and promote life-long learning opportunities for all" and its corresponding targets continue to advocate for the exploration of emerging technologies, supports the anytime-anywhere learning (Evans et al., 2008; Haughey, 2010; UNESCO, 2015 p.1). Midwives carry their mobile phones almost all their time in anyplace, harboring the potential of orchestrating information exchange which can result in intentional or accidental learning.

The learning and teaching support theory emphasizes the need for support systems in learning and teaching. Naismith and others (2006) pointed out that provision of training/education is not just about providing content and learning activities to learners but also about a great deal of coordination of these learners and the resources. While midwives can support each other in learning, a tutor can also support midwives through provision of relevant URLs to reading materials or such a tutor can use an SMS or voice message to coordinate activities of his/her learners(midwives).

1.6 Methodology

1.6.1 Introduction

The aim of the thesis was to design and validate a mobile learning open innovation framework to provide healthcare technical skills to midwives in Uganda. The research sought to investigate the affordances of mLearning in the design of a mLearning framework that brings together the collaborative efforts of different stakeholders (internal and external) in order to reduce maternal mortality. Affordance in the mLearning context refers to the perceived and actual properties of mLearning that have the potential to be used by the learner, if they appreciate them and proceed to utilise these inherent properties (Bower, 2008)

In particular, the research:

i) identified the technical knowledge artifacts that could be ported onto mobile devices for improved efficiency of midwives using an open innovation approach;
ii) established the cost-benefit implications for delivering mLearning technical knowledge artifacts;
iii) established and validated a mLearning framework for effectively harnessing knowledge artifacts from different stakeholders using an open innovative approach.

1.6.2 Study design

A design science methodology framework was adopted because of its suitability for handling socially responsible studies of this nature that lead to instructional technology improvement, design, development and evaluation (Oliver et al., 2005). Research founded on design science methodology involves undertaking empirical research, design and practice and its outputs include: constructs, models, methods/frameworks, instantiations and better theories (Wang & Hannafin, 2005).

The design science methodology considers problem relevancy, research rigor, design as a search process, and design as an artifact, design evaluation, research contribution and research communication. The empirical study involved the use of empirical data and scientific techniques and methods for performing relationship mapping of components that form an artifact (A. Hevner & Chatterjee, 2010). Accordingly, the research rigor involved the application of mixed research approaches to collect and analyze data. All in all, the design science methodology was a good approach to use in undertaking this research as it engrained the best research design characteristics for a study by, among others:

- integrating known and hypothetical design principles with technological affordances to render plausible solutions to complex problems
- requiring rigorous and reflective inquiry to test and refine innovation learning environments as well as revealing new design principles
- undertaking long-term engagement involving continual refinement of protocols and questions
- involving intensive collaboration among researchers and practitioners
- committing to theory construction and explanation while solving real-world problems (Oliver, Reeves, & Herrington, 2005, p. 103).

Empirical Research in the Study

The empirical research in this study addressed two specific objectives, i.e. (i) and (ii) above.

1.6.3 Area of study

The study was conducted in Uganda. Like many other Sub-Saharan African countries, Uganda has an acute shortage of the required skilled human resources especially in the health sector. This shortage has hampered the proper provision of health services and the attainment of required health outcomes and health-related SDGs (WHO, 2017b). Providing venues for improving Uganda's health workers' technical skills through mLearning is vital to ensure that even the remotest of remote areas is served.

1.6.4 Target population

A population is a group of all possible objects of investigation in a given domain (Calder, 1998). In this research, the target population was mainly midwives in Uganda's health facilities. It is from these that a representative sample was scientifically drawn.

1.6.5 Sample size and selection method

Uganda has over 35,000 enrolled midwives. The Calder's (2000) sample size determination formula was used to determine the representative sample size. The formula is:

$$n = \frac{(desired \quad confidence \quad level)^2 * (s\tan dard \quad deviation)^2}{(desired \quad level \quad of \quad precision)^2}$$

At a desired precision level of 0.5, a confidence level of 95% ($p < 0.05$) = 1.96, and a standard deviation of 4 (assumed from a previous similar mLearning study),

$$The \quad Minimum \quad Sample \quad Size \quad (n) = \frac{(1.96 \times 4)^2}{0.5^2} = 245.86 \approx 246 \cdot$$

With a minimum sample size of 246 respondents coupled with a high degree of nonresponses of as much as 80% for self-administered questionnaires, a mitigation plan was inevitable (Burgess, 2001).

Burgess advises researchers to factor in nonresponse associated with surveys. The 80% nonresponse rate was factored in by multiplying the minimum sample size of 246 by a factor of five (5) to obtain a maximum sample size of 1,230 across the Northern, Central, Western, Southern and Eastern Regions of Uganda. For each of the aforementioned regions, midwives constituted the strata and were chosen using simple random sampling. This sampling method was used because it gives equal chance for every member of the population to be selected for sample without bias (Amin, 2005). However, at the end of the survey, 880 questionnaires (72%) were responded to and returned. This was well above the required minimum sample size of 246.

1.6.6 Data collection methods and tools; data quality control and assurance

There were two types of data that is; primary and secondary. Primary data was collected from a sample group of 1,230 respondents selected from the different regions of the country using a self-administered questionnaire. The questionnaire had both open- and closed-ended questions. Closed-ended questions were of option type or logical type or Likert scale type or single-response type depending on the investigation being done. Primary data was triangulated with secondary data collected through a review of literature on mobile health systems. An interview guide was also employed to enlist information from key informants, such as: The Uganda Nurses and Midwives Council, the Ministry of Health, educationists, and open and eLearning specialists. According to Karoro (2001), interviews can provide in-depth data not possible with a questionnaire. The researcher will opt for interviews because they have a high response rate, first hand data can be obtained from persons of interest, more than one view of the matter can be got, quick information is collected, flexibility is high and clarifications can be made on spot. Information that will be gathered through the interview guide will then be corroborated by that will have been collected using questionnaires to ensure reliability (Wragg 1990, Mashall 1989 and Kakooza 2002). In order to ensure high-quality data and information from the field data collection, data collection exercise involved developing the as well as overseeing it. Permission was sought from respondents and indeed no respondent was forced to participate in the research against his/her will. A consent clause was clearly included in the first phase of the data collection tool.

1.6.7 Data processing and analysis procedures

In preparation for analysis, data was processed. Data was edited by checking the responses in each questionnaire to ensure that there were no inconsistencies or inaccuracies. EpiData was used to create an electronic copy of the questionnaire to capture the paper-based responses, where the captured data was exported for analysis.

1.6.8 The Framework Design

After empirical research and understanding the problem, the next stage in design science methodology is the design. The data obtained from the empirical study was vital for contextualizing the requirements for the design of an effective framework for harnessing technical knowledge artifacts from different healthcare practitioners for the improved efficiency of midwives using mobile devices. The design thus addressed the objective of establishing a mobile learning framework for effectively harnessing knowledge artifacts from different stakeholders using an open innovative approach. The framework was premised on the mapping paradigm concept. Through Papers 1 to 3, herein incorporated as Chapters 2 to 4, a trail in arriving at the mobile learning open innovation framework is presented. Chapter 2 presents the mLearning knowledge artifacts for improved efficiency of midwives, Chapter 3 presents the mLearning cost-benefit implications while Chapter 4 presents the mLearning open innovation framework and its validation.

CHAPTER TWO

PAPER 1: mLearning Knowledge Artifacts For Improved Efficiency of Midwives

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2.1 Abstract

Midwives as frontline healthcare providers interact with patients at all times. These patients have varying medical needs that presuppose "at-the-fingertip" solutions. Prior studies have shown that the knowledge and skills' base of the majority of midwives in Uganda is inadequate for effective healthcare provision. In addition, the midwife-to-patient ratio of 1: 6,838 sounds too high. This calls for more pre-service and in-service training and increased opportunities for continuous professional development (CPD) for midwives. The main focus in the area of maternal health in Uganda has been on increasing access to maternal health rather than on improving the capacity and number of healthcare providers (midwives). Currently (early in 2018), the Ministry of Health uses conventional classrooms, ward rounds, ward meetings and wall charts to develop more skills among midwives, but these methods are unable to tap into the expertise and knowledge base of specialists who are not co-located. This calls for appropriate and viable approaches that can seamlessly tap into the expertise of these disparately located knowledge sources for the benefit of midwives. Mobile devices are increasingly being used to co-locate knowledge in a concept known as mobile learning (mLearning). mLearning is a supplementary learning channel to traditional pedagogy. The use of mLearning for the CPD of healthcare providers is understudied. The paper, therefore, identified the knowledge artifacts that could be extended to midwives through mLearning using an open innovation approach. This approach has the potential to widen the scope of knowledge provided to midwives at their workplaces or training institutions in an up-to-date and real-time fashion. The knowledge artifacts that midwives liked to freely access and/or share on their mobile phones included: medical literature from books, the Internet and others (70.5%, n = 601), medical training simulations (62.1%, n = 529), patient diagnostic pictures (58.8%, n = 501), support on medical literature from tutors or senior medical officers (53.9%, n = 459), dosage administration (52.1%, n = 444), patient day-to-day support (49.5%, n = 422) and real-time patient diagnostic support (37.4%, n = 319).

Keywords:
Healthcare Providers, Midwife, mLearning, Mobile Devices, Open Innovation, mHealth and Technical Knowledge Artifacts

2.2 Introduction

A midwife is a health professional who helps women during the course of pregnancy with childbirth, postpartum, women's sexual and reproductive health (including annual gynecological examinations, family planning, menopausal care and others), and newborn care (WHO, 2015, 2017a).

The mid-wives are critical health care providers, especially in Africa, where they provide the first line of care for mothers and babies. According to the World Health Organization, the shortage of midwives was estimated to be around 350,000 in 58 countries (WHO, 2015). At least a third of these were needed in the world's poorest countries, including Sub-Saharan Africa and Uganda in particular, where the midwife-to-patient ratio is 1: 6,838 as opposed to the World Health Organization's recommendation of a staffing ratio of at least 1:439 (https//inmo.ie/Print Article/11417). This places a huge work burden and pressure on the few existing midwives. Over 160,000 (55%) women's deaths occurred in Sub-Saharan Africa out of 289,000 deaths around the world. It is important and indeed urgent to ensure that all women have access to sexual, reproductive, maternal and newborn services. This can be attained with an adequate number of midwives who are well equipped with the knowledge, attitude and skills (competencies) required for attending to mothers to enable them to take proper care of themselves and their babies (WHO, 2015).

The process of midwives providing healthcare services is multifaceted because it necessitates an active interaction among a number of technical knowledge providers, including, but not limited to, peers and experts (WHO, 2015). The sharing of tacit and explicit knowledge, clinical experiences, collaborative discussions, operational policies, educational resources and decision support rules is a pathway for facilitating patient knowledge for the best patient safety practices, care quality and patient-centeredness (Abidi, 2008).

Good quality healthcare for obstetric emergencies drawn from specialists in cases of among others; high blood pressure, infections, severe bleeding, delivery complications, unsafe abortions, malaria and HIV/Aids has been found to contribute to a reduction in maternal mortality in Uganda (Kyomuhendo, 2003).

Whilst many people in Sub-Saharan Africa desire to be trained as health workers, particularly midwives, many of them do not get the chance to receive training for multiple reasons. These reasons include the inability to afford housing or food among those who come from the countryside, commuting costs for those who are close to cities where training facilities are located and parallel financial responsibilities like providing for the family. Going to school would imply absence from work, leading to a major setback in payment and further suppressing the little manpower available (B. P. Muyinda et al., 2010). Reducing maternal deaths requires the physical presence of trained and skilled midwives to attend to every pregnancy and delivery (Osungbade et al., 2008). No other better, more innovative approach seems to provide a more reliable solution to the enormous shortage of midwives in Sub-Saharan Africa than the use of developments in the ICT sector to support education and training with the use of computers and mobile devices (Lampe, 2015).

The current investigation explores the role of mobile devices in eliciting the increased ability of midwives to access and apply current and relevant technical knowledge in a timely fashion in Uganda. In essence, it attempts to provide a blueprint for increased awareness of the optimal utilization of relevant and newly researched mobile device innovations loaded which are compatible with technical artifacts throughout the diagnostic-therapeutic cycle.

It is a truism that upgrading the technical skills of midwives reduces maternal deaths. As such, all possible and feasible and viable interventions must be found to democratize the needed technical knowledge. Ubiquitous ICTs such as mobile devices are known to be democratic channels for information dissemination, translation and application.

As midwives go about their duties, they tend to draw varied support from a range of sources/personnel such as doctors, nurses, clinicians, pharmacists, laboratory technicians, radiographers among others. From any of these sources, a midwife can obtain support ranging from but not limited to diagnostic photographs/pictures, real-time patient diagnostic, patient day-to-day care, medical literature from books or other sources such as AMREF, medical literature offered by tutors and senior medical personnel, medical training videos or simulations as well as dosage administration.

Patient diagnostic photographs/pictures are vital in supplementing and strengthening the numerical identifiers most especially where they may be the only identifiers in the event that the patients are of the unconscious trauma type (Ramamurthy et al., 2013).

In this era of the rapidly changing technologies, more personalized real-time patient care is gradually taking shape as a result of diagnostic technology pairing up well with professional healthcare expertise (Bates, 2017). However, even in real-time patient care, day-to-day care support may be necessary depending on the condition of an expecting or delivered mother as well as their babies. Even when it takes a shorter time, day-to-day care support enables midwives to monitor their clients through structured times such as for eating, napping and medication until such a time when it is deemed fit for discharge from the health care facility. Another source from which midwives seek support is literature from books, tutors and other senior medical personnel. Non-use of literature from books and journals can sink a practicing Physician to the level of a mere cross-counter prescriber not only in practice (Osler, 1897).

In verbatim, Osler (1897) revealed that a physician who does not use books and journals, who does not need a library, who does not read one or two of the best weeklies and monthlies, soon sinks to the level of the cross-counter prescriber, and not alone in practice, but in those mercenary feelings and habits that characterize a trade". Midwifery peer-reviewed journal articles carry extraordinary extensive and careful research findings relative to an original manuscript and can therefore aid continuous professional improvement. Besides text content, tutors and other senior medical personnel are beneficial in ensuring that midwives keep abreast with trending best practices, values and attitudes (Burgess et al., 2015). In other studies, tutors and senior medical personnel act as role models and, therefore, facilitate the development of a professional identity (Haider et al., 2016).

Role modeling is an indispensable part of medical education especially through ward rounds where students learn through observation of their tutors and seniors especially in the way of behaving and interacting with patients, colleagues and others (Prideaux et al., 2000).

Another CPD aspect through which midwives could improve their medical training is through medical training videos and simulations. Well or rightly produced medical training videos are a perfect self-study tool due to its ability to combine visuals, audio, language and many more. Rightly designed and produced videos are mainly those that catch the eye and engage the target audience on the onset. In the same way, midwives can partake of mLearning through the use of such medical training videos. On the other hand, it is said that "To Err Is Human" (Al-Elq, 2010). In order to preserve the safety of patients, midwives can upgrade their skills through use of medical simulations, which is a deliberate practice rather than an apprentice style of learning and uses aid tools to serve as an alternative to real patients (Kohn et al., 2000).

Simple dosage administration errors can lead to undesirable health outcomes. An error is something incorrectly done through inadvertence or a mistake, e.g. in calculation, judgment, speech, writing, action and many others (Kohn et al, 1999). It is therefore important to detect any errors so as to have the right dosage administered at the right time with prescribed conditions. Patients ought not to take their dose(s) too soon, too late, miss out and/or waiting too long between doses for better results.

In this study, those technical knowledge artifacts inherent in healthcare providers that could be democratized through mobile devices for improved efficiency of midwives in Uganda are identified. This was answered through the following research questions:

i) What are the factors necessary for freely accessing and/or sharing maternal health knowledge artifacts using mobile devices?

ii) What knowledge artifacts do midwives prefer to freely access and/or share with different healthcare providers using their mobile devices?

The rest of this research report is structured as follows. In *Section 2.3*, I present a theoretical framing of the study. This is followed by *Section 2.4*, which focuses on the methods used in undertaking the research. *Section 2.5* presents the findings of my study. Finally, the study drew a number of conclusions and discussion of the findings within the broader framework of mLearning under *Section 2.6*.

2.3 Theoretical framework

According to WHO, (2015), in 2013, about 800 women die every day due to preventable complications of pregnancy and childbirth, with 99% of these deaths occurring in developing countries and being highest among women in poor rural areas. Specifically, 56% of the deaths in developing countries occur in Sub-Saharan Africa, where 20% of the total world population is found with only 3% of the total health workforce (Lampe, 2015). The absence of healthcare workers leads to increased medical errors and maternal mortality.

There is a need for a concerted effort to avert the preventable medical errors and complications (such as unsafe abortion, high blood pressure during pregnancy, infections usually after childbirth, severe bleeding mostly after childbirth and complications from delivery) that contribute to nearly 75% of maternal deaths through the provision of skilled care before, during and after childbirth (Kohn et al., 2000; McCann, 2014).

To fill healthcare and advice gaps in order to reduce preventable complications, new knowledge and skills through continuous professional development should be sought to suit the changing healthcare environment (National Council for the Professional Development of Nursing and Midwifery, 2003; Rogers, 1991).

While many learning theories have been advanced over the past 2,500 years, almost all have been based on the notion that learning occurs in a classroom and is mediated by a trained teacher (Vavoula & Sharples, 2009). Only a few educational thinkers have developed theory-based learning outside the classroom. One such form of learning is mLearning, where learning can occur through a wireless, handheld and portable device that is electronic in nature (Muyinda, 2010). This learning should not be portrayed as a stand-alone but rather as a support mechanism.

A study by (G. N. Vavoula, 2005) on everyday adult learning established that 51% of reported learning episodes took place at home or in the learner's own office at the workplace, i.e. in the learner's usual environment. With more than 5 billion mobile phones already in use around the world, doctors and nurses can send texts or create automated messages to remind patients to take their medicine or to help them quit smoking (Carey et al., 2015).

In Uganda, the mobile phone penetration stands at 63.9% and handheld phones have almost outgrown the fixed-line segment (UCC, 2019). In the last decade, Uganda's telecommunications sector registered great strides in mobile money transfer services as well as voice and data communications (ibid.). According to Opoku et al (2017), a realist review of the use of mHealth for long-term conditions in Sub-Saharan Africa was lauded for addressing capacity-building shortages. Another study by Beratarrechea, Moyano, Irazola, & Rubinstein (2017) revealed that mobile phones improved access to affordable and effective mHealth initiatives in resource constrained areas.

In this case, mLearning presents an opportunity to overcome some of the obstacles and problems related to information delivery and, therefore, to include learners belonging to such groups as mature-aged, international and remote learners, as well as those with cognitive, behavioural, or social difficulties (Cobcroft et al., 2006).

According toTetard and Patokorpi (2008), mLearning is a valuable means of gaining easy access to information as well as reducing student dropouts and avoiding social exclusion. mLearning portals permit the presentation and use of learning materials that make them more adaptable to individual learning styles and even level out the approaches to tackling problems with numeracy and literacy (Attewell & Savill-Smith, 2004). mLearning addresses some of the issues relevant to inclusion and student retention, i.e. mitigating resistance to using IT, engaging reluctant learners, enabling learners to remain more focused for longer periods, and promoting self-esteem and self-confidence (Attewell, 2005).

In a survey carried out among CEOs in public and private healthcare, as well as pharmaceuticals, biotechnology and medical device manufacturing in 23 countries, most (64%) executives believed in the ability of new mobile technologies and services to provide greater patient access to medical information in order to dramatically improve health outcomes (Carey et al., 2015).

Almost a similar proportion (63%) also predicted that greater patient access to their personal data would allow people to make better decisions about their health. The use of smartphones by Taiwanese nursing students as clinical examination tools in simulations resulted in higher learning outcomes than in a control group who used pen and paper to record and evaluate patients' symptoms (Wu et al., 2011).

Reference tools on mobile devices such as drug and diagnostic/laboratory applications were found to be particularly popular and valued (George et al., 2010). In a British study, multimedia podcasts on iPods were used directly at the bedside to support the learning of midwives regarding the New-born Infant Physical Examination (Clay, 2011). Furthermore, studies from the US and Canada came to the conclusion that nurses and nursing students viewed mobile devices as effective means to support their learning in the workplace by enabling access to various sources of expertise in decision-making processes (Pimmer et al., 2014).

Student nurses showed a significant increase in self-efficacy in their preparation for medication administration while using PDAs (Goldsworthy et al., 2006) while students utilizing PDAs had increasing numbers of questions when in the practice setting, as well as a greater recognition of the need to use current resources (Miller, Boggin, Blue, & Berrier, 2005).

In the past decade, nurses used mobile devices for many reasons such as to keep task lists, memo pads and calendar/date books to access clinical reference material for e-mail and for Internet access (Kenny et al., 2009). Nursing instructors have used such devices to keep records of student assignments and checklists for completing physical assessments as a source of point-of-care reference (drug software) and to document student progress on the spot (Lehman, 2003).

According to Newbold (2003), mobile devices are associated with additional potential for clinical applications such as interdisciplinary consultations, electronic ordering and test results, patient histories, progress notes and assessments, references, protocols and prescription information. Other reasons why nurses recommended mobile devices such as PDAs for use in practice included their light weight, their convenience, the decrease in medication errors they afford (as their use is safer than relying on memory), the immensity of the information they make available and their use to explore options with clients (Davenport, 2004). iPods have been identified as the current leading platforms for mLearning with 47% of trainers and educators using mLearning, indicating they target iPods for the delivery of their content, and mobile phones are the second most popular platform (Low, 2007).

In northern Arizona (USA), many individuals lack electricity or running water and live a reasonably long distance from hospitals and/or health clinics. Home monitors with an automated data mechanism to the NAH through a mobile phone connection were given to people suffering from congestive heart failure to measure weight, blood pressure, heart rate and oxygen levels in order to test whether technological mobile health services could improve care and cut costs in a rural population (Carey et al., 2015). Patients without electricity received solar chargers and batteries, and this resulted in a plunge in the average number of days each patient spent in hospital from 14 to just over five, thereby, saving more than $90,000 per person.

For as long as users can comfortably and effectively use their mobile devices for the specific task at hand, mobile technologies are most useful for supporting learning that is more situated to allow a full range of pedagogies to be adopted (Traxler & Kukulska-Hulme, 2005). More specifically, both human and technical aspects surround the use of mobile devices for remote access (Low, 2007). According to a study by Waters (Waters, 2006), mLearning content is not just delivered but may also be created using mobile devices. An understanding of the relevant formats, codecs and containers used to support learning activities becomes more important as learning activities are developed and become an important issue for resource developers (Low, 2007).

With the emergence of the Internet and ubiquitous technologies, knowledge is no longer a preserve for a few but can now be sourced by a wide array of knowledgeable workers in an open access paradigm. This study lays down a framework for continuous professional development for midwives through mobile learning, i.e. outside the conventional education dynamics, in order to enable a better understanding of what knowledge and skills can be transferred through their mobile devices. This framework is drawn upon the open innovation theory to facilitate an understanding of how different healthcare knowledge artifacts could be ported onto mobile devices to improve the efficiency of midwives (Cheng & Huizingh, 2014; Chesbrough, 2003).

The open innovation theory is grounded on the notion of knowledge abundance and the ability of such knowledge to freely provide added value from within and/or outside an institution through pecuniary and non-pecuniary mechanisms that are in line with the institution's strategic direction. The open innovation theory has been applied in various fields to innovatively seek solutions to different problems. In the health sector, midwives draw knowledge (with clear boundaries) from a number of sources, including: doctors, nurses, traditional birth attendants, nurse and midwife councils, ministries of health and NGOs. By so doing, midwives attain a rich learning experience through this external knowledge network that is vital for saving mothers, the unborn and newborn babies (Roijakkers et al., 2014). From the foregoing review, the following research questions emerge:

i) What are the factors necessary for freely accessing and/or sharing maternal health knowledge artifacts using mobile devices?

ii) What knowledge artifacts do midwives prefer to freely access and/or share with different healthcare providers using their mobile devices?

2.4 Methods

The study took a research survey approach with mixed methods. Research surveys encompass measurement procedures for large scale data sets that involve asking questions of respondents to assess thoughts, opinions and feelings (Macdonald & Headlam, 2008). Proponents of mixed research methods in information systems (ISs) have arguably been found to have the ability to address confirmatory and exploratory research questions simultaneously (Teddlie & Tashakkori, 2009).

Typically, qualitative methods have been used in ISs and other social sciences for exploratory research to develop a deep understanding of a phenomenon and/or to inductively generate new theoretical insights, while quantitative methods in IS studies have provided confirmations such as theory testing (Walsham, 2006). A self-administered questionnaire comprising both structured and unstructured items was administered to a sample of 1,236 geographically spread respondents in five regions of Uganda (Central, Northern, Eastern, Western and Southern) with a response rate of 71%. Respondents were midwives drawn from nine (9) nursing and midwifery training institutions, 17 hospitals and five (5) health centres.

In order to ensure validity and reliability experienced research assistants with good communication and interpersonal skills were recruited. Research assistants were taken through step-by-step training ahead of the data collection exercise. Furthermore, the entire data collection exercise was supervised from its inception to completion. The researcher took the lead in interviewing some of the key informants. For ethical reasons, respondent names were omitted from the study tools to allow free and unbiased responses.

Permission from relevant authorities and the respondents themselves was sought before any data collection commenced. At each of the authority levels, the research assistant explained the research purpose.

2.5 Findings

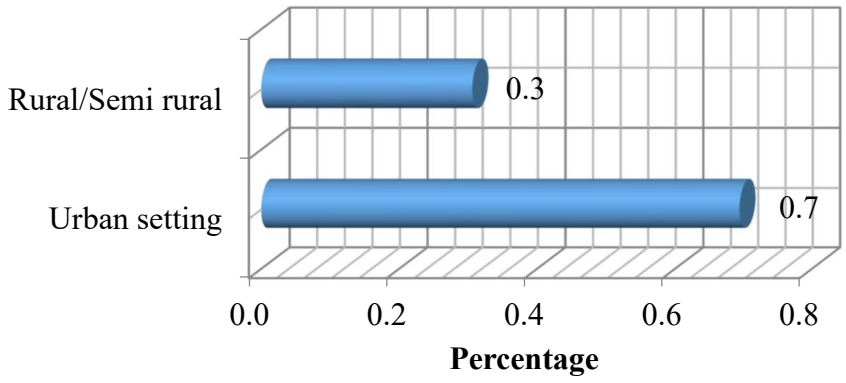
This study is underpinned by the Open Innovation Theory. The theory presupposes an abundance of created and co-created knowledge and the ability of such knowledge to be freely distributed or harnessed within, and/or outside an institution through pecuniary and non-pecuniary mechanisms that are in line with the institution's strategic direction (Chesbrough, 2003). In Uganda, there is a lot of medical knowledge among medical workers that if freely accessed and/or shared can be of value to midwives and other health workers.

The goal of this study was to establish knowledge artifacts (from the existing open knowledge bases) that could be freely distributed to midwives using mobile devices in the context of mLearning.

In this chapter, empirical findings related to factors that could assist or inhibit the use of mLearning for freely distributing or accessing medical knowledge are provided before adducing artifacts that could be freely accessed and/or shared through mLearning. In *Sections 2.5.1* to *2.5.5,* the factors are presented and include: location of health facility and mobile devices owned; types of health facility; age and working experience of midwives, usual learning content as well as the preferred content packaging and knowledge of mLearning and its use. In *Section 2.5.6*, an analysis of some forms of mLearning knowledge artifacts received and preferred by midwives is presented in form of tables, graphs, relationship mappings, logit regression and differentials.

2.5.1 Location of health facility and mobile devices owned

The location of a healthy facility affects the way midwives access CPD opportunities. Those in urban centers are likely to have more access than those in rural areas. As such, the study sought to establish the most prevalent location settings where midwives worked or were trained. The findings are indicated in Graph 1 below.

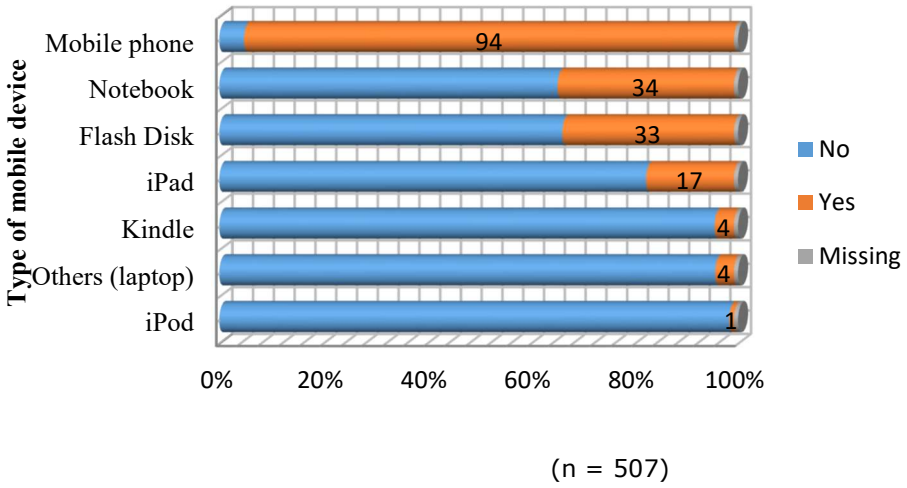


(n = 872)

Source: Field Data (2017)

Graph 1: Location setting of health facility

As reflected in Graph 1, nearly three quarters of the respondents served at mainly urban health centers. In Uganda, urban and/or semi-urban centers are characterized by a number of economies of scale, including but not limited to a stable hydropower supply and good mobile network and Internet connectivity. Urban dwellers are more likely to have a mobile device than rural dwellers due to the aforementioned conditions, which tend to favor ownership of mobile devices. As revealed in graph 2 that mobile phones are the most owned, a columnar cross tabulation of mobile phone ownership and location of college/workplace reveals that actually 95% (n=602) of the urban dwellers owned a mobile phone.



Source: Field Data (2017)

Graph 2: Mobile devices owned

The most widely owned mobile device is the mobile phone, which is owned by 94% of the respondents. Mobile devices vary in screen and keyboard sizes. The size of the screen and keyboard determines the learning affordances of the mobile device and therefore the content that can be rendered on it. The bigger the screen and keyboard the better. As can be seen in *Graph 2*, the majority of midwives do not own larger keyboard and screen mobile devices such as notebooks, laptops, kindles and iPads. As such, knowledge artifacts accessible on mobile phones are more likely to be accessed and used than those meant to be accessed on larger-screen mobile devices.

Already, according to Carey et al. (2015), more than 5 billion mobile phones are owned and used around the world by doctors and nurses to send texts or create automated messages to remind patients to take their medicine or to help them overturn unhealthy habits. In Uganda, mobile phone penetration stands at 63.9% and handheld phones have almost outgrown the fixed-line segment (UCC, 2019). Over the last decade alone, Uganda's telecommunications sector has registered great strides, especially in affordances of phone handsets, mobile money transfer services, and voice and data communications (UCC, 2019). A realist review of the use of mHealth for long-term conditions in Sub-Saharan Africa has been lauded for addressing the capacity-building shortage (Opoku et al., 2017). Similarly, Beratarrechea et al. (2017) revealed that mobile phones potentially improved access to affordable and effective mHealth initiatives in resource-constrained areas.

2.5.2 Types of health facilities

The study sought to establish the type of ownership of health facilities where the midwives were working. It was established that 65% were working/training in public institutions while 35% were in private institutions (n = 870). Public health facilities are more likely to permit their staff to use mobile phones at work than private ones. Since the majority of midwives are based at public health facilities, they can access knowledge artifacts on their mobile phones without much restriction. Further, government should prioritize investment in expensive medical devices to permit access to specialized healthcare services by all.

2.5.3 Age and working experience of midwives

Young people are more likely to use mobile devices than elderly midwifery students are. On the other hand, the elderly have more work experience than the young. As such, it was important to establish the age and working experience of respondents. The results are shown in Table 1 below.

Table 1: Cross-tabulation of age vs. experience/number of years worked (column)

Number of years of working	**Age**		
	15–30 (young)	**31 and above (old)**	**Total**
0–5 years (n)	584	64	648
Column %	82.4%	41.0%	74.9%
Row %	90.1%	9.9%	100%
5+ years (n)	125	92	217
Column %	17.6%	59.0%	25.1%
Row %	57.6%	42.4%	100%
Total	**709**	**156**	**865**
Row %	**82.0%**	**18.0%**	**100%**
Column	**100.0%**	**100.0%**	

Source: Field Data (2017)

The majority of respondents (82.0%, n = 709) were young (15–30 years old) with only 18.0% being older than 30. The percentage of young participants was 82.4% in the category of people that had worked for no more than five years of experience. The share of young respondents dropped to 57.6% in the category of midwives that had worked for more than five years. In short, even in the category with experienced midwives, the majority were not older than 30. In total, we observe that 74.9% of the respondents have less than five years of experience.

This percentage shifts strongly with age, as 82.4% of those no older than 30 have no more than five years of experience while only 41.0% of those older than 30 have less than five years of experience. Although these percentages are in line with our expectations, it shows that almost two out of five respondents older than 30 had been working for a relatively short period, entering the midwife market at a later stage in their life.

The fact that young people dominate the population of midwife students is good news. Relatively young people have a wide-ranging desire for social life, the potential for further training and a high affinity for emerging digital technologies, especially mobile devices, but are less experienced professionally. As such, the ground is fertile for the use of technology to extend CPD to these young people.

Since the majority own mobile phones as is indicated in Graph 2 above, knowledge artifacts rendered on these devices can be consumed for CPD. As Pimmer et al. (2014) proposed, mLearning is an effective way of filling the knowledge and skills gap. The use of mobile devices supports learning in the workplace by enabling access to various sources of expertise for decision-making processes. Similarly, as Clay (2011) indicated, multimedia podcasts on iPods have been used directly at the bedside to support the learning of midwives regarding the newborn infant physical examination. As such, what remains is the ability of the user to comfortably and effectively use the mobile technology at her/his disposal to support learning through the adoption of a full range of pedagogies (Traxler & Kukulska-Hulme, 2005).

2.5.4 Age, usual learning content and preferred content packaging

Table 2: Cross-tabulation of age and usual learning content

Usual learning content		**Age**		
		15–30 (young)	**31 and above (old)**	**Total**
Paper based	n	356	80	436
	Row	81.7%	18.3%	100.0%
	Column	50.3%	51.3%	50.5%
Electronic	n	45	12	57
	Row	78.9%	21.1%	100.0%
	Column	6.4%	7.7%	6.6%
Mixture of paper & electronic	n	307	64	371
	Row	82.7%	17.3%	100.0%
	Column	43.4%	41.0%	42.9%
Total Row percentage	n	708	156	864
	Row	81.9%	18.1%	100.0%
	Column	100.0%	100.0%	

Source: Field Data (2017)

From Table 2, only 6.4% of the young respondents preferred purely electronic content compared to only about 8% of the elderly who preferred the same. Also, 43.4% of the young preferred a mixture of paper and electronic learning content compared to 41% of the elderly who were comfortable with the same, indicating a relatively stable preference for the mixed content. This implies the need for blended learning for midwives. Electronic knowledge artifacts and paper-based content could complement each other.

Furthermore, both the young and the elderly are willing to make use of electronic devices for learning in a complementary manner, but with more emphasis among the young people.

Less emphasis on the young is bound to dampen the potential of electronic devices to offer multidisciplinary solutions to medical problems as put forward by Newbold, Davenport and Carey. Newbold (2003) established that mobile devices could offer additional potential clinical applications such as interdisciplinary consultations, electronic ordering and test results, patient histories, progress notes and assessments, references, protocols and prescription information.

In Davenport (2004), the use of mobile devices has been lauded for causing a decrease in medication errors since their use is safer than relying on memory for offering real-time information. Further, new mobile technologies have been applauded among public and private pharmacists, biotechnologists and medical device manufacturers for enabling improved access to medical information (Carey et al., 2015).

Since it has been adduced that electronic knowledge artifacts should be those that help midwives to understand paper-based content, it goes without saying that the most preferred packaging of content is that which is mixed/blended. When asked to state their preferred form of content packaging, mixed media won the day with about 51% (n = 444) of the respondents. The others included: text (22%, n = 189); video (21%, n = 179); picture (5%, n = 41) and audio (2%, n = 16). Mobile devices have the potential to present mixed media to learners to support learning activities (Low, 2007; Waters, 2006), in a concept known as "mLearning."

2.5.5 Knowledge of mLearning vs. mLearning use

In order to determine the proliferation of mLearning among midwives, respondents were asked to state whether they had ever heard about mLearning and whether they were using it. The responses are shown in Table 3 below.

Table 3: mLearning knowledge vs. mLearning Use

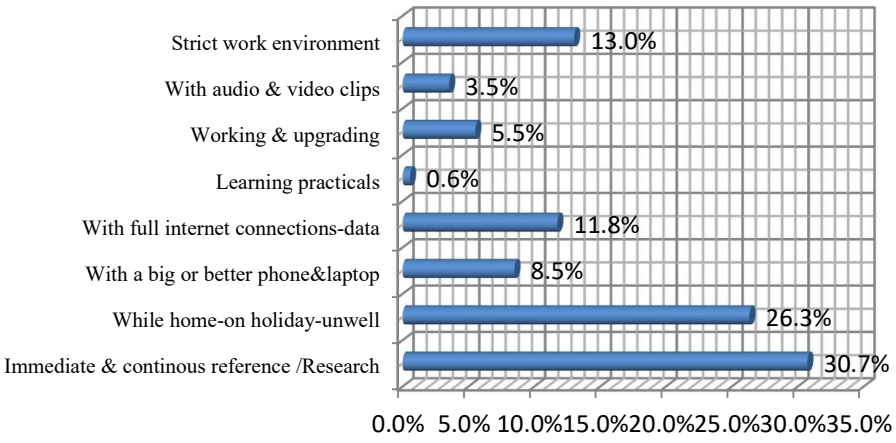
Knowledge (Ever heard of mLearning system)	Are you using any mLearning system		Total
	Yes	No	
Yes (n)	190	530	720
Row Percentage	26.39	73.61	100
Column Percentage	96.6	80.4	84.2
No (n)	6	129	135
Row Percentage	4.44	95.56	100
Column Percentage	3.06	19.6	15.7
Total (n)	196	659	855
Row Percentage	22.92	77.08	100
Column Percentage	100	100	

Source: Field Data (2017)

mLearning is not an alien concept to midwives since 84.2% of the respondents had heard about it. However, its use is still in its infancy. Of the 84% who had heard about mLearning, only about 26% (n = 190) were using it. Since mLearning use is still in its initial stages, open innovation learning approaches using mLearning can only succeed with great sensitization and training. The uptake of this sensitization and training is likely to be high considering the fact that the majority (82%, n = 712) of midwives are young (less than 30 years old) and therefore more receptive to training in the use of technology for learning.

This implies that mLearning has the potential to grow and reduce the knowledge and skills gap among midwives in the future.

Although the use of mLearning was limited, the potential for growth of mLearning is high since respondents were able to spot circumstances where mLearning could be applicable. Further, their views towards mLearning were mainly positive. Graphs 3 and 4 present the circumstances for and views towards mLearning, respectively.



(n = 706)

Source: Field Data (2017)

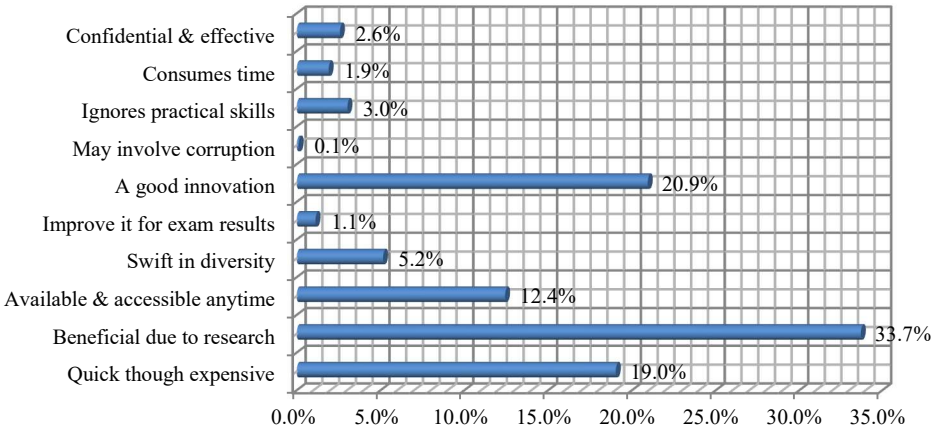
Graph 3: Circumstances under which midwives prefer mLearning

Findings from Graph 3 confirm the earlier finding in this paper that electronic knowledge artifacts should be those that supplement or help midwives to understand paper-based content.

The majority (30.7%, n = 217) of respondents felt that mLearning should be used under circumstances where immediate and continuous access to medical resources at any time anywhere is required. Constant Internet connectivity is paramount to permit anytime and anywhere learning.

Therefore, mobile devices with mixed media affordances will be required for learning as information is shared amongst practicing midwives, apprentice midwives, government, hospitals, medical schools, other medical training institutions, telecom providers, smartphone sellers/manufacturers, medical service centres, nongovernmental organizations (NGOs), content providers, mobile app developers, and other healthcare providers such as doctors and nurses.

When such devices are employed, a huge amount of information that is vital for the reduction of medical errors will be accessed by midwives, as was argued by Davenport (2004). Anytime and anywhere access to information has the potential to get learners to focus on knowledge acquisition for longer periods and conveniently utilize their mobile devices during leisure time and while on the move (Attewell, 2005).



(n = 893)

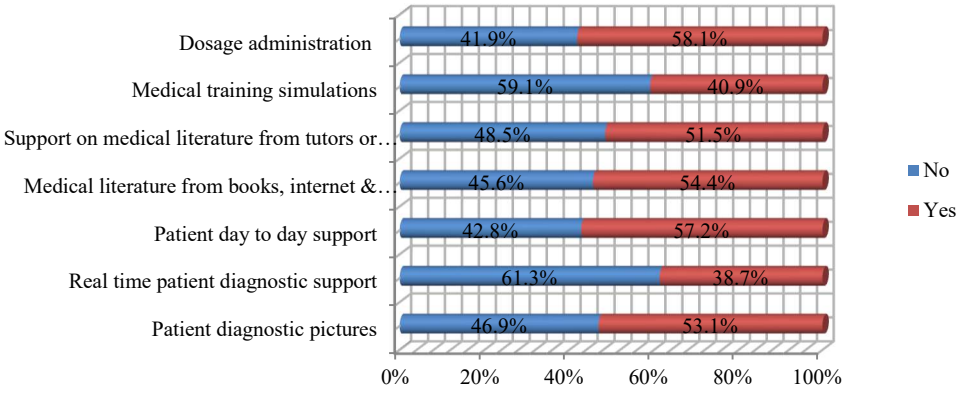
Source: Field Data (2017)

Graph 4: General views of respondents towards mLearning

The interviewees (see Graph 4) consider mLearning to be positive because it has the potential to provide up-to-date and real-time research information (33.7%, n = 301), to be a good innovation in pedagogy (20.9%, n = 187) and to provide quick access to information (19%, n = 170). The downsides of mLearning are its high cost (19%, n = 170), its inability to provide hands-on skills (3%, n = 27) and its misuse (1.9%, n = 17). This implies that the success of an open innovation based on mLearning depends on mitigating the costs while maximizing the benefits of mLearning. A detailed investigation into costs and benefits for mLearning as an open innovation tool is provided in my Paper 2 on "Cost-benefit implications for delivering mLearning knowledge artifacts to midwives."

2.5.6 Forms of mLearning knowledge artifacts preferred by midwives

So as to better understand what mLearning knowledge artifacts are preferred by midwives, it is important to explore the current state of affairs. In Graph 5 below, mLearning knowledge artifacts currently received from other health care professionals are presented. A further investigation into the kind of mLearning knowledge artifacts midwives preferred to receive from other healthcare professionals is presented in Graph 6. An insight into how differently midwives used their mobile phones was also explored and how such usage impacted on a number of technical assistance targets. The latter undertook a multivariate logit regression approach using both coefficients and odds ratios as shown in Graphs 5 and 6.



(n = 853)

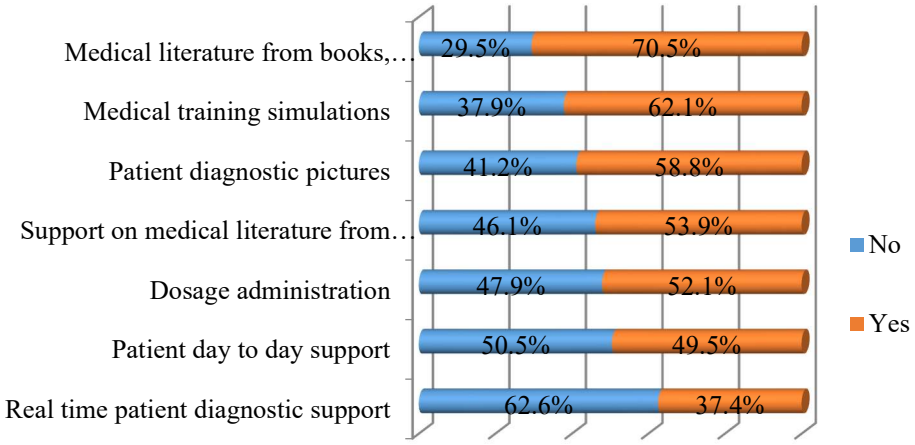
Source: Field Data (2017)

Graph 5: Forms of mLearning knowledge artifacts received from other health workers

Graph 5 above shows that mobile phones can help midwives obtain more information on: dosage administration (58%), patient day-to-day care support (57%), and medical literature from various sources (54%), patient diagnostic pictures (53%), and medical literature from their tutors and senior healthcare providers (52%). Knowledge on bedside real-time patient support (39%) and medical training simulations are the other support services afforded by mobile phones to midwives. In Clay (2011), it was revealed that multimedia podcasts on iPods offered mainly bedside support to midwives regarding newborn infant examinations.

When asked who constituted other healthcare professionals from whom support was drawn, midwives indicated these to be the ward in-charge/supervisors (31.9%, n = 314), doctors (22.3%, n = 219) and support organizations (14.9%, n = 147). They also mentioned colleagues (14.8%, n = 146), the Internet (6.4%, n = 63), consultants (5.6%, n = 55), books (3.7%, n = 36) and pharmacists (0.3%, n = 3). In an open innovation approach, a combination of these sources can and should be brought together to form a rich knowledge base to support midwives.

In Graph 5, the affordances of the mobile phone to midwives are given. However, out of all these affordances, which do the midwives prefer? A further investigation of this is in the following Graph 6.



(n = 852)

Source: Field Data (2017)

Graph 6: Preferred mLearning knowledge artifacts

The findings in Graph 6 above confirm earlier findings in this paper supporting the view that mLearning is a supplementary learning channel to traditional pedagogy. Midwives would like to freely access and/or share the following knowledge artifacts on their mobile phones: medical literature from books, the Internet and others (70.5%, n = 601), medical training simulations (62.1%, n = 529) and patient diagnostic pictures (58.8%, n = 501). They also referred to support on medical literature from tutors or senior medical officers (53.9%, n = 459), dosage administration (52.1%, n = 444), patient day-to-day support (49.5%, n = 422) and real-time patient diagnostic support (37.4%, n = 319). These findings are in line with Carey et al. (2015), who found that with the prevalence of over 5 billion mobile phones around the world, doctors and nurses could send texts or create automated messages to remind patients to take their medicine or to help them quit smoking.

In Table 4 below, different ways in which respondents use their mobile phones are presented.

Table 4: How people using mLearning use their mobile phones differently

Using mLearning	Other Uses of Mobile Phones										
	Leisure	Education	Communication	Business	Mobile Money	Lottery	Talk Shows	Calculations	Data Transfer	Others	Total
Yes (n)	154	148	132	58	97	27	50	95	97	7	865
Row %	17.8	17.1	15.3	6.7	11.2	3.1	5.8	11.0	11.2	0.8	100.0
Column %	22.0	23.8	20.8	21.5	17.1	17.6	19.5	18.2	22.6	14.0	20.6
No (n)	545	473	503	212	471	126	206	426	332	43	3,337
Row %	16.3	14.2	15.1	6.4	14.1	3.8	6.2	12.8	9.9	1.3	100.0
Column %	78.0	76.2	79.2	78.5	82.9	82.4	80.5	81.8	77.4	86.0	79.4
Total (n)	699	621	635	270	568	153	256	521	429	50	4,202
Total Row %	34.1	31.3	30.3	13.1	25.3	6.9	12.0	23.7	21.2	2.1	
Total Col. %	100	100	100	100	100	100	100	100	100	100	

(n = 839)

Source: Field Data (2017)

From Table 4, it is evident that mLearning is just one of the applications installed on midwives' mobile phones (23.8%, n =148). Midwives using mLearning also reported using their mobile phones for data transfer (22.6%, n = 97), leisure/entertainment (22%, n = 154), business (21.5%, n = 58), communication (20.8%, n = 132) and participating in talk shows (19.5%, n = 50).

Other uses of the mobile phones include working as a calculator, lotteries, mobile money, and others such as taking pictures and video.

The study was to understand how mobile device communications impacted on a number of technical assistance targets, such as patient diagnostic photographs/pictures (A), real-time patient diagnostic support (B) and patient day-to-day care/support **(C)**. We further wanted to study the impact of medical literature from books, the Internet or other sources (e.g. AMREF) (D), support on medical literature offered by tutors or other senior medical personnel (E), medical training videos or simulations (F) and dosage administration (G). An investigation of this scenario has been undertaken through a multivariate logit regression as the most appropriate owing to the fact that the dependent variables are all binary outcomes. The regression models were fitted using the formula;

$$\log \quad y = a + \sum_{i=1}^{n} b_i x_i$$

Where; $y = \left(\frac{p}{1-p} \right)$ is the dependent variable (technical knowledge artifact) presented as columns.

p = Probability of occurrence of events Q16A, Q16B, Q16C, Q16D, Q16E, Q16F and Q16G

$1-p$ = Probability of non-occurrence of events Q16A, Q16B, Q16C, Q16D, Q16E, Q16F and Q16G

x_i = Selected explanatory variables (Q17A, Q17B, Q17C, Q17D, Q17E, Q1A, Q2A, Q3 and Q4) presented as rows

a = Constant of the equation

b_i = Coefficients

$n = number \quad of \quad \text{exp}lanatory \quad \text{var}iables$

In *Table 5* below, the results using coefficients are presented, while *Table 6* presents the results using odds ratios.

Table 5: Section of Logit regression results (coefficients)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Diagnostic Pictures Q16A	**Real-time patient diagnostics Q16B**	**Patient day-to-day care Q16C**	**Medical literature Q16D**	**Support by tutors & medical personnel Q16E**	**Medical training videos & simulations Q16F**	Dosage administration **Q16G**
	Coefficients						
Q17A	1.496***	0.808***	1.088***	-0.521	1.757***	0.103	1.223***
Word of mouth	(6.34)	(3.52)	(4.86)	(-0.25)	(7.35)	(0.47)	(5.34)
Q17B	0.5630***	0.669***	1.114***	0.671***	0.337*	1.196***	1.232***
Brief meetings	(3.09)	(3.53)	(5.85)	(3.64)	(1.85)	(5.57)	(6.29)
Q17C	0.262	0.0161	0.748***	0.823***	0.136	1.085***	0.512**
Knowledge repositories	(1.51)	(0.10)	(3.95)	(4.68)	(0.81)	(6.38)	(2.66)
Q17D	1.161***	0.634***	1.056***	1.407***	0.172	1.198***	1.528***
Mobile phone communication	(7.30)	(4.10)	(6.60)	(8.91)	(1.09)	(7.27)	(8.73)
Q17E	-1.003	-0.0405	1.240**	0.019	0.462	0.400	1.154*
Others	(-1.61)	(-0.08)	(1.97)	(0.04)	(0.86)	(0.69)	(1.93)
Q1A	0.061	-0.1103	-0.326	-0.139	-0.750*	-0.073	0.289

			*		**		
Urban setting	(0.35)	(-0.67)	(-1.77)	(-0.81)	(-4.32)	(-0.42)	(1.55)
Q2A	0.216	0.136	-0.958***	-0.340**	0.007	-0.045	-1.330***
Publicly owned	(1.29)	(0.85)	(-5.51)	(-2.05)	(0.05)	(-0.26)	(7.34)
Q3	0.275**	-0.0678	0.441***	0.001	-0.812***	-0.089	-0.220*
5+ Years of practice	(2.36)	(-0.62)	(3.50)	(0.01)	(-6.73)	(-0.77))	(-1.76)
Q4	-0.137	0.142	-0.214**	-0.003	0.241**	-0.030	-0.082
Old	(-1.71)	(1.88)	(-2.54)	(-0.03)	(2.99)	(-0.37)	(-0.99)
Constant	-2.047***	-2.25***	-1.92**	-1.018***	-0.357	-2.09***	-1.569***
	(-6.19)	(-5.76)	(-4.81)	(-2.72)	(-0.94)	(-5.17)	(-3.95)
N *Chi 2* *Pseudo R2*	825 155.50*** 0.1365	823 54.26*** 0.0493	823 232.26*** 0.2067	823 159.39*** 1.1405	822 117.53*** 1.032	825 176.69*** 1.1582	825 270.76*** 0.2409

t statistics in parentheses

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Source: Field Data (2017)

Table 6: Section of Logit regression results (odds ratio)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Diagnostic Pictures **Q16A**	Real-time patient diagnostics **Q16B**	Patient day-to-day care **Q16C**	Medical literature **Q16D**	Support by tutors & medical personnel **Q16E**	Medical training videos & simulations **Q16F**	Dosage administration **Q16G**
	Odds Ratio	–					
Q17A Word of mouth	**4.65**	**2.22**	**3.27**	0.91	**5.30**	1.05	**3.25**
	(2.94 – 7.38)	(1.43 – 3.47)	(2.11 – 5.05)	(0.61 – 1.37)	(3.34 – 8.41)	(0.68 – 1.62)	(2.10 – 5.05)
Q17B Brief meetings	**1.72**	**2.03**	**2.95**	**1.94**	**1.56**	**3.26**	**3.37**
	(1.20 – 2.46)	(1.40 – 2.95)	(2.03 – 4.28)	(1.35 – 2.78)	(1.09 – 2.23)	(2.14 – 4.97)	(2.30 – 4.94)
Q17C Knowledge repositories	1.22	1.06	**2.02**	**2.17**	1.31	**2.91**	**1.65**
	(0.86 – 1.72)	(0.77 – 1.46)	(1.39 – 2.93)	(1.53 – 3.07)	(0.94 – 1.84)	(2.08 – 4.08)	(1.13 – 2.41)
Q17D Mobile phone communication	**3.12**	**1.93**	**3.08**	**3.86**	1.16	**3.22**	**4.21**
	(2.29 – 4.27)	(1.42 – 2.62)	(2.22 – 4.27)	(2.83 – 5.26)	(0.85 – 1.58)	(2.33 – 4.44)	(3.00 – 5.90)
Q17E Others	0.39	0.96	3.44	1.01	1.39	1.50	2.85
	(0.12 – 1.30)	(0.34 – 2.73)	(1.00 – 11.84)	(0.34 – 3.00)	(0.48 – 3.99)	(0.48 – 4.70)	(0.88 – 9.24)
Q1A Urban setting	0.98	0.88	0.71	0.85	**0.49**	0.95	1.37
	(0.70 – 1.38)	(0.63 – 1.21)	(0.50 – 1.02)	(0.60 – 1.19)	(0.35 – 0.69)	(0.68 – 1.34)	(0.95 – 1.97)

Q2A Publicly owned	0.84	0.91	**2.57**	**1.48**	1.00	1.04	**3.68**
	(0.60 – 1.16)	(0.67 – 1.25)	(1.84 – 3.61)	(1.07 – 2.05)	(0.73 – 1.37)	(0.74 – 1.45)	(2.59 – 5.23)
Q3 Years of practice	**1.57**	**0.66**	**2.03**	**1.57**	**0.23**	1.14	1.24
	(1.05 – 2.35)	(0.46 – 0.95)	(1.31 – 3.15)	(1.05 – 2.37)	(0.15 – 0.34)	(0.77 – 1.70)	(0.79 – 1.94)
Q4 Age	**0.50**	**1.55**	0.74	**0.54**	**2.41**	0.64	**0.58**
	(0.32 – 0.77)	(1.02 – 2.37)	(0.46 – 1.18)	(0.35 – 0.83)	(1.53 – 3.80)	(0.40 – 1.01)	(0.36 – 0.94)
Constant	**0.13**	**0.15**	**0.06**	**0.28**	**0.32**	**0.10**	**0.03**
	(0.07 – 0.23)	(0.09 – 0.27)	(0.03 – 0.12)	(0.16 – 0.48)	(0.18 – 0.57)	(0.06 – 0.18)	(0.02 – 0.06)
N *Chi 2* *Pseudo R2*	823 159.53 0.14	821 57.33 0.05	821 229.70 0.21	821 167.46 0.15	820 127.57 0.11	823 181.20 0.16	823 267.31 0.24

Bold means p-value < 0.05.

Confidence interval (CI 95%) in parenthesis

Source: Field Data (2017)

Table 5 shows how the likelihood of getting different forms of technical assistance is affected by different means of providing this technical assistance. One of these means is mobile phone communications and we are interested in understanding how this means compared to others in the provision of technical assistance to midwives. Different control variables are added in the regressions to control for effects that are linked to the respondents rather than to the different means of providing assistance. The control variables chosen include location setting of a health facility, type of ownership of such a health facility, years of experience of a midwife and age. All these factors are important for mLearning to thrive. Different age groups have varying passions for emerging technologies, yet vast experience lies with those midwives who have served for more years. Further, location of a healthy facility affects the way midwives can access CPD opportunities and the type of health facility predicts the flexibility of the use of emerging technologies.

Table 5 reveals that word of mouth in ward rounds is an important means of providing assistance to midwives. This is the case for patient diagnostics/pictures, real-time patient diagnostics, patient day-to-day care, and support on medical literature by tutors or other senior medical personnel, and dosage administration. Brief meetings are important as well: They are useful in all forms of assistance, ranging from providing assistance for patient diagnostics/pictures, real-time patient diagnostics, and medical literature from books and the internet to support on medical literature by tutors or other senior medical personnel, medical training, and videos and simulation, and dosage administration.

Knowledge repositories (library, central database) are helpful for patient-day-today care, access to medical literature, medical training, videos and simulation, and dosage administration. Mobile phone communication is also very useful for all types of assistance except when it comes to assistance on medical literature from tutors or other senior medical personnel. In other words, midwives use mobile phone communication as an important means to get technical support for many purposes, ranging for diagnostics and patient day-to-day care to retrieval of medical literature and training videos, and to information about dosage administration. In contrast, midwives use mobile phone information independently of the assistance they get from tutors about medical literature. There is no substitution effect as information from tutors doesn't lead to more use of information on the Internet.

Two more conclusions have to be drawn: First, these different means of assisting midwives technically all have a positive effect on the technical assistance midwives receive. That implies that mobile phone communication is one specific means that is used among others to get the required technical assistance in different aspects of the job. Mobile communication is not used for a specific purpose but is utilized along with other means to obtain almost all types of technical assistance in different parts/aspects of the job. Second, the coefficients for mobile phone communication are relatively high and for most types of technical assistance they are in line with (or higher than) coefficients of traditional means of communication such as word of mouth in ward rounds. This implies that mobile phone communication has a major impact on the (different types of) technical assistance that midwives receive.

In summary, mobile phone communication is important for the technical assistance of midwives. The actual use of mobile phone communication in the technical assistance for midwives is currently about 51.7% (*see Q17D*) and is substantially lower than other means such as word of mouth in ward rounds 84.3% (*see Q17A*) and brief meetings - 75.8% (*see Q17B*) but already higher than the use of knowledge repositories such as ward libraries and central databases - 31.3% (*see Q17C*). Mobile phone communication thus already has a respectable place as a means of supporting technical assistance for midwives, but as only half of the sample use this channel of communication, there is still room for further use of mobile phone communication. Interestingly, the logit regression results show that mobile phone communication is supporting midwives in assisting them in many aspects of their work, and its impact is larger than other means of technical assistance such as word of mouth in ward rounds, brief meetings or knowledge repositories. These are important findings from the survey: Midwives already use their mobile phones a lot for technical assistance, and it seems to be an effective way to get the required technical support.

However, as only a small minority of the midwives use mLearning, the use of mobile phones should be extended from technical support to systematic mLearning practices.

Table 6 shows the results of logistic regression of forms of technical assistance controlling for means of providing this technical assistance and selected explanatory variables. Seven models were then fitted to measure the relationship between these forms of technical assistance and independent variables.

Results revealed that word of mouth, brief meetings and mobile phone communications were the different means of providing technical assistance that had a significant relationship with most of the forms of technical assistance. Specifically, midwives who used word of mouth, brief meetings and mobile phone communication had increased odds of obtaining different forms of technical assistance.

Knowledge repositories like a library as a means of providing technical assistance were only correlated with day-to-day patient support, medical literature from books, medical training simulations and dosage administration. All midwives who used knowledge repositories were more likely to receive the aforesaid forms of technical assistance.

Other means (Q17E) had no significant association with any of the different forms of technical assistance.

Among the control variables, only age and years of experience had their influence spread to almost all forms of technical assistance. Notably, midwives with 5+ years of experience had decreased odds of getting real-time patient diagnostic support (OR = 0.66) and support on medical literature from tutors/seniors (OR = 0.23), and yet they were more likely to get patient diagnostic pictures (OR = 1.57), day-to-day patient support (OR = 2.03) and medical literature from books (OR = 1.57). Midwives who were old (31+ years) were less likely to get patient diagnostic pictures (OR = 0.50), medical literature from books and the Internet (OR = 0.54), and dosage administration (OR = 0.58) but more likely to get real-time patient diagnostic support (OR = 1.55) and support on medical literature from tutors/seniors (OR = 2.41).

Location of health center/college was only a predictor of support on medical literature from tutors/seniors as midwives in urban locations had decreased odds (OR = 0.49) of getting support on medical literature from tutors/seniors than their counterparts in rural locations.

Type of college/workplace had an influence on three modals (forms of assistance): patient day-to-day support, medical literature from books/the Internet and dosage administration. Midwives from publicly owned colleges/workplaces had increased odds of getting day-to-day patient support (OR = 2.57), medical literature from books (OR = 1.48) and dosage administration (OR = 3.68) than their colleagues from privately owned colleges/workplaces.

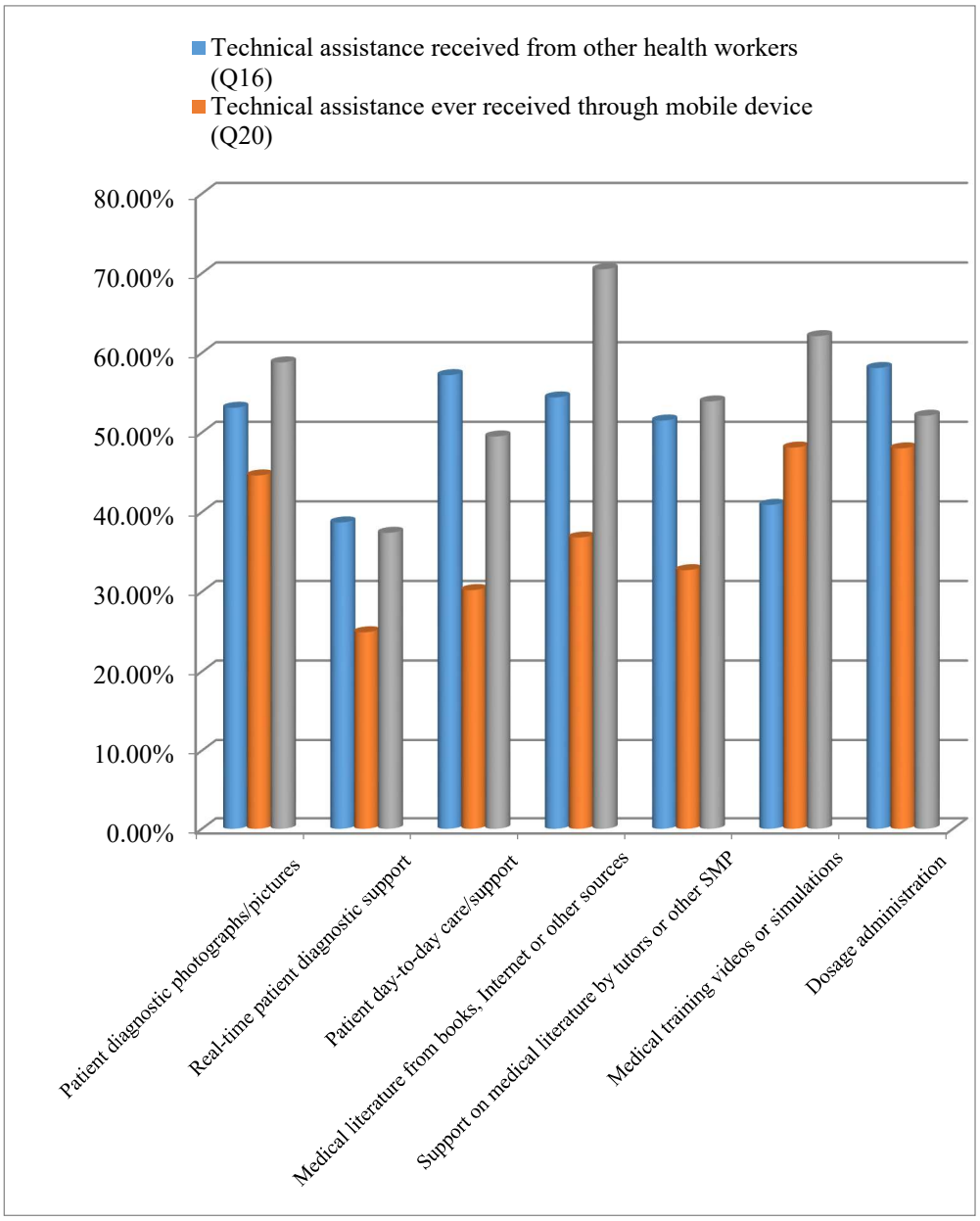
A further scrutiny of the form of technical assistance midwives received from other health workers, assistance they have ever received via their mobile phones and the assistance they wished to access via their mobile phones is presented first in Table 7 and then as Graphs 7 and 8 below.

Table 7: Relationship between technical assistance received from other health workers, technical assistance ever received through mobile device and, technical assistance wished to be accessed through a mobile device.

	A	**B**	**C**	**D**	**E**	**F**	**G**
Technical assistance received from other health workers **(Q16**)	53.1%	38.7%	57.2%	54.4%	51.5%	40.9%	58.1%
Technical assistance ever received through mobile device (**Q20)**	44.6%	24.9%	30.2%	36.8%	32.7%	48.1%	48.0%
Technical assistance wished to be accessed through a mobile device **(Q21)**	58.8%	37.4%	49.5%	70.5%	53.9%	62.1%	52.1%
Difference **Q16–Q20**	8.5%	13.8%	27.1%	17.6%	18.9%	-7.2%	10.1%
Difference **Q21–Q20**	14.2%	12.6%	19.4%	33.7%	21.2%	14.0%	4.1%

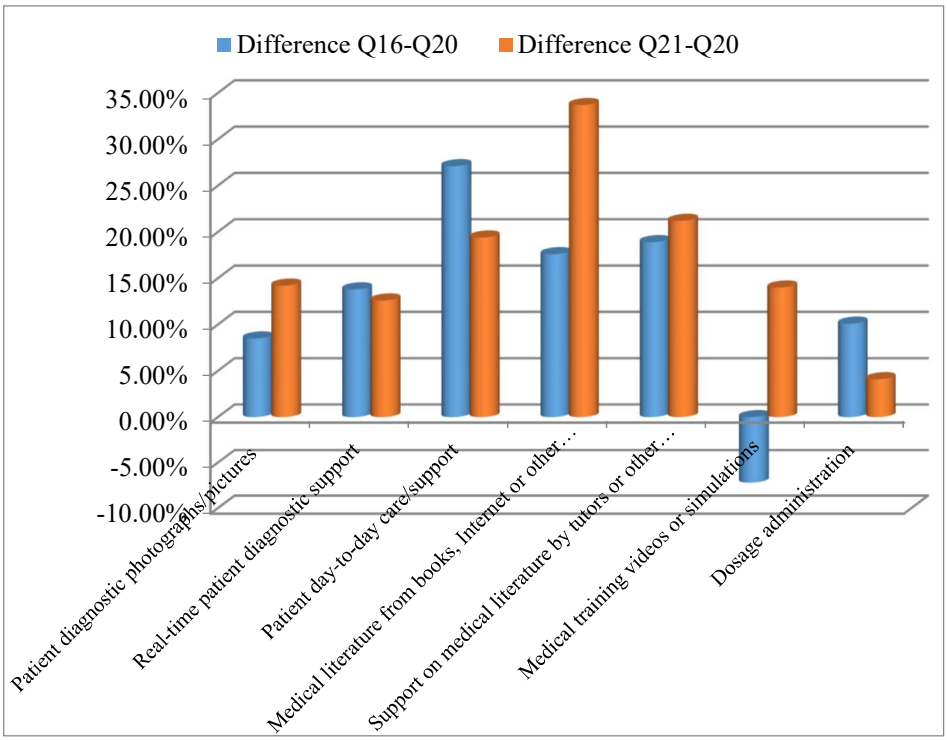
Source: Field Data (2017)

Where, A = Patient diagnostic photographs/pictures
B = Real-time patient diagnostic support
C = Patient day-to-day care/support
D = Medical literature from books, the Internet or other sources
E = Support on medical literature offered by tutors or other senior medical personnel
F = Medical training videos or simulations
G = Dosage administration



Source: Field Data (2017)

Graph 7: Relationship between Q16, Q20 and Q21



Source: Field Data (2017)

Graph 8: Differentials between Q16, Q20 and Q21

Where, SMP = senior medical personnel.

Graph 7 shows the different types of technical assistance that midwives receive from interaction with other health workers (left column) and through mobile devices (middle column). We also added the technical support that midwives expect to receive through their mobile devices. The difference between the assistance received through interaction with health workers and through mobile devices is represented by the left column in Graph 8. The bars on the right represent the differences between what technical assistance midwives expect from their mobile devices and the actual assistance they get from these devices.

The first graph, Graph 7, shows that mobile devices are used most for three (3) reasons: medical access to training videos and simulations (48.1%), dosage administration (48.0%) and inspection of patient diagnostic pictures (44.6%). It's obvious from the second graph, Graph 8, that mobile devices still provide different forms of assistance at a lower level than the technical assistance midwives receive from other health workers. The differences are the biggest for patient day-to-day care, medical literature from books, the Internet or other sources, and support on medical literature by tutors and medical personnel.

The difference is a bit lower for medical dosage and patient diagnostic support. Mobile devices are even the preferred means for the use of medical training videos and simulations (rather than watching videos and running simulations in a centralized setting). The difference between the actual use of mobile phone communication and the desired use by midwives is also interesting. The second graph (Graph 8) shows that all bars are positive, indicating that midwives want to use their mobile phone for a lot more technical assistance than they actually do. The biggest difference is for access to medical literature of books, the Internet and other sources (33.7%): 7 out of 10 midwives want to use their mobile phones for this type of technical assistance. Next is support on medical literature offered by tutors or other medical personnel (21.2%): This implies that tutors should be more acquainted with online materials so they can refer students to medical literature that they can access through their mobile phones. They also want to use their mobile phone more for day-to-day patient care (19.4%).

Finally, it is interesting to note that for most types of technical assistance, the desired level of mobile phone use is higher than the current technical assistance midwives receive from health workers. In other words, the mobile phone seems to have the potential (at least in the mind of the midwives) to increase the overall level of technical assistance, as they use their mobile phones to complement the assistance they receive from health workers, thereby enhancing their skills.

2.6 Conclusion

The aim of this paper was to identify specific knowledge artifacts that are vital in training midwives through pre-existing literature and knowledge on mLearning. mLearning is a necessary open innovation strategy in Sub-Saharan Africa, especially Uganda, where most maternal and infant mortalities emanate from preventable conditions due to the existence of few and inexperienced midwives. With the rapid rise in the penetration rate of, access to, and use and ownership of personalized mobile devices, especially the mobile phone, midwives can be re-tooled for "at-the-fingertips" solutions using an Internet-connected mobile phone. The mLearning innovation is bound to permit the development (and/or co-development) and sharing of knowledge and experiences as well as real-time access to support from medical professionals/experts who are not co-located but important in the implementation of maternal healthcare tasks.

The foregoing statement can only be meaningful if midwives are willing and able to actively interact among a number of technical knowledge providers, including their own peers and other healthcare professionals/experts. mLearning as an innovative strategy can also help in tackling the critical challenge of the shortage of midwives.

Statistics from Uganda's Ministry of Health indicated that the midwife-to-patient ratio was 1:6,838 in comparison to the World Health Organization's recommended ratio of at least 1:439. This calls for continuous professional development (CPD).

As revealed in the study findings, mLearning can only be a supportive learning tool for traditional pedagogy and therefore not an end in itself. It is a suitable support for the currently used conventional classroom, ward rounds, ward meetings and wall chart pinning techniques in developing more skills among midwives.

Further, with the revelation that 82% of the midwives were young (not older than 30 years old) and less experienced, mLearning is bound to thrive with ease. This age group is passionate about social life and has the potential for further training and a generally high affinity for emerging digital technologies, especially mobile devices. Adoption of mLearning therefore offers fertile ground for improving the knowledge and experience gaps of these young midwives through continuous professional development drawn from, in particular, the ward in charge/supervisors, doctors, support organizations, colleagues, the Internet, consultants, books and pharmacists. Nonetheless, success in this regard can only come with great sensitization and training.

On the other hand, the knowledge artifacts midwives liked to freely access and/or share on their mobile phones (in order of priority) included: medical literature from books, the Internet and others (70.5%, n = 601), medical training simulations (62.1%, n = 529), patient diagnostic pictures (58.8%, n = 501), support on medical literature from tutors or senior medical officers (53.9%, n = 459), dosage administration (52.1%, n = 444), patient day-to-day support

(49.5%, n = 422) and real-time patient diagnostic support (37.4%, n = 319). This state of affairs advocates the formation of a rich knowledge base to support midwives, an approach with the potential to widen the scope of knowledge provided to midwives at their workplaces or training institutions in an up-to-date and real-time fashion.

So to summarize, the use of developments in the ICT sector presents a good opportunity to increase access to education and training among midwives in Sub-Saharan Africa. However, this has to be balanced with other questions, such as: Can the policy makers accept the changes? Is the will of players automatic or does it need a catalyst? Has adequate investment in mLearning infrastructure (such as telecom towers) been made?

To avoid stakeholders being wary about the potential and quality of mLearning as an open innovative strategy, a deeper understanding of the factors that could aid or inhibit free access to knowledge artifacts amongst midwives using mLearning as an open innovation approach is necessary. Such factors include but are not limited to: the supply of stable hydropower or alternative power sources, a good mobile network and internet connectivity, smart mobile phones, favorable policies permitting mLearning in health facilities and training institutions, etc. Further still, for a midwife to purposefully use a heterogeneous/rich technical knowledge flood from several sources, different stakeholders have to collaborate and support innovations that support the co-creation and sharing of such technical knowledge from the different sources in the healthcare sphere. It would also be of interest in subsequent studies to device means of aiding the experienced midwives presumed to be one of the primary sources of expert knowledge yet digitally handicapped.

In my next chapter, Chapter 3, I present the cost-benefit implications for delivering mLearning knowledge artifacts to midwives, while in Chapter 4, a framework for effectively harnessing technical knowledge artifacts from different healthcare practitioners for the improved efficiency of midwives using mobile devices is presented.

Appendix 1: Questionnaire for Midwives

Dear Respondent,

My name is Charles Maina, a PhD student at Hasselt University, Belgium. I am undertaking a research titled, **Mobile Learning as an Innovative Strategy for upgrading Technical skills in developing countries: A case study of mobile learning for midwives in Uganda.** The study is aimed at exploring avenues for reducing the incidence of high preventable maternal deaths that emanate from short supply of health workers and low levels of knowledge and skills. Elsewhere, mobile learning has led to increased knowledge and skills as well as supply of health workers without necessarily drawing them from their current work stations.

Accordingly, as a midwife, your services are central in the aforementioned cause. I kindly request you to take about 15-20 minutes of your precious time to truthfully complete a couple of questions herein enclosed. Guidance on completing the questions is henceforth provided alongside each question.

I assure you that all the answers/information provided shall be treated with utmost secrecy and for the sole purpose of completion of my PhD studies. Indeed, your personal identifier will not be recorded anywhere to ensure that information provided cannot be traced to its provider.

Once again, your participation in this study is much obliged.

CHARLES MAINA M.

RESEARCHER

CONSENT

Note that you are free to participate or not to participate and even answer or not to answer any question(s). However, on acceptance to participate, kindly answer all the questions. I reiterate, all the information you will provide shall be treated with confidentiality and strictly used for academic purposes.

1	I agree to participate in the study (Answer questions in the questionnaire)	
2	I do not agree to participate (Return un answered questionnaire)	

SECTION A: RESPONDENT'S CHARACTERISTICS

1. My college/workplace is considered to be located in *... (Tick only one)*

1	An urban setting	
2	A semi/peri-urban setting	
3	A rural setting	

2. My college/workplace is ... (*Tick only one*)

1	Publicly owned/Government entity	
2	Privately owned/Private entity	

3. Number of years of working... (*Tick only one*)

1	0 – 2 years	
2	2 – 5 years	
3	5 – 10 years	
4	More than 10 years	

4. Age (*Tick only one*)

15-19	20-25	26-30	31-35	36-40	41-45	46-50	Above 50
1	2	3	4	5	6	7	8

5. I own the following mobile device(s) (*Tick all that which you own*)

	Mobile phone	
	iPad	
	iPod	
	Book reader (Kindle)	
	Notebook	
	Flash Disk	
	Others (Specify)_____	

6. The majority of times I have communicated to other people with a mobile phone, ... (*Tick only one*)

1	I have mainly used my own mobile phone	
2	I have mainly used someone else's mobile phone	
3	I have mainly used my spouse's or our family mobile phone	
4	I have mainly used a public telephone booth	

7. My usual learning content are in ---------- form *(Tick only one)*

Paper based [1]	Electronic [2]	A mixture of paper based & electronic [3]
1	2	3

8. I learn the most when a learning activity is expressed in terms of -- *(Tick only one)*

Text [1]	Audio [2]	Video [3]	Picture [4]	Mixture of all media [5]
1	2	3	4	5

9. Have you ever heard of the concept of mobile learning (m-learning) or learning using mobile devices such as mobile phones? (*Tick only one*)

Yes [1]	No [2]
1	2

10. Are you using any m-learning applications/system on any of your mobile devices? (*Tick only one*)

Yes [1]	No [2]
1	2

11. If yes, who is the service provider of that m-learning system? (*Write in the box*)

12. Under what circumstances would you prefer learning on a mobile device? (*Write in the box*)

13. What is your general view towards using mobile devices in the training of nurses and midwives? *(Write in the box)*

14. What value added services do you perform on your mobile device? (*Tick all what applies to you*)

	Leisure/entertainment (taking pictures and playing music and videos)	
	Learning/education	
	General communication (placing and receiving calls and SMSs)	
	Transacting profit oriented businesses	
	Transacting in mobile money services	
	Participating in lottery to win cash and other prizes	
	Calling in during radio/TV talk shows	
	Performing mathematical calculations	
	Transfer of information from one location to another	
	Others (specify) _____	

SECTION B: ACCESS TO TECHNICAL ASSISTANCE THROUGH MOBILE DEVICES BY NURSES AND MIDWIVES

15. The world over, execution of nursing/midwifery work quite often requires technical support from other health care providers. For you, from whom do you receive such technical assistance? *(Write in the box)*

16. Mention the form of technical assistance you receive from other health workers *(Tick all that which applies to you)*

	Patient diagnostic photographs/pictures	
	Real-time patient diagnostic support	
	Patient day-to-day care/support	
	Medical literature from books, Internet or other sources (e.g. AMREF)	
	Support on medical literature offered by tutors or other senior medical personnel (SMP)	
	Medical training videos or simulations	
	Dosage administration	
	Others (specify)_____	

17. How is this technical assistance extended to you? *(Tick all that which applies to you)*

	Through word of mouth in ward rounds	
	Through brief meetings	
	Through a knowledge repository e.g. a ward library, central database	
	Through mobile phone communication e.g., call, SMS, WhatsApp, Facebook, etc.	
	Others (specify)_____	

18. When technical assistance is offered through any of the above ways in *question 17* above, how is it preserved for future use? (*Write in the box*)

19. How would you prefer technical assistance knowledge to be preserved in your organisation for future reference? (*Write in the box*)

20. Which technical assistance have you **EVER** received via your mobile phone/device? (*Tick all that which applies to you)*

	Patient diagnostic photographs/pictures	
	Real-time patient diagnostic support	
	Patient day-to-day care/support	
	Medical literature from e-books, Internet or other sources (e.g. AMREF)	
	Support on medical literature offered by tutors or other senior medical personnel	
	Medical training videos or simulations	
	Dosage administration	
	Others (specify)_____	

21. Which technical assistance would you wish to receive/access through your mobile device? (*Tick all that which applies to you*)

	Patient diagnostic photographs/pictures	
	Real-time patient diagnostic support	
	Patient day-to-day care/support	
	Medical literature from e-books, Internet or other sources (e.g. AMREF)	
	Support on medical literature offered by tutors or other senior medical personnel	
	Medical training videos or simulations	
	Dosage administration	
	Others (specify)_____	

22. What challenges do you face in accessing technical assistance from other health workers? (*Write in the box*)

23. Provide any useful suggestions to institutions wishing to have nurses and midwives access technical assistance through mobile devices? (*Write in the box*)

24. Suggest **cost-effective** ways in which health practitioners would be motivated to contribute to technical assistance knowledge database using mobile devices

SECTION C: COST-BENEFIT IMPLICATIONS OF DELIVERING TECHNICAL ASSITANCE USING MOBILE DEVICES

25. I own the following mobile device(s) (*Tick all that which you own*)

	Mobile phone	
	iPad	
	iPod	
	Book reader (Kindle)	
	Notebook/Laptop	
	Flash Disk	
	Others (Specify)_____	

26. The mobile device I use most of the time is operated by (*Tick only one*)

1	Using its coloured touch screen	
2	Using buttons on its keyboard	

27. My mobile device is capable of …. (*Tick all functions which are possible on your device*)

	Making/receiving voice calls	
	Sending/receiving text messages	
	Accessing the Internet	
	Sending/receiving e-mails	
	Accessing Facebook	
	Accessing WhatsApp	
	Accessing Chat On	
	Having mobile games installed on it	
	Reading, editing and managing digital files/folders	
	Recording and viewing videos	
	Recording audio/sound and playing it back	
	Taking and sharing pictures/photographs with my friends	
	Others (specify)_____	

28. Who pays the bulk of your mobile device bill(s)/costs (*Tick only one*)

1	Myself	
2	My parents	
3	My husband/wife/partner	
4	My employer	
5	Others (specify)_____	

29. What is your average monthly mobile device(s) **airtime** bill/cost in UGX? (*Tick only one*)

1	UGX 0	
2	Less or equal to UGX 5,000	
3	UGX 5,001 to UGX 10,000	
4	UGX 10,001 to UGX 20,000	
5	UGX 20,001 to UGX 30,000	
6	More than UGX 30,000	

29. What is your average monthly mobile device(s) **data (MBs)** bill/cost in UGX? (*Tick only one*)

1	UGX 0	
2	Less or equal to UGX 5,000	
3	UGX 5,001 to UGX 10,000	
4	UGX 10,001 to UGX 20,000	
5	UGX 20,001 to UGX 30,000	
6	More than UGX 30,000	

30. Comment on the following as **monetary costs** of accessing technical assistance through your mobile phone?

Cost category	**Cost type**	**Your comment (How is it a cost?)**
Communication	*e.g., locating network presence*	*e.g., This is a cost because every time I need to make a call, I take a Bodaboda of UGX 2,000 to get to a place with a network signal.*
	Mobile device acquisition	
	Airtime	
	Data (MBs)	
Human Resource	Persons providing technical assistance	
	Persons developing the mobile learning system	
	Persons maintaining the mobile learning system	

31. Comment on the following as **non-monetary costs** of accessing technical assistance through your mobile phone?

Non-monetary cost type	**Your comment (How is it a cost?)**
e.g., mobile phone carrying	*e.g., This is a cost in the sense that it can inconvenience me as I go about with my duties.*
Size of mobile devices	
Inappropriate use of mobile devices on the ward	
Poor network connectivity	
Persons providing technical assistance	
Persons developing the mobile learning system	
Persons maintaining the mobile learning system	

32. Mention the benefits you would get if technical assistance is readily available to you via your mobile devices. (*write in the box)*

THANK YOU FOR YOUR PARTICIPATION

CHAPTER THREE

PAPER 2: Cost-benefit implications for delivering mLearning knowledge artifacts to midwives

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3.1 Abstract

The radical transformation of how we access and/or share information from knowledge sources is now phenomenal majorly pivoted on mLearning. Lifelong learning for skills improvement is becoming the norm, thanks to the emergence of various educational technologies. The omnipresence of low-priced mobile devices and their increasing affordances and acceptability are aiding mLearning in all disciplines, including nursing and midwifery. Recent studies have shown that midwives wish to access on their mobile phones, knowledge artifacts related to real-time disease diagnosis, medical literature support, day-to-day patient care, dosage administration and simple procedure executions. While this wish is legitimate, no study has been undertaken to explore the mLearning open innovation cost and benefit implications. Extending knowledge artifacts to midwives on their mobile devices comes with a number of benefits and costs (monetary and nonmonetary). Using the open innovation and cost-benefit analysis theories, this paper presents cost-benefit implications of new knowledge artifacts on midwives' mobile devices. Monetary implications relate to the cost of mobile devices, communication credit, Internet data, connectivity codes (SMS or USSD codes) and human resources (system analysts, programmers and technicians) implication while nonmonetary implications relate to strain on the eyes due to limited screen sizes, inappropriate use of mobile devices on the ward and poor network connectivity in some locations. Benefits unveiled were mainly nonmonetary and difficult to measure in terms of top- or bottom-line dollar values but only manifested in non-monetary implications. The benefits unveiled included: ease of obtaining expert knowledge, improved maternal care, flexible career development, time saving through real-time support for emergencies, increased income attributed to improved knowledge and skills, limited breaks in employment, low cost of knowledge acquisition, ease of reference to technical knowledge, saving of limited resources that would otherwise have been used in residential training, increased professionalism at work and improved practice In terms of outcomes, the benefits implications clearly outweigh the costs implications adduced.

Keywords:
Cost-Benefit Implications, Midwives, Knowledge Artifacts, mLearning, Open Innovation

3.2 Introduction

The training and development of midwives through the use of innovative approaches is a precursor for sustainable socioeconomic development in Africa. This in turn is key to the attainment of the fourth and fifth Sustainable Development Goals (to reduce child mortality and improve maternal health) and the successor, the Sustainable Development Goal of promoting good health and well-being (SDG 3) and quality education, including lifelong learning (SDG 4) (UNDP, 2016).

One such innovative approach is mobile learning (mLearning), a process of learning at any time in any place using mobile devices (B. P. Muyinda et al., 2010; Traxler, 2007). Such technological devices can include cellphones, smartphones, tablets, iPods, handheld computers, gaming consoles, iPads, personal digital assistants (PDAs), media players, e-book readers and more because they satisfy the mobile learning characteristics of on-the-go, lightweight, handheld portability – in a bag or pocket and rechargeable at various locations (Terrel, 2018). Applying mobile learning to the right problem in the right way delivers enormous gains in terms of efficiency and efficacy. Through the open innovation approach (Chesbrough, 2003), mobile devices provide a space for reaching out to renowned experts. Since this does not come free, an insight into the cost-benefit implications becomes vital. The cost-benefit implication is a process of understanding all the potential costs and benefits by way of calculating and/or comparing of a decision or project over a given period of time (Sen, 2000). It is a justification for the implementation of a decision, project or government policy based on both tangible and intangible items.

This paper examines the cost-benefit implications of using mobile devices to augment the technical skills of midwives in Sub-Saharan Africa and particularly in Uganda.

Sub-Saharan Africa has continued to be the riskiest region of the world for a woman to give birth, with Uganda accounting for 343 maternal deaths per 100,000 live births compared to a maternal mortality rate of 216 maternal deaths per 100,000 live births for the rest of the world (Kabayambi, 2015; WHO, 2015).

This high figure is the result of a high midwife-patient ratio of 1:6,838 compared to the WHO threshold of 1:224 (Ministry of Health, 2017; WHO, 2017b). Even where there are midwives present, unfortunately they are not continuously retrained and updated on modern healthcare practices. The need to increase the numbers and retrain existing midwives in Uganda is quite apparent. Since traditional approaches have failed to satisfy the demand, innovative and effective approaches to extend modern technical skills to midwives are necessary.

Earlier studies (Parsons, 2014a, 2014b) have shown that skills related to real-time disease diagnosis, medical literature support, patient day-to-day care, dosage administration and simple procedure execution could be ported onto mobile devices and extended to midwives. In Ayala and Castillo (2008), mLearning is fronted as a learning model with the capacity to address some of the challenges regarding access because of its power to leverage learning through value-added features such as alerts, personalized agents or communication aids, and access to interaction or discussion utilities that help users convert their dead time to productive activity while in transit.

What has not been exhaustively covered, however, is the establishment of mLearning open innovation costs and benefits.

This paper studies the cost-benefit implications of delivering knowledge artifacts to, and accessing them on, midwives' mobile devices. Hereafter, the paper provides the theoretical framing of the study in which theories underpinning the study are discussed in *Section 3.3*. This is followed by the methodology used in the study under *Section 3.4*. Next, we discuss the findings in *Section 3.5* and finally we draw some conclusions in *Section 3.6.*

3.3 Theoretical framework

Midwifery is a key element of sexual, reproductive, maternal and new-born care (WHO, UNICEF, UNFPA, World Bank, & United Nations Population Division, 2014). A global shortage of 350,000 midwives translates into many expecting/delivering women and newborn babies dying from complications that are easily preventable by midwives with the right skills, right knowledge, right equipment and right support (Rawe, 2011). Each year in Uganda, hundreds of women die and three million newborns do not survive the first week of life because they lack access to maternal healthcare services due to the limited supply of skilled midwives (Ninsiima, 2015). The need for more health workers and up skilling of existing ones cannot be overemphasized. The solution is espoused in mLearning as a learner support technology (Muyinda, Mayende, & Kizito, 2015).

According to Douch and others (2010), mobile technologies can improve professional development and teacher training in several areas, such as communication, self-assessment and innovation.

As such, mobile devices can be used in conjunction with wireless broadband and video-call services like Skype® to facilitate communication between teachers and mentors. Through video cameras, lessons can be recorded to allow teachers to reflect on their teaching practice and identify specific areas for improvement. Mobile technologies can be used in teacher education programs to challenge teachers to think creatively about mobile learning and develop the confidence to try new ideas. Mobile devices are cheaper than, for instance, a personal computer (PC), and their features, usability and accessibility are such that they can potentially complement or even replace traditional computer technology (Tetard & Patokorpi, 2008).

Mobile devices are advantageous in helping learners to:

i) utilize their redundant or would-be idle time,

ii) get motivated for learning,

iii) communicate with others and hence save precious time and effort that would be spent checking notice boards and other secondary information sources (de Marcos et al., 2006; Pettit & Kukulska-Hulme, 2007).

Furthermore, a mobile training method can deliver valuable training information on products and services to customers, strategic partners and third-party vendors while also providing another potential stream of income, along with cost and time savings and a decreased time to market (Sum Total, 2012). The benefits of using mobile phones for learning continue to prevail, notwithstanding formidable barriers to effective adoption of mobile learning for healthcare purposes.

For example, 54% of respondents in a survey about the use of new technology indicated that many people would actually find it hard to use new technology because they are afraid of compromising the security of their personal information (Carey et al., 2015). In Muyinda (2010), 46% of the respondents pointed to a limited or lack of mobile network connectivity in some areas as a major restriction to using mobile phones. According to Robert B. McCray, the President and CEO of the Wireless-Life Sciences Alliance, privacy is a big issue in technology matters: "If people won't use the technology because of data breaches, we run the risk of losing the benefits of these technologies." In addition to the limited knowledge on how to use mobile device functionalities, mobile device purchases are often made without sufficient guidance from knowledgeable people (Muyinda, 2010). "…. mLearning can be hindered by a lack of mLearning technical staff, limited staff enthusiasm, commitment and confidence and general ignorance about mLearning" (Muyinda et al., 2015, p. 201).

Relatedly, diversion from the primary objective due to distractions is well cited as a serious risk (Crescente & Lee, 2011). Mobile devices are also technically constrained by their tiny screen sizes, keyboards, memory, processing power and bandwidth (Grant et al., 2007).

Therefore, the provision of technical skills through effective and non-disruptive approaches is called for. Knowledge co-creation through open innovation approaches is one of the ways suggested for creating and attaining knowledge and skills in an effective way (Chesbrough et al., 2014). Attaining knowledge and skills in an effective manner through mLearning as an open innovation tool is yet to be studied. Effectiveness in any endeavor can be studied through cost-benefit implication in a social welfare perspective.

It is possible to skill midwives via mLearning while at the same time, they attend to their patients. A patient's life is saved on one part as the midwife is skilled on another.

Open Innovation Theory postulates that knowledge can be openly sourced from different experts (Chesbrough et al., 2014). In the field of learning, all stakeholders can contribute to unique innovations, each of which comes with their costs and benefits. In this paper, the stakeholders are midwives, their training institutions, hospitals, content developers, mobile app providers, smartphone sellers, NGOs, telecommunication companies and other healthcare professionals. In general, the benefits of working in an open innovation fashion include shared risks and costs, access to and leverage of complementary resources, speedy service delivery and higher financial returns (Leten et al., 2012).

Through the open innovation paradigm, midwives can, using their mobile phones, access knowledge related to real-time patient diagnostic support, day-to-day patient care/support, dosage administration procedures, medical training videos or simulations, support on medical literature offered by tutors or supervisors, patient diagnostic photographs/pictures, and medical literature from books, the Internet or other sources (Holmberg, 2017; Maina et al., 2018).

Through mLearning, it is possible to access content in speedy ways, thereby reducing the risk of mothers dying from preventable medical errors as midwives can easily seek assistance from experts. Likewise, midwives can create and share knowledge on the aforementioned learning areas.

With convergence of technologies, nursing and midwifery training institutions and hospitals can provide open innovation such as a competitive quality of healthcare, joint research activities and complementary working relationships, among others (Holmberg, 2017). Through complementary working relationships, institutions can rediscover themselves with a view to providing improved healthcare.

mLearning for midwives is an open innovation application as any content developers can create and widely distribute knowledge that can be tapped into by midwives and other stakeholders (Chesbrough, 2003). Furthermore, the open innovation relates to content providers' systematic use and exploration of a wide range of internal and external sources of content. With Internet-connected smartphones, midwives are able to study educational content, preferably one of high quality.

The open innovation model is reflected by the abundant knowledge that freely flows across boundaries from within and/or outside an institution but in a manner that cherishes value added (Chesbrough & Bogers, 2014). The open innovation approach is an affectionate means of enabling midwives to draw technical knowledge from pundits. While there are a number of benefits in this approach, some costs abound for all the above-mentioned stakeholders. The costs relate to money, effort, time and investments. Midwives will require smartphones, airtime, time and effort spent to benefit from the open innovations. Content developers will require effort to develop the content.

The cost and benefit implications of open innovations can be underpinned by cost-benefit analysis theory. Cost-Benefit Analysis (CBA) is a commonly applied method in evaluating public and private policy decisions to assess whether or not the social benefits of a proposed policy or project outweigh its social costs through a multistage process of identification, measurement, comparison over a project's life, and the selection of relevant costs and benefits (Kotchen, 2010). In the public sector, the welfare economics (social utility gains and losses) and public finance (policy formulation and regulation) frameworks that bring about society's efficiency and equity objectives (Nas, 1996) underpin it. CBA postulates that a systematic method should be used to measure/estimate the costs and benefits of a single option, or compare two or more options in order to select the option that maximizes the benefits for a given dollar value (Bronsteen et al., 2012). For a given decision, CBA is a monetary measure that helps decision-makers to understand not only tangible costs and benefits, but also hard-to-quantify intangibles such as employee morale, customer satisfaction, human life and mortality. Unlike profit-oriented businesses, many of the benefits of mLearning cannot be measured in terms of top- or bottom-line revenues but these are better measured in terms of 21st-century skills, learners' achievement, learners' behavior, learners' equity and impact on the community, among others (Consortium for School Networking, 2015).

It therefore follows that CBA involves the use of both quantitative and qualitative measures. Harwood (2016) has disaggregated the benefits and costs of open innovation using the open innovation value (OIV) formula below:

$$OIV = (Q+B)/(C+E)$$

Where
OIV = Open Innovation Value
Q = Quality of Open Innovation
B = Benefit of Open Innovation
C = Cost of Open Innovation
E = Effort of Open Innovation

The number of experts in an organization will always be smaller than the number of experts outside the organization. As such, it is a truism that tapping into the vast expertise from outside the organization has the potential to bring more value (monetary and otherwise) to the organization than in the case where an organization only depends on its internal expertise. When the quality of, and benefits from, the expertise obtained from outside the organization is bigger than the cost and effort expended in doing so, we expect to achieve the most out of the open innovation initiative. On the contrary, if the cost and effort expended in obtaining expertise from outside the organization is bigger than the quality of and benefits from such expertise, then the open innovation value would be small. This paper ekes out the cost/benefit implications of m-learning open innovations among midwives in Uganda

3.4 Methods

Methods are techniques and procedures used in the process of data gathering, processing and analysis (Cohen et al., 2002). The findings in this paper derive their being from a field survey carried out among midwives in nursing and midwifery training institutions, hospitals and health centers in Uganda. The aim of the survey was to understand how mobile devices could be used in the provision of continuous professional training for midwives, through mLearning as an open innovative approach to learning. As such, data was obtained from midwives through a survey/questionnaire with quantitative and qualitative variables. A self-administered questionnaire comprising both structured and unstructured questions was administered to a sample of 1,236 geographically spread respondents in 2016 in five regions of Uganda (central, northern, eastern, western and southern). This data collection instrument asked a wide variety of questions related to the respondents' characteristics, knowledge artifacts inherent in different healthcare providers that would be ported onto mobile devices for the benefit and/or efficiency of midwives, cost and benefit implications of mLearning and sustainability avenues for mLearning. In actual terms, 880 midwives responded. This paper in particular presents findings from the section on cost and benefit implications for innovatively delivering technical knowledge and skills to midwives through mLearning. The paper employed the cost-benefit analysis (CBA) approach to derive the open innovation value as espoused by Harwood (2016).

3.5 Study findings and discussion

The research question at hand is: What are the cost-benefit implications of innovatively delivering/accessing knowledge artifacts on midwives' mobile devices? The study findings are presented and discussed in *Sections 3.5.1* and *3.5.2*, on costs (C) and benefits (B), respectively.

3.5.1 Cost (C)

The survey results reveal that there are monetary and nonmonetary costs associated with the use of mLearning by nurses and midwives. A summary of these costs is presented in Table 8 below and explained thereafter.

Table 8: mLearning Open Innovation Cost Implications

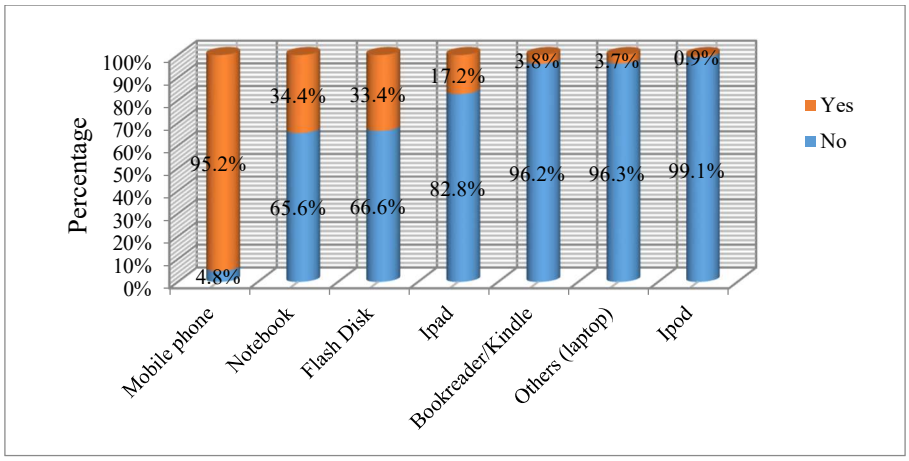
Monetary costs
Cost of mobile devices and/or associated infrastructure
Communication credit (airtime/data bundles)
Connectivity costs (SMS or USSD codes)
Human resource costs
Nonmonetary costs
Strain on the eyes due to limited screen and keyboard sizes
Inappropriate use of mobile devices on the ward
Poor network connectivity in some locations
Social costs

Source: Field Data (2017)

3.5.1.1 Monetary costs

a) Cost of mobile devices and/or associated infrastructure

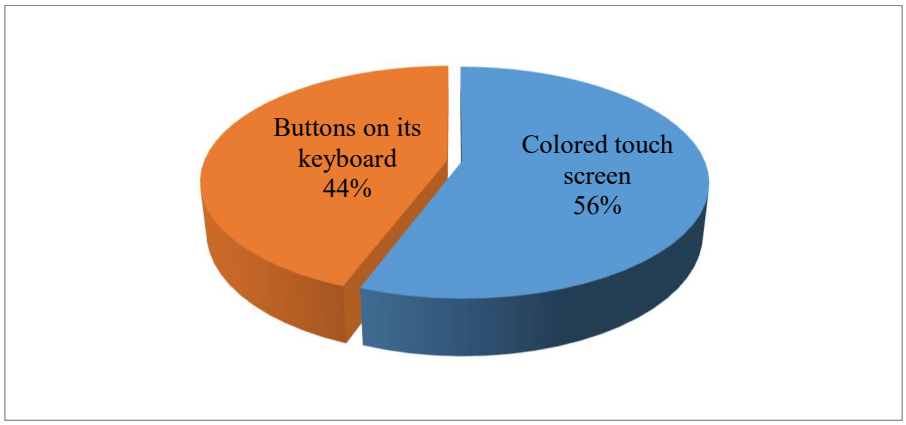
To estimate the cost of mobile devices and infrastructure commonly owned and used, midwives were asked to state the most commonly used mobile device, operating system and functionality of the mobile devices they own. The results are shown in Graphs 9, 10 and 11.



(n = 507)

Source: Field Data (2017)

Graph 9: Type of mobile device owned/used



(n = 822)

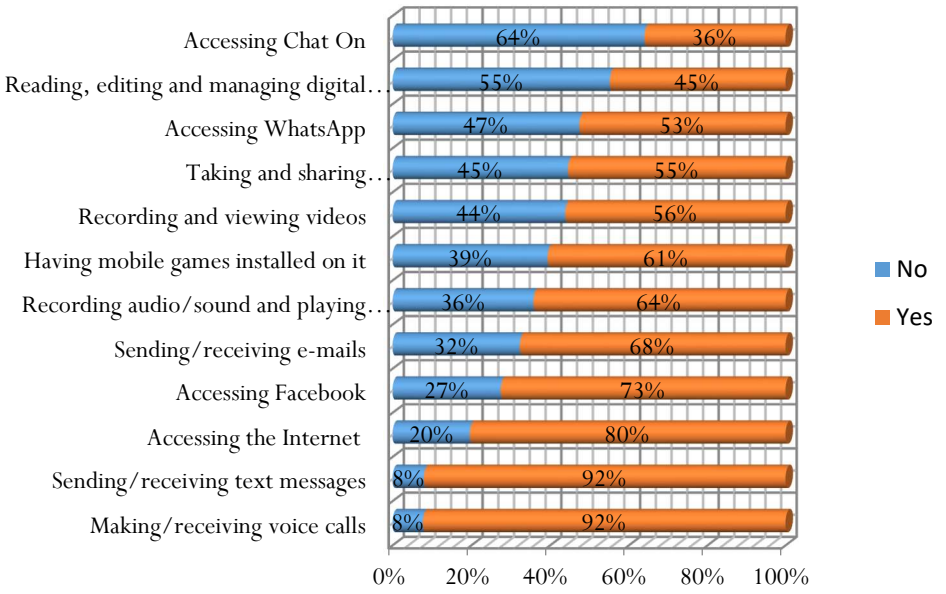
Source: Field Data (2017)

Graph 10: Operating system of mobile device

The most prevalent mobile device used and owned by midwives is the mobile phone as can be seen in *Graph 9* above. Over 95% of midwives owned a mobile phone.

The type of operating system was used to determine whether the mobile phones were smart or not. More than half (56%) of the phones owned had colored touch screens, meaning they were running an Android operating system and were hence smartphones.

Mobile phone types can also be determined by their functional capabilities. Mobile phones that support multimedia functionalities are classified as smartphones. The functionalities of mobile phones owned by midwives are shown in Graph 11 below.



Source: Field Data (2017)

Graph 11: Functional capabilities of mobile devices

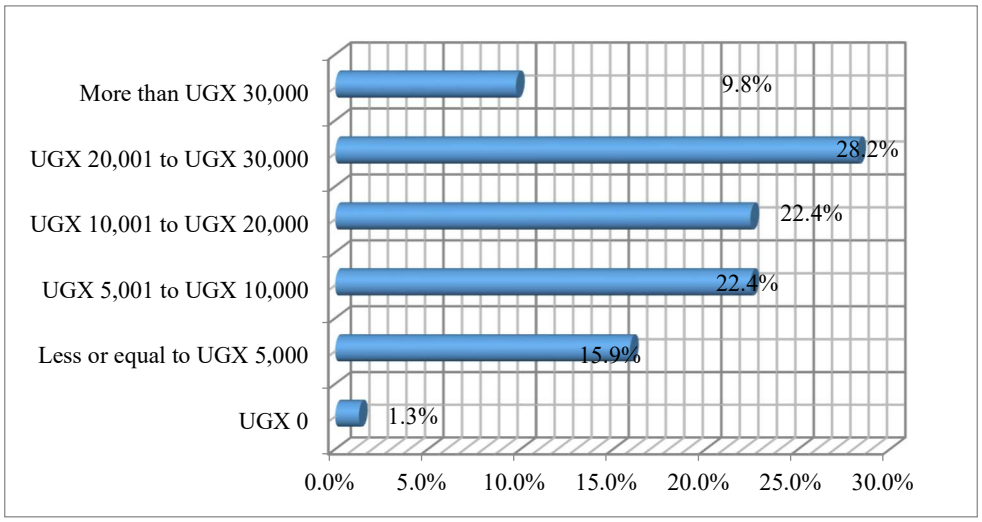
As can be seen in Graph 11, there is good use of multimedia features on the mobile phones owned. This indicates that the majority of the midwives would technically be able to use mLearning on their smartphone.

The cost of smartphones, for example the Samsung® S6 Edge, is about USD 752 (Simba Telecom, 2017), which is well above the earning capacity of midwives in Uganda. However, as new phone models are developed, the cost of earlier models keeps declining.

In addition, smartphones from China, for example the Tecno®, have flooded Uganda's market. These are relatively cheap and within the financial budget of midwives. It is possible to get a Tecno smartphone at USD 82. In five years' time, it is likely that the smartphone prices will drop below USD 27 said one of the senior midwifery tutors who also doubles as a Principal of a health care training institution. According to Harwood's (2016) open innovation value formula, the reduction in the cost of mobile phones has the potential to increase mLearning open innovations for midwives.

b) Costs of communication (airtime credit and/or data bundles)

Another cost center with the potential to affect mLearning open innovations relates to the costs of communication. Voice and data costs are important in this respect. Graphs 12 and 13 provide the voice and data costs respectively as derived from the field research.



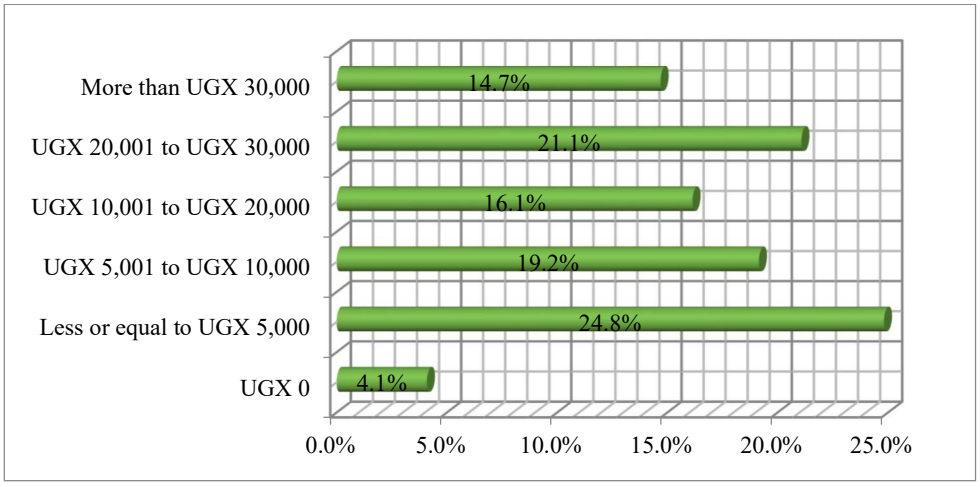
(n = 861)

Source: Field Data (2017)

Graph 12: Average monthly mobile device(s) airtime bill/cost

From Graph 12, it is evident that the majority of respondents spend less than UGX 30,000 (USD 8.2) per month on airtime for voice communication.

The picture is no different when it comes to expenditure on Internet data, as seen in Graph 13 below.



(n = 830)

Source: Field Data (2017)

Graph 13: Average monthly data bill

While voice communication could be one of the avenues for extending mLearning open innovations, the bulk of innovations can be best achieved through use of the Internet on mobile phones. This requires Internet data. On average in Uganda, an average monthly data package of 5 GB costs about UGX 30,000 (Airtel, 2018). In order to offer uninterrupted mLearning, 5 GB may not last the test of time given the unique skills and knowledge midwives may require on a real-time basis. From Graph 13, only 14.7% of the respondents used more than UGX 30,000 per month, implying that the cost of Internet data was still prohibitive for the majority. However, with the coming of new players in the telecommunication sector and the setting up of fiber backbones, a declining trend in prices for Internet data bundles is being observed. It is anticipated that a further decline in the cost of data bundles will occur in the next five years. This will trigger a higher mLearning open innovation value.

c) Costs of connectivity (SMS or USSD codes)

mLearning open innovations are implemented using mobile apps. There are web-based and telecom-based mobile apps. Telecom-based mobile apps are implemented using either Unstructured Supplementary Service Data (USSD) or short text message (SMS) codes. Unlike SMS codes, USSD are menu-driven and utilizes codes made up of characters at least ending in a hash (#) sign and pressing <Send/Enter> e.g. *165*1*1*<telephone number>*<amount># is a USSD code for sending mobile money in Uganda via the MTN network.

The cost of acquiring these codes in Uganda is shown in Table 9 below.

Table 9: Cost of Communication Codes

Type of code	**Annual subscription cost**
SMS code	USD 2,500
USSD code	USD 10,000

Source: Uganda Communications Commission (2015)

If an institution is to implement a telecom-based mobile app, beneficiaries of the mobile app are likely to share in the cost of connectivity. In other words, this becomes the cost for the midwives. To increase the value of mLearning open innovations for midwives, institutions have to find a way of having the code cost subsidized outside the tuition fees collected from trainee midwives.

d) Costs of human resources

Mobile system developers undertake the development and maintenance of mLearning apps. The cost of human resources is, therefore, one of the costs of these developers. Human resources such as doctors, supervisors, system analysts, educationists, programmers and technicians are involved in a wide range of activities, including instructional design, system design, development, installation, implementation, maintenance, monitoring and evaluation. The study was thus keen to understand the extent of the cost of human resources in mLearning.

In order to establish the monetized aspect of developing the mLearning system, midwives were asked to provide comments on this matter through an open-ended question. Out of the 404 comments received, 70% of them were in line with the view that the development of mLearning systems was slow because of inadequate training. Assuming the aggregate annual salaries of a system analyst (USD 10,000), a doctor/supervisor (USD 16,667), an educationist (USD 10,000), a programmer (USD 13,333) and a technician (USD 6,667), the total annual assumed cost of developing a mobile learning system would be USD 56,667, which is approximately USD 60,000. From such an assumption, prorated values can be arrived at for people working for less than a year on developing a mLearning system. This cost has to be borne by institutions intending to introduce mLearning.

Development aside, mLearning systems require maintenance and upgrading in order to operate to their highest capability and in an efficient manner year after year (Stoneburner et al., 2002). Assuming other factors are held constant, midwives revealed that people in charge of maintenance and system upgrade were not easily accessible due to a lack of monetary motivation. Indeed, one of the respondents, an academician as well as a Systems Programming Specialist at Makerere University revealed that:

> "…. *maintenance of a single mobile app could be somewhere in the range of one million shillings per month* …."

This translates to about USD 275 per annum. The maintenance referred to in this statement mainly refers to the costs of routine app preventive maintenance and upgrades.

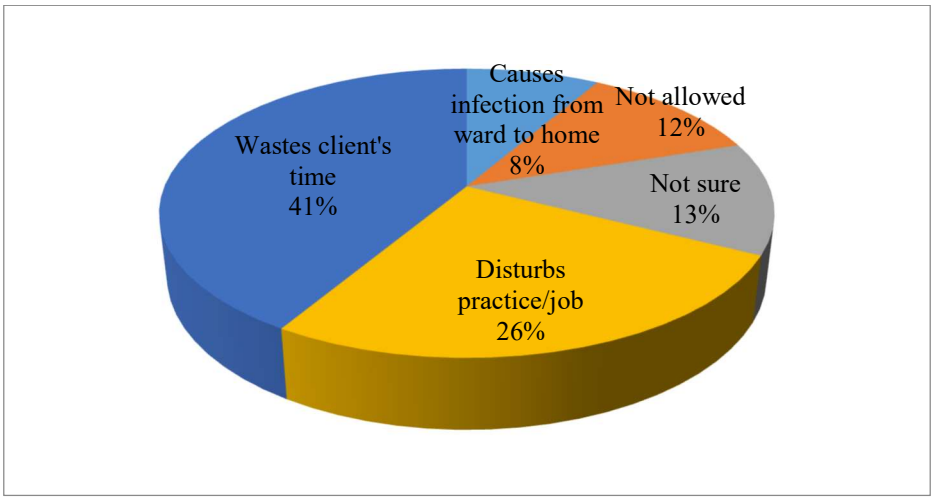
This is quite prohibitive for an individual midwife. Collective maintenance will be required to lower the cost and increase mLearning open innovations.

3.5.1.2 Nonmonetary cost

a) Costs associated with strain on the eyes due to limited screen and keyboard sizes

To gain an understanding of this matter, respondents were asked through an open-ended question to comment on the size of mobile devices as a nonmonetary cost of accessing technical assistance among midwives. Respondents revealed that while mobile devices with limited screen and keyboard sizes were lauded for their portability, they were uncomfortable and tiresome when reading, as they require time and effort to compose a document, which may present a hindrance to effective use of the device. Tiny screen and keyboard sizes lead to gazing at the same spot for longer periods, thereby straining the auxiliary muscle of the eye, which can cause temporary blurred vision, headaches and dry eyes. This finding correlates with those revealed earlier in *Section 3.5.1.1* (*Graph 10*), where a reasonable proportion (44%) of the mobile devices were still of first-generation (1G) order and therefore characterized by tiny/limited screen sizes and keyboards. This state of affairs is an indicator that precautionary health measures such as the purchase and use of eyeglasses at the advice of an ophthalmologist are relevant and hence a cost.

b) Costs associated with inappropriate use of mobile devices on the ward



Source: Field Data (2017)

Graph 14: Inappropriate use of mobile device on ward

Since the provision of mobile phones to midwives for mLearning is not necessarily a guarantee that the midwives will only be restricted to mLearning, the study sought to understand the opinions of midwives on the inappropriate use of mobile phones while on the ward. Inappropriate use of mobile phones may crop up, thereby causing distraction from offering healthcare on the ward. Distractions are likely to emanate from functionalities of mobile phones other than those affording healthcare services. Graph 14 above indicates that 67% of the respondents affirmed that inappropriate use of mobile phones while on the ward wastes time and disrupts job practice. As midwives engage in out-of-context functionalities using their mobile phones, the time meant to attend to mothers is lost in translating into disruption of the core job function of caring for mothers.

c) Costs associated with poor network connectivity in some locations

The future of mLearning in education and training holds much promise but can be constrained by intermittent or no network connectivity. Good network connectivity enables mobile devices to communicate wirelessly. In an open-ended question, respondents were asked to comment on poor network connectivity as a profound nonmonetary hindrance to accessing technical assistance through their mobile phone. Only about 5% did not have any challenges. The majority (95%) of midwives were constrained by poor mobile network connectivity, thereby presenting a need to create offline and online states of the respondents' mobile phone/device to enhance real-time access to the desired information. Costs that emanate from poor or no network connection are multidimensional (connectivity, networking, service providers and bandwidth) and therefore require an integrated cost-accounting approach to arrive at a fair value. Non-monetary costs can be prohibitive, especially in rural areas. If action is not taken to stabilize connectivity in rural areas where most preventable maternal deaths occur, mLearning open innovations for midwives will have little chance of success.

An additional cost that schools have to incur is adapting their courses to mLearning platforms. They can save costs by reducing, say, the number of contact hours, but the cost of switching to blended learning or integration of mLearning into classes/courses is an investment in time that has to be undertaken by the schools.

3.5.2 Benefits

The benefit implications of mLearning can be directly linked to Harwood's (2016) open innovation value. The open innovation value recognizes the economies of scale inherent in having a wider population of experts from within and outside an organization contributing to the development of an artifact. Within the context of mLearning for midwives, it is possible for both internal and external experts to collaboratively develop learning or practicing content for midwives. Using their smartphones, medical schools, hospitals and midwives can contribute to the development of a shared knowledge repository. They may also use their smartphones to contribute to the development of open courseware. As such, the benefits that midwives reap from mLearning innovations are directly proportional to the value of open innovation. With a rich knowledge base contributed to by a plethora of experts and ease of access to this repository aided by smartphones, ailment diagnosis and treatment become more apparent. Consequently, maternal deaths arising out of a lack of knowledge on the part of midwives are likely to reduce.

In a survey conducted among midwives, the benefits of co-creating knowledge were investigated.

Table 10 below summarizes the findings.

Table 10: mLearning Innovation Benefits

Ease of reaching expert knowledge, since we use open innovation approach
Improved maternal care
Flexible career development
Saves time through real-time support for emergencies
Increased income attributed to improved knowledge and skills
Permits continuity in employment for existing midwives
Low cost of knowledge acquisition
Ease of reference to technical knowledge
Saving of limited resources that would otherwise have been used in residential training
Increased professionalism at work
Improved practice

Source: Field Data (2017)

Broadly speaking, mobile devices are an easy means of gaining access to expert information and maintaining literacy skills at home, while on a bus, in a classroom, on a ward, indeed anywhere. In an earlier study, respondents were asked in an open-ended question to list the experts from whom they drew technical assistance once deemed necessary. A great deal of this technical support is drawn from immediate supervisors, doctors, representatives of partner organizations and colleagues (Maina, 2017). Through an open innovation paradigm, midwives are able to access and seek expert knowledge and skills from within and outside their organization in order to provide real-time healthcare services.

Improved maternal care

The inadequacy of better-quality maternal, infant and childcare is still a desperate challenge in some nations. In *Section 3.5.1.1*, while estimating the cost of mobile devices and/or associated infrastructure, mobile devices were described as flexible channels for delivering continuous professional development on the doorstep in order to avert maternal care challenges.

Maina reported that to foster improved maternal care, midwives ought to access a range of technical care through their mobile devices (Maina, 2018). Prominently pinpointed among these were day-to-day patient support and dosage administration guidelines. These findings indicate that gaining optimal results in maternal care points to cascading the mLearning effect onto expectant mothers and those who have recently given birth.

Flexible career development

Mobile devices interoperable with desktop e-mail and Internet systems are capable of increasing flexibility in career development through mLearning. The study sought to establish how midwives' mobile devices functioned to enrich midwives with flexible continuous professional development or lifelong learning. Prior research indicated that the majority (80%) of midwifery cadres were young people aged between 20 and 30 and had worked for between one and five years (Maina, 2017). This scenario presents knowledge and skills gap whose solution resides in mLearning, which delivers flexible doorstep training. This necessitates the promulgation of continuous technical knowledge support from different healthcare providers in order for midwives to offer the necessary support to expectant and delivering mothers. The longer a worker stays in the job, the stronger the reputation, skill and dependability.

Gaining such continuous knowledge and skills requires an approach that cannot compromise the already low number of midwives by drawing them away from their workstations but rather connect them to a virtual rich learning experience sharing a platform through their mobile phones.

The benefit is the opportunity cost of remaining at the workstation to consolidate and complement the few midwives there are to save lives. In today's connected world, mLearning innovations can offer great opportunities for career growth for midwives.

Saves time through real-time support for emergencies

There is a positive correlation between the provision of real-time support for emergency cases and the skills of midwives who make use of mobile equipment (Behera, 2013). Access to expert knowledge in handling emergencies through mobile devices as an innovative strategy is capable of supporting the real-time capture of "exact" information rather than the traditional learning approach of flipping pages in a textbook. In an interview, one of the respondents said:

> *"…. mLearning is only possible after the basic midwifery course because some conditions require patient history, which mLearning does not have. Let it only remain a complement …."*

Another respondent said:

> *"…. An emergency is when someone is at the point of losing their life and off head information should be got within less than a few minutes, short of which you lose life. Therefore, we don't see mLearning in the case of a junior person but in a person with fundamentals."*

An educationist also said:

> *"…. mLearning is an interesting opportunity because it is a reality. When you look around, four out of 10 of our students hold a touch screen gadget and the sooner these are able to support learning, the better…."*

The findings imply that mLearning is indeed a relevant learner support platform that could be employed in emergencies.

Motivates learning through increased income emanating from improved knowledge and skills

A wide knowledge base increases the quality of the service provided to one's clientele. New knowledge and skills acquired through mLearning empower midwives to work efficiently. With improved efficiency, one is able to attract more clientele. As such, those in private healthcare practices are likely to attract more paying clients and hence more income. Increased income may lead to better salaries and eventually better standards of living for midwives and their families.

Permits continuity in employment for existing midwives

In Uganda, the midwife-patient ratio of 1: 6,838 is still high, which translates into maternal healthcare challenges. mLearning open innovations have the potential to provide the flexible lifelong learning necessary for increasing the number of midwives and improving the skills of existing midwives without necessarily drawing them away from their workstations. While at their workstations, midwives are able to continue earning an appropriate living for their personal, family and school requirements.

Low cost of knowledge acquisition

As described in the immediate preceding paragraph, mLearning has the potential to deliver continuous professional development for midwives at their doorsteps. Gaining lifelong learning knowledge through mLearning is far less costly than gaining the same knowledge through full-time classrooms (Arinto, 2013; P. B. Muyinda et al., 2015).

With mLearning, the costs of buying school requirements, textbooks, dormitory/hostel fees, meals and transport to and from the training institution are minimized.

Ease of reference to technical knowledge

The study aimed to discover the ease with which midwives accessed reference materials through their mobile devices. To do this, they were asked (in an earlier study) to indicate how they preserved technical assistance as well as their preferred technical assistance preservation method for future reference. In their responses, 61% commonly preserved technical assistance through hard copies and wall charts (Maina, 2018). These require physical presence and are limited in terms of cascading learning support to future generations. Further, midwives pinpointed a need to adopt a mixed approach to saving content, which includes hard and soft copies.

Similarly, a craving for multimedia and videography has already been cited in a JIBU survey as a preferred/suitable packaging approach and subsequent preservation to enhance access to learning content and learnability (Amref Health Africa, 2011).

Saving on resources that would otherwise have been used for training in midwifery institutions

According to a JIBU survey, 75% of midwives were women. In Uganda, society has demarcated (albeit opposed by gender activists) gender roles. In addition to their professional careers, women are required (by the society) to take care of their children and husbands and cook for their families. These societal obligations hinder women's capacity to go for further studies or get better-paying jobs.

As such, training opportunities that do not necessarily draw participants from their workplaces and save on financial resources present huge benefits to midwives.

In this case, mLearning preserves family relationships/marriages rather than keeping one of the partners in a conventional learning environment in a place away from home.

Increased professionalism at work

Through a Problem-Based Learning Approach, mLearning is vital in providing midwives with hints on practical knowledge and skills gaps. As already established under the benefits of ease of reaching expert knowledge, improved maternal care, flexible career development and learning motivation through increased income outlined above, respondents approved mLearning as a suitable learner support platform.

Improved practice

Self-confidence acquired through traversing evidence-based facts through a mobile device is perfectly capable of helping midwives to make a difference at their place of work. Such traversing can be the utilization of idle time, reflection on practice, collaboration and cooperative working.

For example, the use of would-be idle time for professional learning and communicating with others using mobile devices is advantageous by way of building confidence through accessing evidence-based medical facts. In the event of constraint of content delivery, simple SMSs save midwives' time and effort that would be expended on conventionally establishing the same information.

When asked about their perceived views about mLearning as a good form of learner support, 74% of midwives revealed in an earlier study that learning using mobile devices was a timely learner support intervention as regards access to up-to-date and evidence-based medical facts (Maina, 2017).

Twelve percent of the respondents perceived mLearning as an available and anytime system that is vital for saving lives.

Having looked at the costs and benefits above (in a qualitative form), it follows that using Harwood's open innovation value formula of OIV = (Q+B)/(C+E), the OIV is greater than 1 as long as the initial value of 'E' is lower than 'Q' and 'C' is less than 'B'. Sections 3.5.1 and 3.5.2 paint a picture that benefits of mLearning outweigh costs of mLearning.

3.6 Conclusion

This paper has adduced the cost-benefit implication of mLearning among midwives using the open innovation approach. This approach has demonstrated that over time, when several costs of inputs into mLearning go down, more value for mLearning will be attained as more high-quality content is developed and freely made available for access through smartphones. Smartphones are increasingly being used to deliver valuable training information on products and services to customers, strategic partners and third-party vendors. In the health sector, open innovations are bound to lead to positive health outcomes. Midwives as frontline health workers are vital in the care of pregnant mothers and their unborn babies in order to end preventable child and maternal deaths. To execute their mandate sufficiently well, midwives need to improve their knowledge and skills, especially in Uganda where there is an enormous shortage of midwives.

More midwives are required and at the same time, the population of existing midwives needs continuous professional development. Adopting mLearning innovations has the potential to reduce the number of preventable medical errors that happen to delivering mothers and their newborns.

The use of smartphones by midwives has been identified as one of the means through which midwives can participate in mLearning open innovations to overcome the situation. Smartphones have the potential to improve the accuracy, completeness and timeliness of data about pregnant women, mothers and children, which is necessary for increasing survival rates for women and their newborns.

With technology advancements, the Ugandan market continues to be flooded with cheaper phones. Such phones especially of Chinese brand are relatively cheaper and day by day, they become affordable for midwives, proposing favourable open innovation values. However, prohibitive mLearning open innovation costs need to be addressed if favourable or increased mLearning open innovations are to be realised. One approach to do this is cost-sharing in order to source telecom-based mobile apps and hire the necessary technical personnel. An appropriate mix of instructional designers, system designers and developers, technicians who install, implement, maintain, monitor and evaluate is required.

On a general note, increasing mLearning innovations is associated with a flexible career development path, a phenomenon that depicts that knowledge freely flows from high knowledge levels to low knowledge levels. In another dimension, mLearning provides a potential stream of income to midwives through improved knowledge and skills and reduced time and cost of accessing technical support.

This form of low-cost knowledge accumulation is well engrained with the potential to increase the number of skilled midwives and the quality of the maternal care services offered. Mobile devices help learners to utilize would-be idle time, become motivated for learning, communicate with others, and hence save precious time and effort that would be expended traversing notice boards and other secondary information. Costs such as for buying school requirements, transport to and from training institutions, accommodation fees, meals and textbooks are minimized and thus saved and/or utilized for alternative demands.

Owing to the above state of affairs, caution is required. Acquisition of a mobile device and communication airtime and/or data vital for kick-starting any mLearning among midwives are in themselves not sufficient to cause learning (pedagogy) and objectivity of the learner.

Unless a learner is objective, distractions such as the use of social media, texting, calling, etc. pose a serious risk to mLearning and thus may cripple efforts to improve survival rates for delivering women and their newborn babies. Further, while the role of emerging technologies is spot on, mLearning open innovations cannot be successful with limited or no network connectivity. To support continuous professional development, there is a need to profile both online and offline states of connectivity to permit improved survival rates for women and newborns.

Lastly, while some costs of mLearning innovations are easily quantifiable, others are not. Attaching monetary values (in dollar terms) to the benefits of mLearning is also not tenable as human life is regarded a "nonmarket good," implying that its costs and benefits can best be evaluated in terms of how society members can be made happy by mothers and their newborns being saved. This makes it difficult to quantitatively establish mLearning cost-benefit ratios, since the questionnaire method is not the best tool for use in such analyses. In subsequent studies, it would be crucial to explore how to monetize benefits with certainity using appropriate techniques such as value of statistical life. Reflecting on the above survey results, it is conclusive that the benefits of introducing mLearning for midwives outweigh the costs. In the next chapter (Chapter 4), how open innovation is made possible is discussed.

CHAPTER FOUR

PAPER 3: A framework for effectively harnessing technical knowledge artifacts from different healthcare practitioners for improved efficiency of midwives using mobile devices

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4.1 Abstract

Co-creation and subsequent sharing of knowledge and skills for midwives using mLearning entails an ecosystem involving different stakeholders (both internal and external). The framework was designed using the design research methodology and established ten (10) stakeholders to jointly work together in developing significant and broader innovations in the health sector. These include practicing midwives, apprentice midwives, government, hospitals, medical schools, other medical training institutions, telecom providers, smartphone sellers/manufacturers, medical service centres, nongovernmental organizations (NGOs), content providers, mobile app developers and other healthcare providers such as doctors and nurses. In order to effectively harness technical knowledge artifacts from different healthcare practitioners for improved efficiency of midwives using mobile devices, the framework was validated using domain experts. The domain expert technique was employed to validate the framework due to its suitability where internal and external constructs exist. An interview guide used previously to validate Muyinda's Mobile Learning Object Deployment and Utilization Framework (B. P. Muyinda et al., 2010) was adapted. Whereas the experts approved the proposed Mobile Learning Open Innovation Framework for Midwives (MLOIF4M), they pointed out that the framework did not address key components like quality assurance, the mLearning technical personnel who develop and maintain the mLearning system, and a knowledge repository as a database for the co-created, shared and quality-assured knowledge artifacts generated through the open approach. These were included in the validated framework. As such, the validated MLOIF4M is comprised of 13 constructs/stakeholders as opposed to the ten (10) initially established. Of these, the government has been proposed to steer the operationalization of the validated framework by providing conducive investment policies and a regulatory framework on the use of mobile phones for learning.

Keywords:

Midwives, Healthcare Practitioners, Mobile Devices, Open Innovation, Technical Knowledge Artifacts, Validation, Usability Evaluation, Co-Creation

4.2 Introduction

Sub-Saharan Africa is suffering from a health workforce crisis with most health facilities having a staffing level of only half the required number, which hampers the proper provision of health services and the attainment of the required health outcomes and health-related MDGs (Amref Health Africa, 2014; WHO, 2015). Health workers are also constrained by a number of challenges, such as limited access to cutting-edge literature and new skills, working for longer hours than expected with less or no time for learning activities, limited or no access to online learning technologies and fewer hours of contact with their supervisors (mentors), among others. One of the solutions to this human capital gap involves training new cadres of health professionals and upgrading the skills of current workers using open innovation approaches such as lifelong learning. Such pedagogies can improve the number (through new cadres of health professionals partaking of mLearning) and quality of midwives without necessarily drawing them away from their workstations. eLearning has been suggested as an innovative educational strategy to cushion against the short supply of high-quality training and mentorship for current training programs and continuing professional development or education opportunities for health workers (Aluttis et al., 2014; Amref Health Africa, 2014b; Bollinger et al., 2013; Nartker et al., 2010).

Owing to the growing technological innovations and recent global investment in fiber and wireless infrastructure, much hope lies in using mobile information and communication technologies (ICTs) for training, deploying, supporting and empowering midwives.

Mobile devices can empower trainers and learners by facilitating communication and interaction, offering new modes of delivery, and generally transforming teaching and learning processes (Aguti & Fraser, 2006). Among the family of mobile devices, the mobile phone is the most pervasive in Uganda, with over 90% of midwives owning a personal mobile phone (Amref Health Africa, 2014).

Furthermore, studies (Chib et al., 2008; Iluyemi et al., 2007; Kaplan, 2006; Lee et al., 2011; Obaid, 2007) have shown that midwives could access practice-related knowledge and skills on their mobile phones. However, models and frameworks for the sustainable use of mobile phones for accessing technical knowledge and skills by midwives are still in their infancy. This paper builds a framework for employing an open innovation approach to develop and harness mLearning technical artifacts for the lifelong learning needs of midwives in an effective way. As such, it attempts to explore the cost-benefit implications for all stakeholders in the learning of midwives using mLearning. The rest of the paper provides a stakeholder cost-benefit scrutiny from which a framework for effectively harnessing technical knowledge artifacts is derived.

The current chapter is structured as follows. In *Section 4.3*, a stakeholder benefit/cost implication matrix for mLearning open innovation is presented. Next, the benefits and costs of mLearning open innovation are discussed in *Section 4.4*. In *Section 4.5*, the effect of mLearning is presented, while in *Section 4.6*, I finally wrap up the conclusions and discuss a number of consequences for ecosystem management of technologies that transform existing businesses or practices such as the professional training of midwives.

4.3 Stakeholder benefit/cost implications for mLearning open innovation

According to Maina (2018), stakeholders in a mLearning open innovation include: midwives, telecoms, content developers, hospitals, training institutions, health and healthcare NGOs, mobile app developers, other healthcare providers, smartphone sellers and government. The matrix below provides an analysis of implications of these stakeholders' benefits and costs as they participate in mLearning open innovation for the learning of midwives.

Table 11: Stakeholder Benefit/Cost Implication Matrix for mLearning Open Innovation

Stakeholder	Benefits	Costs	Cost reduction and benefit enhancing strategies	Responsibility for cost reduction and benefit enhancement
Midwives	• Real-time access to patient diagnostic support • Real-time patient day-to-day care/support • Real-time access to dosage administration procedures • Real-time access to continuous professional development • Internet access • Creation of a community of	• Cost of smartphones • Cost of airtime • Costs of Internet data • Inappropriate use of smartphones on the ward • Poor bandwidth • Strain on the eyes due to limited screen and keyboard sizes	• Provide subsidies on mLearning goods and services • Training on mLearning use • Use bigger-screen mobile devices such as iPads • Reduce pricing of telecom services and products	• Hospitals • NGOs • Telecoms • Smartphone sellers

	practice among midwives • Reduced maternal mortality • Subsidies from telecoms • Subsidies from NGOs • Open access licenses for mLearning apps		• Ensure countrywide Internet connectivity	
Telecoms	• Bulk market for smartphones • Bulk market for airtime credit and data bundles • Increased customer subscriptions	• Reduced profitability due to social corporate responsibility subsidies	• Reduce taxes on social corporate responsibility goods or services • Widen tax base • Ensure countrywide Internet connectivity	• Government • NGO funding costs of smartphones and subscriptions
Content Providers	• Wide distribution of knowledge • Opportunity for lifelong learning availed • Rich content accessed/shared • Peer review of content is made possible	• Infringement of intellectual property rights (IPR) • Plagiarism • Limited return on time investment	• Sensitize open innovation stakeholders on IPR • Enforce IPR Laws • Formulate a business model for open innovation in mLearning	• Content developers • Government • Midwives • NGOs • Telecoms
Hospitals	• Reduced maternal mortality • Provision of competitive quality of healthcare	• Cost of smartphones • Cost of other mLearning support	• Provide subsidies on mLearning goods and services • Training on	• Hospitals • Government • Telecoms • Training institutions

	• Joint research activities undertaken • Complementary working relationships inculcated • Sharing of scarce resources made possible • Hospitals can rediscover themselves for improved healthcare	technologies • Cost of airtime • Costs of Internet data • Inappropriate use of smartphones on the ward • Poor bandwidth • Overreliance on technology	mLearning use • Put in place guidelines for use of mLearning • Ensure countrywide Internet connectivity	
Training Institutions	• Joint research activities undertaken • Sharing of scarce resources made possible • Skilled and efficient healthcare providers produced	• Cost of mLearning research • Cost of mLearning training • Cost of smartphones • Cost of other mLearning support technologies • Cost of airtime • Costs of Internet data • Inappropriate use of smartphones • Poor bandwidth • Overreliance on technology	• Provide subsidies on mLearning goods and services • Training on mLearning use • Put in place guidelines for use of mLearning • Ensure countrywide Internet connectivity	• Training institutions • Hospitals • Telecoms • Government • Smartphone sellers • NGOs
Health and Healthcare NGOs	• Attainment of their goals of improving health and healthcare	• Cost of healthcare subsidies	• Develop more funding proposals	• NGOs

	• Increased visibility of NGOs' activities in the community			
App Developers	• Increased sales of health apps • Increased employment for health apps developers • Increased automation of healthcare services	• Costs of app development and hiring app developers • Cost of mLearning app licenses • Demand for open-access licenses for mLearning apps	• Open development of apps • Budgeting for mLearning app development	• App developers • Hospitals • Training institutions • Telecoms
Other healthcare providers	As for midwives	• Cost of smartphones • Cost of airtime • Costs of Internet data • Inappropriate use of smartphones • Poor bandwidth • Strain on the eyes due to limited screen and keyboard sizes	• Provide subsidies on mLearning goods and services • Training on mLearning use • Use bigger-screen mobile devices such as iPads • Reduce pricing of telecom services and products • Ensure countrywide Internet connectivity	• Hospitals • NGOs • Telecoms • Smartphone sellers

Smartphone sellers	• Bulk market for smartphones	• Reduced profitability due to social corporate responsibility subsidies	• Reduce taxes on social corporate responsibility goods or services • Widen tax base	• Government
Government	• Improved healthcare system	• Increased expenditure on mLearning healthcare goods and services	• Diversify tax base • Prioritize resources for mLearning healthcare • Seek alternative funding sources	• Government • Health and Healthcare NGOs • Telecoms

Source: Field Data (2017)

4.4 Benefits and costs of mLearning open innovation

The benefits of mLearning open innovation accrue variously to all stakeholders in the learning of midwives. As previously indicated, the stakeholders include: midwives, telecoms, content developers, hospitals, training institutions, health and healthcare NGOs, mobile app developers, other healthcare providers, smartphone sellers and government.

a) Midwives and other healthcare providers

These are knowledge consumers and generators. Using mobile phones, midwives can consume knowledge from a knowledge repository or other healthcare providers. Similarly, other healthcare providers can also generate knowledge for use amongst themselves. In doing so, midwives and other healthcare providers will enjoy the following benefits:

Benefits

Real-time access to patient diagnostic support: With a smartphone connected to the Internet, midwives and other healthcare providers in the process of diagnosing an ailment can easily be aided. They can access pictures of similar ailments or manifestations of the same ailment for quick diagnosis.

Real-time patient day-to-day care/support: Different patients require different day-to-day care and support. With a smartphone, a number of healthcare providers can access colleagues or repositories of content to obtain the best care support services for patients.

Real-time access to dosage administration procedures: Different patients respond differently to medication errors as a result of the wrong dose, wrong drug, wrong time, wrong route of administration, etc., with death being the worst outcome. In this case, effective medication therapy is necessary to cure a disease, slow the progression of disease and improve patient outcomes with few, if any, errors. Using an Internet-connected smartphone, midwives and other healthcare providers are able to access real-time dosage administration procedures that are vital for reducing unintended consequences.

Real-time access to continuous professional development: In order to prevent and minimize maternal errors, midwives need to stay current with skills and experience by taking advantage of the ever-changing technological landscape.

One approach through which this can happen is distance/open/blended/online learning. Through a smartphone connected to the Internet, a number of healthcare providers can take advantage of flexible (anywhere, anytime) lifelong learning opportunities. As midwives and other healthcare providers determine their own learning needs through reflection, they are able to "learn" and become "fit to practice," and hence know both the whys and the hows.

Internet access: The relevance of an Internet connection is well articulated above in supporting mLearning open innovation. Access to the internet is an enabler of stimulating healthcare providers' involvement in co-creation and utilization of services through an Internet-connected device such as a smartphone. Healthcare providers with smartphones purchase airtime credit codes for loading data onto their local mobile SIM cards in order to, among other things: permit co-creation of knowledge, use the knowledge repository, and research and strengthen public-private-people partnerships or collaborations.

Creation of a community of practice: As midwives and other healthcare providers form and get hooked onto some sort of "localized" network, they are bound to regularly share their concerns and passion for their profession, and learn how to do things better with the help of an Internet-connected smartphone. In the course of sharing, a rich community of skilled healthcare providers who can birth new ideas with a high possibility of turning them into practical solutions is created.

Reduced maternal mortality: As already pointed out under the creation of a community of practice, a smartphone connected to the Internet is necessary for the formation of a customized network amongst midwives and other healthcare providers. As a number of these healthcare providers regularly share and innovate new ideas within their network, a rich pool of skilled people is created, and is capable of offering the services and partnerships required for the development of successful and sustainable innovations. The creation of new ideas and their subsequent development into practical and sustainable solutions is a recipe for tackling the growing socioeconomic and societal concerns such as maternal mortality.

Subsidies from telecoms: As part of their social corporate responsibility, telecommunication companies can play a pivotal role in offering subsidies to healthcare providers through a reduction in, or scrapping of, tariffs on education-related communication services. Further, the government of Uganda can ask well-known mobile phone sellers (such as MTN® and Airtel to provide subsidized smartphones of a specific type and family for issuance to apprentice healthcare providers especially midwives on their registration into training institutions.

Subsidies from NGOs: NGOs do charity work and finance their activities through donations. While the majority of NGOs focus on the general living standards of people, some, such as AMREF, envision health initiatives. The provision of smartphones and the subsequent training on how to use them to co-create and share knowledge is a great benefit to healthcare providers.

A sustainable stream of benefits is also bound to arise if deliberate steps are taken by the government to implore all NGOs to contribute a small fee on towards mLearning as a payback to the community especially in regard to women and children in the labor ward.

Open-access licenses for mLearning apps: In an open innovation approach, there is freedom to access, copy, modify and redistribute research resources that reside in the common access to mLearning apps that permit their free use or repurposing by others. A smartphone connected to the Internet can enable a number of healthcare providers to gain free access to a range of primary resources such as apps for streaming videos, audio and various software that support open access to knowledge. However, even when open access is advocated in this case, a little oversight (adaptive governance) is necessary so as to continue the ideals of the open access resource (Ostrom, 2008). In her guidance, Ostrom (2008) fronted among others the need to achieve accurate and relevant information, adaptation to cope with new developments as well as conflict management, if any.

Costs

The above benefits of mLearning open innovation to midwives and other healthcare providers come with costs, including:

Cost of smartphones: One of the most significant drawbacks to mLearning amongst midwives and other healthcare providers is the initial financial cost of purchasing a smartphone with its apps, which is a prohibitive cost in the short run.

Cost of airtime: Since midwives can use their smartphones for voice communication as an avenue for participating in mLearning open innovations, the cost of communication (airtime credit) must be borne. This cost is still too high for midwives to advantageously engage in mLearning open innovation initiatives (Amref, 2011; Muyinda et al., 2015).

Costs of Internet data: In order to obtain the bulk of mLearning open innovations via smartphones, use of the internet is required. Internet data costs are generally high for a number of midwives and other healthcare providers given their earning capacity in Uganda (Muyinda, 2010; Amref 2011).

Inappropriate use of smartphones on the ward: Even with the provision of a smartphone, airtime credit and complete data plans, mLearning open innovations are not necessarily guaranteed. Midwives may deliberately choose (while on the ward) to pursue divergent functionalities other than those affording healthcare services. This translates into costs by other healthcare providers including but not limited to their tutors and/or employers.

Poor bandwidth: Access to reliable broadband services is necessary if midwives and other healthcare providers are to effectively participate in mLearning open innovations. As they use their smartphones to participate in bandwidth-heavy activities like gaming and video streaming, Wi-Fi speed can be slowed down. A slow Wi-Fi speed is a hindrance to the provision of real-time maternal healthcare that is vital for addressing preventable maternal errors (Amref, 2011).

Strain on the eyes due to limited screen and keyboard sizes: Midwives and other healthcare providers whose smartphones have limited screen and keyboard sizes are likely to experience discomfort due to strain on the auxiliary muscle of the eye. This state of affairs is bound to cause headaches and consequently dissuade midwives from effectively participating in mLearning open innovations (Muyinda, 2010).

Strategies

Strategies are vital because the resources available to assist in achieving mLearning open innovation are generally limited. In this case, the importance of strategies for reducing costs and enhancing benefits identified for mLearning open innovation cannot be overemphasized. The costs can be reduced and benefits enhanced through:

Provision of subsidies on mLearning goods and services: Effective integration of smartphones in the provision of access to education and learning requires enormous support from government and various stakeholders. Such stakeholders can include: telecommunications companies, donors, universities, parents/guardians and learners (midwives) themselves. Government needs to influence policy and also provide either full or partial subsidies for mLearning open innovations to thrive. Government can subsidize mLearning open innovations by reducing or removing taxes levied against education-related communications. Further, the provision of a policy directive towards a strong and scalable network based on clear telecommunications and ICT in education is necessary at institutional, district, regional and national levels. This is bound to create competition, which breeds low costs and efficient services.

Other stakeholders can also be implored into contributing towards mLearning open innovations through compulsory contributions and/or giving back to community initiatives.

Training on mLearning use: One of the critical duties of a number of healthcare providers is to offer real-time support to mothers lest they suffer unintended negative consequences. A smartphone has the potential to aid midwives (while on the ward) and other healthcare providers (while on or off the ward) to save mothers' lives. The use of a smartphone for activities other than those that support access to real-time support can best be combated through training on netiquette. Training all healthcare providers about netiquette is just as important as teaching them how to use smartphones in their learning.

Using bigger-screen mobile devices such as iPads: With an influx of smartphones from China such as Tecno, bigger-screen smartphones and other mobile devices are becoming relatively cheaper, midwives and other healthcare providers have the financial ability to access them. In five years' time, the prices of smartphones and other bigger-screen mobile devices are likely to drop. This is necessary for promoting mLearning open innovations for midwives.

Reducing pricing of telecom services and products: A reduction in taxation is one of the avenues through which high telecom prices for services and products can be reviewed downwards. Luxury tax is one of the taxes on telecom services and products. A host of other mobile-specific taxes range from airtime excises to fixed contributions on connection and handsets. Scrapping and/or reducing all these forms of taxation for mLearning open innovations can benefit medical fraternity.

Ensuring countrywide Internet connectivity: This can effectively support involvement in mLearning open innovations where access to learning objects is aided by a stable Internet or Wi-Fi connectivity. Infrastructure and connectivity plans for mLearning need to be aligned with Uganda's national network infrastructure strategies such as fixed and wireless (hotspot) connectivity. High-speed fixed connectivity is necessary for strong mobile network connectivity. These need to be rolled out to cover as much of the population as possible including in remote areas.

b) Telecoms

In Uganda, until recently, telecoms have been the primary dealers in mobile communication devices, credit and data. Knowledge co-creation and sharing can only be possible if there is seamless access to the Internet as well as smartphones. Seamless access to the Internet is only attainable with sufficient bandwidth, meaning a sufficient Internet data supply by telecoms. In the mLearning context, the following benefits accrue to telecoms:

Benefits

Bulk market for smartphones: mLearning has the potential to trigger increased demand for smartphones with big screen and keyboard sizes. Even when the success and impact of mLearning does not wholly rely on technological developments and possibilities, possession and/or ownership of such smartphones is important if mLearning is to move forward. This presents a bulk market for these smartphones.

Bulk market for airtime credit and data bundles: The process of co-creating knowledge and subsequently supporting seamless access to it via a smartphone requires airtime credit and data bundles. As a result of mLearning, a high demand for airtime and data emerges (Muyinda et al., 2015). Such bulk demand is an automatic market, which directly benefits telecoms.

Increased customer subscription: Co-creating knowledge with the help of a smartphone can be engaging. Optimizing teaching and learning via a smartphone can be more engaging and therefore cause parties to the teaching and learning processes to participate effectively. Fear of missing out is a reality and other parties to the mLearning domain may feel left out of something interesting. This pervasiveness in subscription has the potential to compel other people to join the telecom customers' base.

Cost

In light of all the above benefits to telecoms, a profound cost faced by telecoms is the reduced profitability due to social corporate responsibility subsidies and discounts on bulk purchases. Bulk purchases reduce the cost per unit and therefore reduce how much is received in the long run. Dealing with this cost has been suggested to lie in the strategies outlined below:

Strategies

Reducing taxes on social corporate responsibility goods or services: The government can subsidize mLearning by reducing or removing taxes imposed on education-related services or goods. Similarly, the government can reduce exemptions on non-priority social services and relocate such exemptions to priority social services such as education. Further, provision of a conducive investment environment for telecoms to invest in all parts of the country can lead to competition among telecoms. Such competition is vital for lowering costs and the provision of efficient services.

Widening the tax base; Widening of a tax base can result in a downward pressure on tax rates, especially for key social services such as education. Improving entrepreneurial activities and embracing the value-added philosophy can go a long way to increasing the number and value of goods and services. Further, prioritizing the expenditure of taxpayers' money on activities with huge backward linkages is vital for increasing inclusivity, hence the increased number of taxpayers in the tax net.

Ensuring countrywide Internet connectivity: Internet connectivity can be a highly prohibitive cost to mLearning. To connect the country's population to the Internet, government can deliberately take up the initiative to provide the network architecture and infrastructure. This will reduce the cost of connectivity by private telecoms, thereby contributing to the co-creation of knowledge with ease.

c) Content developers

For content developers, a number of benefits are bound to arise as presented in the following section.

Benefits

Wide distribution of knowledge: The use of a smartphone to support co-creation and free sharing of knowledge can provide 24/7 instantaneous access to knowledge well beyond an individual's territory. This continuous knowledge creation and situated learning support midwives can tap from such a rewarding learning experience to improve health outcomes.

Availability of opportunity for lifelong learning: Using smartphones for co-creation of knowledge, teaching and learning provides a catalyst for lifelong learning. Lifelong learning permits anytime anywhere learning and thus its convenience and flexibility. In circumstances where a learner has multiple life obligations related to family, work and society, the use of a smartphone becomes beneficial in integrating a learner's daily life into knowledge co-creation, teaching and learning environments.

Rich content accessed/shared: As content developers use a smartphone to co-create knowledge, they can combine, send and deliver a range of multimedia content. Delivering and sending multiple media content such as text, image, audio, graphics, animation-based instructions and videos is an affordance of smartphones.

These smartphones are also interoperable with other mobile and tethered devices that are vital in supporting the contextualization and personalization of content by midwives to improve health outcomes.

Peer review of content is made possible: Using smartphones to co-create and freely share knowledge at any time anywhere can promote the spirit of active participation. The participatory environment is likely to ignite the practice of making reflections in order to inform reasonable meanings out of specific scenarios.

Costs

Infringement of intellectual property rights (IPR): While planning time and resources for investment into the co-creation and sharing of knowledge, it is important to streamline matters regarding IPR and copyright (Ostrom, 2003). Concerns such as password protection and right of ownership need to be sorted out to allow the user "anytime anywhere" access. In the case of using a smartphone to co-create and share knowledge using an open innovation approach, it becomes meaningful when co-creation freely flows across the parties, thereby subjecting the content developers to a risk of infringement of intellectual property rights.

Plagiarism: Co-created and freely shared knowledge may become private information, and therefore its use, if any, jeopardizes the ethical quality assurance standards such as originality and the wish to make a contribution to filling knowledge gaps. As such, the use of a smartphone to co-create and share knowledge using an open innovation approach can pose serious piracy concerns to content developers.

Limited return on time investment: The process of co-creating, sharing knowledge, researching to cope with new developments and provision of adaptive governance is continuous (Ostrom, 2008). This therefore requires an excessive amount of that precious and limited resource called "time." If highly technical content developers perceive the monetary value of their time, they may rethink about how much time to spend on the co-creation, research to cope with new developments, sharing of knowledge and adaptive governance and hence make less of a contribution.

Strategies

In order to reduce costs and enhance the benefits experienced and enjoyed, respectively, by content developers, there is a need to sensitize all the open innovation stakeholders to intellectual property rights and improve on the enforcement of intellectual property laws. Lastly, while we cannot manufacture more time, we can manage it more effectively. As such, there is a need to formulate a business model to effectively manage the open innovation model for mLearning. One of the effective business models has been suggested by Muyinda (2010) to be the provision of a seed fund (by training institutions especially universities) for showcasing the potential and value of mLearning to key stakeholders such as the business community and line ministries (such as Ministries of Education and Sports and that of ICT and National Guidance in Uganda). Once a good showcasing job is done, a business can possibly support mLearning by way of satisfying important tasks-to-be-done for its customers which are superior to alternatives or at a better price (Chesbrough and Rosenbloom, 2002, Muyinda, 2010).

d) Hospitals

Hospitals as healthcare institutions that provide organized medical and other professional staff plus inpatient facilities 24 hours a day, seven days a week, play a very important role in the healthcare system. In a mLearning environment, a hospital that works with other health and social care providers with a focus on people's needs is bound to be beneficial in a number of ways, as follows:

Benefits

Reduced maternal mortality: As pointed out earlier, an Internet-connected smartphone can help midwives in a hospital to interact with other practitioners in the co-creation and sharing of knowledge. Real-time sharing of, and access to, co-created knowledge is necessary for improved health outcomes. As hospitals focus on the reduction of preventable maternal errors using mLearning, maternal mortalities are reduced.

Provision of competitive quality of healthcare: An Internet-connected smartphone can also help midwives to co-create and share knowledge through behavioral responses to challenges (Naismith et al., 2004). These are vital for influencing the innate value of market-based resource allocation such as production and consumption decisions where prices provide the main signal for such decisions (Chesbrough & Rosenbloom, 2002). Through open innovation, patient choice is strengthened, high-quality care is provided and costs are controlled. To be precise, patients access what they desire in the least costly way.

Joint research activities undertaken: Just as in the case of the provision of a competitive quality of healthcare, challenging and strong reactions can be generated using an Internet-connected smartphone. Pairing people with differing strengths is vital for problem solving, co-creating innovations and performance too (Powell et al., 1996). As midwives pair up with other health care providers and stakeholders in the co-creation of knowledge, there is access to multiple external expertise and talents on how to quickly respond to external environments. Such reactions/responses can spur/promote joint research undertakings amongst midwives, aimed at developing new instruments and techniques in a cost sharing manner(Cosh & Zhang, 2011).

Complementary working relationships inculcated: One of the affordances of a smartphone connected to the Internet is ensuring close proximity to one another. As midwives co-create and share knowledge, it is possible to complement each other as a simple solution to low productivity and poor performance.

Sharing of scarce resources made possible: As the world increasingly becomes an interdependent global business environment, collaboration with, or help from, other external sources is necessary. Even companies with vast resources may not be able to afford to stay within their company boundaries without the support of others.

A smartphone connected to the Internet comes in handy by enabling midwives to participate in knowledge co-creation processes that are vital for the allocation of scarce resources, time and energy.

Hospitals can rediscover themselves for improved healthcare: The human resource base in hospitals is made up of midwives, nurses, clinical officers, doctors and laboratory technicians with varied skills and knowledge. The provision of a platform where the expertise of these officers can be pooled together and cross-fertilized makes it possible for the hospital to rediscover its potential for improved healthcare.

Costs

Hospitals, just like midwives, incur costs of smartphones, airtime, Internet data, inappropriate use of smartphones on the ward and poor bandwidth. When a requirement to use mLearning abounds in hospitals, workers will demand to be compensated for the aforementioned items. The hospitals will also be required to put in place mLearning support technologies such as hospital Wi-Fi, a local area network and storage for generated learning content and other data. The hospitals will also realize sooner or later that when one is used to performing one's duties with technology, failure of that technology at any given time will lead to stalemate in healthcare service delivery.

Strategies

In order to reduce costs and enhance their benefits, hospitals will need to bargain over subsidies on mLearning goods and services, institute guidelines for the use of mLearning in the hospital, train their staff in the efficient use of smartphones for co-creation and sharing of skills and knowledge, and ensure countrywide reliable Internet connectivity.

e) Training institutions

Benefits

Since a number of hospitals also double as teaching hospitals, they can be easily categorized as training institutions. For that matter, the benefits of mLearning accruing to hospitals do cascade down to training institutions. For instance, training institutions also benefit from having joint research activities and sharing scarce resources on a mLearning platform. An improved research environment with an abundance of learning resources is a recipe for producing skilled and efficient healthcare providers.

Costs

The costs faced by training institutions are similar in all respects to the costs that hospitals and their staff incur in using mLearning. Additionally, training institutions have to incur costs for subscribing to research databases and research repositories. These institutions also have to incur costs of human resources capacity development in mLearning.

Strategies

Training institutions will need the same cost reduction and benefit enhancement strategies as hospitals. As such, training institutions will also need to bargain over subsidies on mLearning goods and services, institute guidelines for the use of mLearning in hospitals, train their staff in the efficient use of smartphones for co-creation and sharing of skills and knowledge, and ensure countrywide reliable Internet connectivity.

f) Health and healthcare NGOs

One of the fundamental reasons for the formation and existence of health and healthcare NGOs such as Amref Health Africa is to ensure access to better health for the population. Health and healthcare NGOs have variously contributed through the *"incentivization"* of healthcare activities such as seminars, meetings, workshops and conferences in a bid to promote knowledge co-creation and sharing. Such knowledge can be deposited in the repository for future use.

Benefits

By participating in mLearning open innovation for aiding the learning of midwives, health and healthcare NGOs can attain their goals of improving health and healthcare and thus increase their visibility within the communities in which they operate.

Costs

Like other stakeholders, health and healthcare NGOs also experience costs. These NGOs will incur costs related to the actual provision of the funds required for subsiding healthcare programs.

Strategies

Health and healthcare NGOs need to develop more funding proposals if they are to reduce the burden of costs while enhancing their benefits. A need for continued development of funding proposals will become apparent under the circumstance of continued sustainability of NGO activities in an open innovation.

g) Mobile app developers

The popularity of smartphones performing more than simply the canonical role of mobile phones: to make phone calls and send text messages has brought about the relevance of mobile app developers. Mobile app developers create software for mobile devices with specific applications utilizing the individual characteristics of a particular platform such as the healthcare system. Mobile app developers are mLearning stakeholders and are associated with a number of benefits.

Benefits

Open innovation through mLearning is only made possible if there are mobile apps. As such, mobile app developers are key stakeholders in the co-creation and sharing of skills and knowledge in mLearning. With increased uptake of mLearning in the healthcare system, there will be increased demand for healthcare apps and hence increased sales of these apps. This will translate into increased employment for health app developers and automation of healthcare services.

Costs

A mobile app developer who patents or copyrights his work is bound to enjoy exclusive and assignable legal rights for a fixed number of years. Others are barred from indulging in any form of plagiarism by printing, publishing, performing, filming or recording any literary, artistic or musical materials.

Such free use can only be acceptable on payment of necessary costs, such as the costs for developing apps, the hiring of app developers and mLearning app licenses. Another potential cost would be the ever-increasing demand for open-access licenses for mLearning apps.

Strategies

Infringement of a copyright is a serious matter attracting a legal suit necessitating mechanisms to budget for the development of mLearning apps. On the other hand, open educational resources (OERs) can provide solace. Open access is now a norm in open innovation that necessitates adaptive governance if the ideals (such as accurate and relevant information, adaptation to cope with new developments, conflict management, etc.) are to be preserved (Ostrom, 2008). This calls for careful planning and investment of time and money (Muyinda, 2010). Since creative commons make available apps for others to build upon legally and share, mobile app developers in a way have to open up their apps for open access in a non-commercial manner (Smith, 2004). Unlike under the traditional copyright/patents, creative commons allow work to be downloaded, published, shared, and adapted and the creation of derivatives as well as using such work for non-commercial purposes

h) Smartphone sellers

While mLearning can be achieved using other mobile devices such as iPads, tablets and laptops, this paper focuses more on mLearning attained through smartphones because 94% of the midwives surveyed owned smartphones. Knowledge artifacts accessible on mobile phones are more likely to be accessed and used than those meant for other mobile devices. This implies that sellers of smartphones are key stakeholders in any learning innovation employing mobile devices.

As they participate in this knowledge continuum, they are likely to enjoy the following benefits:

Benefits

One of the most important questions would be: What benefits accrue to smartphone sellers as stakeholders (in the mLearning open innovation) when mLearning is widely adopted? Smartphone sellers are bound to enjoy the bulk market for their products and thus increased profitability resulting from an increase in quantity demanded.

Costs

As smartphone sellers experience an increase in demand, this may be at the expense of price discount demands from institutions buying in bulk and therefore reduce profitability. Similarly, the demand for corporate social responsibility subsidies will be eminent, again resulting in reduced profitability.

Strategies

For smartphone sellers to get a fair deal out of the mLearning open innovation initiative, they will need to advocate for a reduction in taxes on social corporate responsibility goods or services, but also implore government to widen the tax base.

i) Government

Government is duty-bound to provide high-quality and efficient preventive and curative healthcare services.

Benefits

A mLearning platform for helping healthcare providers, especially midwives, to co-create and share skills and knowledge has the potential to provide high-quality and efficient healthcare services. As a key stakeholder, therefore, government can benefit by having an improved healthcare system.

Costs

It is quite obvious that having an improved healthcare system cannot come to government free of charge. Government has to variously support all the other stakeholders. There is a need for government to subsidize the costs of devices, airtime and data. For hospitals, government needs to set up the necessary infrastructure and build staff capacity. This is also true for training institutions.

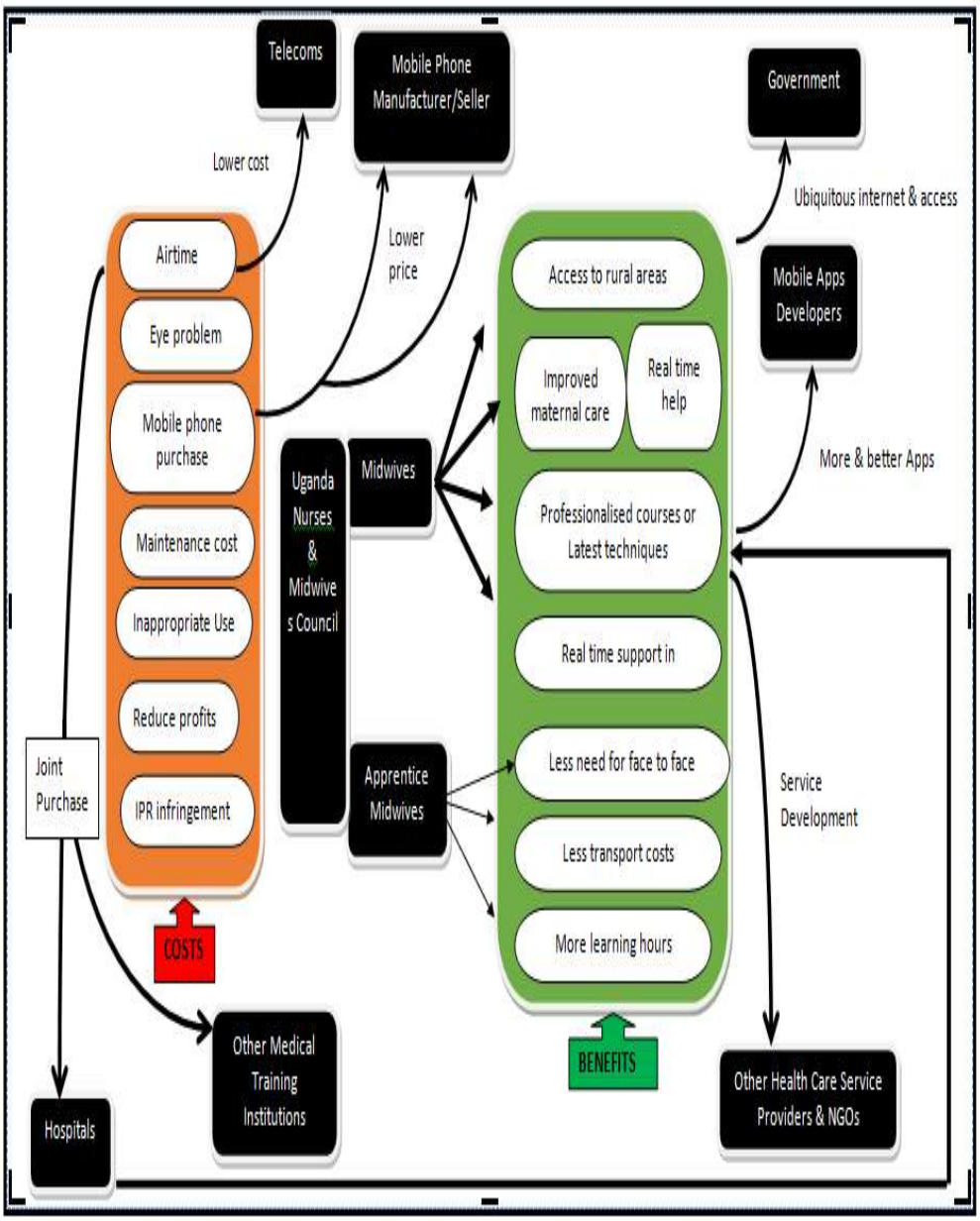
Strategies

In order to consolidate the benefits and reduce the costs government enjoys and faces, respectively, on the mLearning platform, there is a need to diversify the tax base. Taxes on mLearning healthcare goods and services can also be reduced. Further, government is in a better position to seek alternative funding sources to support mLearning in the health sector.

4.5 Effect of mLearning

The effect of mLearning is presented with tenets of an adaptive ecosystem. In an adaptive ecosystem, stakeholders join each other to develop significant and broader innovations that together are vital for strengthening each stakeholder's reason for existence (Adner, 2017; Obstfeld, 2005).

In the midwifery profession, a set of relationships involving multiple players is required to provide high-quality maternal care to mothers as well as their unborn and newly born babies. Both prominent and non-prominent (uncommon) stakeholders need to work closely together towards the common problem of preventable maternal errors, whose solution is work in progress. In the diagram below, a mLearning open innovation with different players is presented. The black rectangles are the different players/stakeholders, the two big rectangles represent costs (orange background) and benefits (green background) for midwives, while the arrows represent the role(s) of each stakeholder in the co-creation and sharing of knowledge cycle.



Source: Field Data (2017)

Figure 2: Maina's Developed Mobile Learning Open Innovation Framework for Midwives (MLOIF4M)

The framework in *Figure 1* above depicts both internal (healthcare) and external (non healthcare) relationships. It is imperative to understand how the interplay between different stakeholders can support a better understanding of how they can work together to co-create and share innovations. Harmonious working together by the different stakeholders via mLearning is instrumental in reducing maternal challenges.

In the framework, the stakeholders are: midwives, telecoms, content developers, hospitals, training institutions, health and healthcare NGOs, mobile app developers, other healthcare providers, smartphone sellers and government. Each of the stakeholders has a part to play, short of which there is suffocation on the part of other stakeholders. A detailed account of the interdependencies between the stakeholders identified in the framework is presented as follows:

Midwives and apprentice midwives, through their umbrella organization of the Uganda Nurses and Midwives Council, benefit a great deal from the mLearning open innovation framework. As can be seen, midwives in hard-to-reach rural areas can be reached and supported via an Internet-connected smartphone so as to improve maternal care outcomes. Midwives do this through the provision of real-time help, the application of professional knowledge and/or recommended latest techniques, and the provision of real-time support in emergency situations.
On the other hand, apprentice midwives also benefit by incurring lower transport costs, and through the availability of more learning hours and the reduced need for face-to-face sessions.

Of all the benefits, building a formidable force of professional midwives and the application of recommended modern techniques cannot be underscored enough in closing the gap for preventable maternal errors, especially in rural areas where shortages in skills and knowledge commonly thrive. This requires midwives and apprentice midwives to work hand in hand with the Uganda Nurses and Midwives Council, government, mobile app developers, hospitals, other healthcare service providers and NGOs.

Mobile app developers have a duty to design more and better user-friendly apps. Professionally trained midwives have a responsibility to offer high-quality healthcare services and train other healthcare service providers and any interested NGO participants, hospitals provide the platform for offering specialized or professional services, and government needs to provide the ubiquitous Internet and enable access to it. Little interest on the part of government in orchestrating mLearning open innovation is bound to curtail improved maternal outcomes. Government's failure to provide the ubiquitous Internet and enable access to it, together with a lack of favorable policies for mLearning, can underplay the value of open innovations in co-creating and sharing knowledge artifacts. For instance, government through its agency (the Uganda Nurses and Midwives Council) has a very big say on the policy environment in which midwives and apprentice midwives operate. Policies such as "Do not use mobile phones on the ward," "Mobile phones are strictly forbidden on the ward," "Do not come with mobile phones to the midwifery schools" and "Switch off your mobile phone while in the ward," among others, need to be rethought in the face of mLearning for improved efficiency of midwives.

Government has to take a leading role so that players in the mLearning ecosystem can optimize gains from the system. Some of the costs faced by other players like telecom companies and smartphone sellers are the direct responsibility of the government in terms of the provision of favorable tax policies, and the provision of subsidies and social amenities such as a power supply.

In terms of costs, midwives and apprentice midwives are challenged by airtime costs, eye problems due to the small sizes of smartphones, the cost of purchasing a smartphone, the maintenance cost of the smartphone, inappropriate use of the smartphone on the ward, reduced profits for smartphone sellers and the infringement of intellectual property rights. Would-be primary stakeholders in this case are telecoms, smartphone manufacturers/sellers, hospitals and other medical training institutions but are largely rooted in the coordinated effort or hand of the lead player, the government.

For midwives to co-create and share skills and knowledge through a mLearning open innovation approach, it is a precondition to have a smartphone with reliable airtime/data plans. In order to make the mLearning open innovation work out, smartphone sellers and telecoms need to reduce the prices of their goods and services, respectively. However, this is possible if there are clear and stable policy environments put in place by the government as an orchestrator to stimulate collaboration and cooperation among the different stakeholders (particularly through the Ministry of Health, Ministry of Education and Sports, National Council for Higher Education, National Curriculum Development Center and the Private Sector).

By so doing, stakeholders with less conventional capabilities such as smartphone sellers, telecom managers, hospital administrators and other medical training institutions can be empowered to make mLearning open innovation operationalized. Hospitals and other medical training institutions can undertake to support joint purchases of airtime. Doing what is possible within their powers, hospitals and other medical training institutions can significantly reduce the hindrances to mLearning.

The above mLearning open innovation ecosystem is not cast in stone. There may be new forms of value in combining with a range of other unexpected stakeholders since not all ecosystem efforts necessarily lead to successful innovations. This presupposes the ability to have a flexible system to account for twists and turns that have no end in sight. In the following section, validation of the proposed framework is presented.

4.6 Validation of the proposed Maina's mLearning Open Innovation Framework (MLOIF4M)

In this section, the definition of validation, validation methodology employed and results are presented.

4.6.1 Validation

Validation is an evaluation based on the functional specifications implicit or explicit in the suggestion (Von Alan et al., 2004). It usually entails evaluating the usability (usability evaluation) of a system, method or framework. Usability evaluation focuses on how well users can learn and use a product to achieve their goals. It may also refer to how satisfied users are with a given process. Usability evaluation includes a number of usability evaluation methods (UEMs) that focus on device characteristics, user knowledge or the test procedures themselves (Jokela et al., 2003; Moritz & Meinel, 2010; Scholtz, 2004). It could also take on methods such as prototyping, comparison of artifacts' functionality with other frameworks, satisfaction surveys, domain expert evaluations and any other appropriate empirical evidence or logical proof (Peffers et al., 2007).

User-based evaluation methods invite actual users to accomplish tasks with a product or to explore its applications while their behaviours are observed and their thoughts recorded (Bastien, 2010). Whilst mobile technologies offer great opportunities for proficient learning, utilizing such innate skills can prove hard, especially in cases where an instructor cannot effectively use them both inside and outside of the classroom (Vesisenaho et al., 2010).

According to Kjeldskov and Stage (2004), there are six main areas of concern for usability testing:

i) the skills and/or technological competence of the user,

ii) costs associated with data collection (participation fees, etc.),

iii) the presence of a researcher changing the phenomenon of interest,

iv) the time and/or personnel required (by the user and tester),

v) inability to completely control experimental variables, and

vi) observations that do not generalize.

Commonly evaluated attributes are learnability, efficiency, memorability, user errors, user satisfaction, simplicity, comprehensibility, safety, flexibility, learning performance and effectiveness (Alshehri & Freeman, 2012).

In Kirkpatrick's four-level training model, the effectiveness of any type of training is evaluated using four variables, namely: reaction, learning, behaviour and results (Ikramina & Gustomo, 2014; Kirkpatrick & Kirkpatrick, 2006). Kirkpatrick's model can be important for measuring the effectiveness of training midwives through mobile devices. However, *section 4.6* aims to validate MLOIF4M beyond just measuring the training effectiveness. It entails validating all the constituent dimensions of the framework. As such, the section below explores the methodology adopted for this task.

4.6.2 Validation methodology

As pointed spelt out in *section 4.6.1,* validation is construed to mean testing the usability of the framework. Testing the usability of Maina's MLOIF4M requires data to be drawn from a wide usability attribute base, such as learnability, user errors, flexibility, user satisfaction, efficiency, memorability, effectiveness, simplicity, comprehensibility, safety and learning performance, among others.

Midwives can enjoy a high degree of collaboration through making rich connections amongst themselves, other healthcare providers and all stakeholders in the MLOIF4M (Kearney et al., 2012). This high-level networking creates shared and socially interactive environments that are vital for co-creating and sharing of technical knowledge among/for midwives.

In the MLOIF4M, midwives consume, co-create and share an array of information and artifacts across time and space. In order to effectively harness technical knowledge artifacts, midwives ought to explore both constructs within and outside the control of midwives, a precursor for continuous improvements. The proposed Maina's MLOIF4M was developed using design research methodology in which iterations in artifact design and development are emphasized to inform a basis for continuous review of existing artifacts (Muyinda, 2010). As such, the creation of successful artifacts is incomplete without making ad hoc arguments for validation (Peffers et al., 2007; Von Alan et al., 2004).

4.6.2.1 Validation methods

Several validation methods exist. They include prototyping, comparison of artifacts' functionality with other frameworks, satisfaction surveys, domain expert evaluations and any other appropriate empirical evidence or logical proof (Peffers et al., 2007).

Prototyping

The process of prototyping involves building a model of a system and helps system designers build for end users an intuitive and easy-to-use information system (Iivari, 1984). It involves building, testing and iterating until an acceptable prototype is finally achieved.

mLearning frameworks

Several frameworks exist, including, but not limited to, Muyinda's 2010 Mobile Learning Object Deployment and Utilization Framework (MoLODUF), Khan's 2001 Global eLearning Framework and Goh and Kinshuk's 2006 Framework.

Muyinda's MoLODUF is a 12-dimensional framework comprising mLearning Costs, Learning Processes, mLearning Devices, mLearning Objects, mLearning Resources, mLearning Evaluation, mLearning Connectivity, mLearning Interface, mLearning Objects User, mLearning Policy, mLearning Context and mLearning Ethics (Muyinda, 2010). The framework is aimed at guiding application developers to instantiate pedagogic mLearning applications. It is not a framework for co-creating and sharing knowledge.

Khan's Global eLearning Framework is an eight-dimensional framework consisting of Resources Support, Management, Evaluation, Technological, Interface Design, Pedagogical, Institutional and Ethical dimensions (Khan, 2001). Khan's framework embraces the whole notion of eLearning but does not put much emphasis on distributed co-creation of knowledge using mobile devices.

On the other hand, Goh and Kinshuk's framework is a multidimensional framework for content adaptation for PC and mLearning environments consisting of only five dimensions, namely: Coordination, Connectivity, Capability, User Model and Content (Goh and Kinshuk, 2006). The framework limits pedagogy to content only though strongly brings out the coordination construct as a key component (ibid). However, it is not this brokerage what is needed to have various partners linked but rather an orchestrator. An orchestrator connects different partners and encourages them to work directly with one another to identify new or nascent opportunities as well as developing significant innovations together (Adner, 2017). By so doing, the right innovative ecosystem is built. In light of open innovation approaches, the variations in dimensions depicted in the frameworks above indicate a dearth in mLearning frameworks.

Satisfaction surveys

The results of a satisfaction survey help to determine the performance of a product or service by measuring satisfaction, identifying unhappy customers and finding potential advocates (Bernazzani, 2019). The actionable feedback is a measure of customer/user loyalty with an ultimate focus on retaining and/or growing the customer user base.

Domain expert evaluation

This validation technique involves enlisting logical and empirical views of experts on a subject matter. Through expert opinions, appropriate logical and empirical proof is easily attainable. Expert validations allow interviews with domain experts to elicit their opinions and attitudes on the suitability of the framework constructs (Hillstone, 2003; Parsons et al., 2007; G. Vavoula & Sharples, 2009).

Whilst Maina's proposed MLOIF4M was validated using prototyping or satisfaction surveys and domain expert evaluation, the latter was adopted. This is because frameworks consisting of both internal and external dimensions are best evaluated using domain expert evaluation techniques (Traxler & Kukulska-Hulme, 2005). The nexus herein is to tell how well Maina's proposed MLOIF4M can help in solving the problem of high maternal mortality through an open innovation approach using the ubiquitous mobile devices. Domain expert techniques allow a descriptive design validation approach that can build a convincing argument for the utility of artifacts (Traxler & Kukulska-Hulme, 2005).

4.6.2.2 Validation population and sample

Domain experts were drawn from eLearning professionals, healthcare professionals and midwives. While one expert was drawn from each of the first two categories, other 4 were drawn from midwives and jointly indexed.

The first domain expert (**Expert A**) is an eLearning professional, Professor and Deputy Vice Chancellor at one of the private higher education institutions. The eLearning professional has a good mix of knowledge and skills on e- and mLearning frameworks.

He is an experienced senior virtual/online/electronic/distance learning lecturer and researcher who has taught at a number of universities, supervised graduate students (Masters and PhD) and published widely. As such, he is familiar with students' assessments.

The second expert (**Expert B**) was drawn from other health care providers. The expert is a medical practitioner at a senior level and a Principal of a health care training institution. The expert has exposure to mLearning and also tutors midwives. The expert is also well versed with activities of the Uganda Nurses and Midwives Examinations Board (UNMEB). The health care training institution is one of the implementing agencies for mLearning.

The third expert (**Expert C**) was drawn from the midwives undertaking continuous professional development using a mobile device. This category of expert involved a midwife trained through a mixture of learning (traditional and eLearning). In other words, expert C is the primary beneficiary of the framework in terms of up-skilling and is acquainted with modalities of Uganda Nurses and Midwives Council. More three experts were identified to validate the framework bringing the total to six (6). These are **Expert T, R** and **M**. **Expert T** is an education specialist and programmer working at the National Council for Higher Education, a regulatory body for higher education in Uganda and accreditor of academic programs. Besides their examination body of UNMEB, Midwifery training institutions have close feeds into NCHE. **Expert R** is a professor of Computer Science with immense experience in developing mobile learning applications. His expertise therefore is vital for reviewing the MLOIF4M framework. **Expert M** is an independent consultant consulting mainly in educational application development including educational mobile apps.

4.6.2.3 Validation tool

Muyinda (2010) interview guide, used for validating the Mobile Learning Object Deployment and Utilization Framework, was adapted. Muyinda analysed the experts' instincts about his twelve (12) dimensions through a reliability test. The choice was informed by the relatedness of Maina's proposed MLOIF4M to that of Muyinda. A Cronbach's alpha of 0.89 and a standardized item Cronbach's alpha of 0.92 were generated underpinning the high reliability and internal consistence of the guide. These were well above the minimum 0.70 requirement for validity and reliability.

In his research, Muyinda (2010) interviewed five (N=5) experts to provide their levels of agreement to the suitability of the different dimensions and sub-dimensions of the *MoLODUF.* The levels of agreement were measured on a nominal four point Likert scale of strongly disagree (1), disagree (2), agree (3) and strongly agree (4). Muyinda adopted the domain expert method to validate his framework codenamed *MoLODUF.* The reason for its use is because it provides a descriptive design evaluation that can be used "…to build a convincing argument for the artifact's utility" (A. R. Hevner et al., 2004, p.18). For every domain expert, the aim of the framework was explained.

In this study, Muyinda's interview guide was adapted to enlist responses so as to gauge the effectiveness of Maina's proposed MLOIF4M in CPD *(see interview guide in Appendix 2).*

4.6.3 Results

Validation results for Maina's proposed MLOIF4M revealed that using the nominal four-point Likert scales (strongly disagree (1), disagree (2), agree (3) and strongly agree (4)), experts agreed 100% that all the stakeholders therein were valid. The majority (83%) of the experts were in strong agreement that a collaborative and reflective interplay amongst the proposed ten stakeholders was important for co-creation and sharing of knowledge for improved health outcomes.

"We can't teach today as we taught yesterday or else we rob our learners of tomorrow," Expert B pointed out, adding that today's learners have to be equipped with 21st-century soft skills such as the ability to generate/construct knowledge, communicate, provide solutions to problems, innovate, think critically and make decisions, among others. A collaborative effort with and amongst stakeholders in Maina's proposed MLOIF4M can aid co-creation and sharing of knowledge for reduced maternal mortality. The agreed-upon stakeholders are: telecoms, other healthcare service providers and NGOs, mobile phone sellers, government, mobile app developers, midwives, apprentice midwives, the Uganda Nurses and Midwives Council, hospitals and other medical training institutions.

Feedback from Experts T and B found Maina's proposed MLOIF4M to conform to the learning requirements for midwives in a Ugandan context. Expert A noted that "the framework could be instrumental in having low-level cadre staff attain training while at work." Both Experts A and B indicated that the constructs therein were effectively critical if midwives were to benefit from the anytime anywhere access to healthcare support.

mLearning was a mere learner support, but blending it with face-to-face continuous professional development and/or continuous medical education sessions (forums) becomes an important component in the efficiency of midwives, suggested Experts A, R and M. Complementarily, Experts T and A pointed out that what is most important is the commitment of the various stakeholders to legally build health interdependencies (interplays) towards joint development and dissemination of innovative ideas. This is important if midwives are to deliver value to mothers and their babies.

The above position was a generalized one. It was important to validate additional interplays between the constructs in the proposed MLOIF4M, establishing how the various constructs can gain or not gain a thing from mLearning in midwifery education in Uganda. The aim here was to try and weed out any invalid stakeholders and/or to try and prioritize who takes the lead.

Accordingly, experts were asked to provide an opinion as to which stakeholder should take the lead in implementing the proposed MLOIF4M. In response, Experts A, B, T and R concurred that it is a two-way game. Both top-notch and lower-end players, that is, the government and learners (midwives), need to take the lead if mLearning is to occur. For the top-notch player (government), there is an urgent call to close policy and regulation gaps.

Expert B commented:

"For mLearning to get rooted, the culture to use phones for educational purposes should be adopted early enough."

Similar with Expert M's mind, Expert B added:

> *"……. We do not allow students to go with phones to schools/class yet in their free time they can engage in productive co-creation, as you say, suggesting that there is no intention to inculcate the culture of mLearning early enough. Once a child is found with a phone at school/in class, it is a disciplinary matter and at worst expulsion from the education institution. Therefore, deliberate efforts must be made to open up the curriculum space for learning. It is therefore upon Mr Government to interest himself in mLearning like it dealt with scratch airtime cards and now that we are tending towards hitting the AI [artificial intelligence] singularity soon around 2023…."*

As a rejoinder, Experts A, R and M suggested that an all-embracing policy and regulatory framework on the part of government is important to cater for ethical issues and promote awareness amongst its citizens. In his comment Expert A said: "… we do not want issues of cybercrime to happen to users of the database." Further, he stated that cost was a key challenge and the situation is even worse in rural areas where connectivity to the power grid and/or the presence of alternative power sources is tepid or nonexistent.

In his words, Expert A:

> *"….. This thing [mLearning] is urgently needed in the upcountry centres, especially villages where access to medical services can be a nightmare. But still then there is no power to charge the phones so it is not very possible to have instant communication all the time for a midwife who has to take her phone for charging to the [trading] centre, where there is electricity or solar …."*.

In a related contribution, Experts B, T and M advised that mLearning requires preparation, competent facilitators and sufficient support.

While the use of a mobile phone to subscribe to the mLearning technical knowledge artifacts repository can be facilitated, it takes the contribution of both prominent and non-prominent stakeholders, stressed Expert M. This may thus make little sense in terms of who takes the lead and who lags behind. It is a full healthcare supply chain, where the omission of any stakeholder is bound to cripple the success of reducing the maternal mortality burden, attested Experts A, T and M.

As to what Experts A and B envisioned as a sustainability plan for the proposed MLOIF4M, responses revealed that an effective mLearning open innovation framework was only possible with successful interdependencies between the stakeholders. The role of the government and its interplay with other stakeholders became vibrantly clear. In one of the feedbacks, Experts C and M could not agree any further that government was at the center of this whole thing. mLearning is about who bears the cost and to what magnitude! In their opinions, Experts C and R painted a similar picture with Expert C's own words being:

> *"……governments should find a means to subsidize mLearning through reduced and even removed taxes on education communication on top of its role in the provision of ample investment space for the telecom players……"*

Let telecom masts be all over the place so that subscription to any network is by choice rather than in circumstances of limited network connectivity. In this way, there can be healthy competition, which is vital for reducing costs, revealed the Expert A.

In a similar comment, Expert B recognized the Corporate Social Responsibility (CSR) by corporate institutions mainly in the banking and telecom sectors. However, this expert noted that this should be well above the usual CSR zebra crossing demarcations and painting of structures alongside major road networks. Experts B, R and M suggested that perhaps telecoms should gazette a specific telephone line strictly for educational purposes so that any phone credit and data bundles thereof can be for educational purposes.

In a business sense, Experts M and T underscored the need to share the cost between universities and students. Relaying the entire burden of educational communication to the government and/or even telecoms is unfair and may reduce participation. Expert M said: "Education is an investment." Teaching and learning institutions can also explore business talks with telecoms, which can culminate in bargains in terms of discounts on bulk consumption of telecom services.
"As we move along, the future points to a brighter end," Expert A noted. Telecoms are competing for favors from consumers of their services or products. As a result of the competition, credit and Internet/data bundle expenses have increasingly become flexible and thus affordable, thereby explaining the increase in the number of users of the Internet via smartphones, concurred Experts M, A and R.

In another question, respondents were asked to suggest important areas for inclusion in, and/or exclusion from, the proposed MLOIF4M framework. Surprisingly, all (100%) experts interviewed commended all ten stakeholders in the proposed MLOIF4M. On the other hand, experts criticized the proposed MLOIF4M for omitting some vital components.

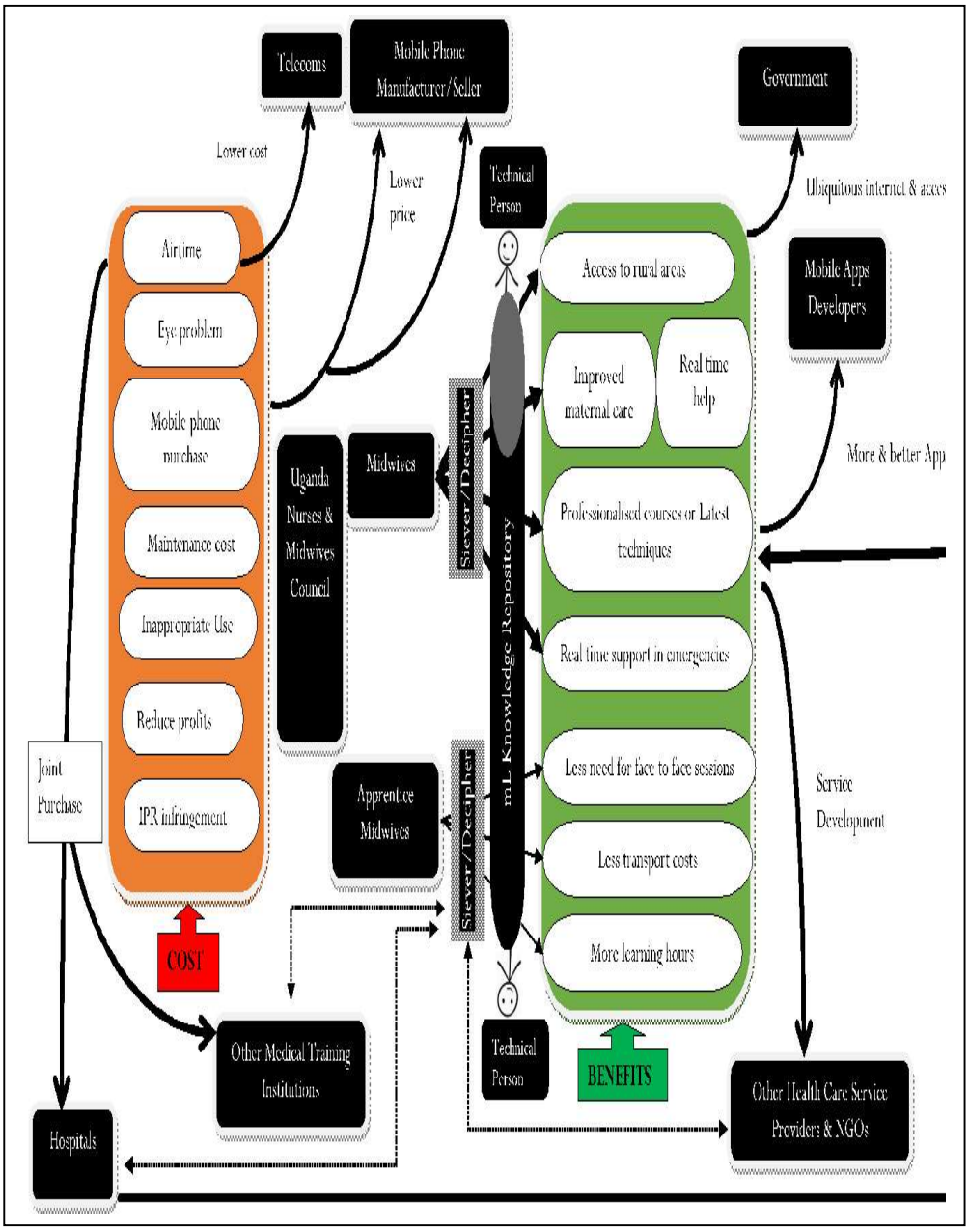
Experts A and T observed the absence of a clear mechanism for deciphering mLearning technical artifacts based on the training needs of midwives. Teaching and learning via a technology-mediated environment requires a cross re-examination of the learning strategies as well as the modes of delivery, Expert T clarified. This demanded a knowledge siever stakeholder/dimension. The siever is a quality assurance construct that safeguards quality and improves teaching and research standards. This quality assurance check will ensure the accuracy of the information as well as regulating the level of learning. In his words, Expert A said:

> *"…….. Well, you have proposed to motivate the people to generate the knowledge but this is Uganda. The process is likely to be abused as people may just generate knowledge for the sake of generating to get the incentive for writing but it may even be less relevant to the midwife. So it is important you think about who should control the knowledge entering the basket and not any Dick, Tom and Hurry to contribute what he/she wants …."*

While absence of a clear mechanism to decipher co-created and freely shared mLearning content undermines quality assurance, there is need to undertake re-examinations before any content can be stored into the repository. One way is through participatory co-creation and sharing between peers and experts. Experts indirectly control the quality of what goes into the repository, commented Expert R. Further, forth and back communications between the knowledge developers and the sievers can ensure mapping of such knowledge onto quality assurance requirements.

This notwithstanding, Expert A noted the absence of human resource development and maintenance of the mLearning environments. Technical personnel are necessary to develop, improve and maintain the mLearning knowledge repository and assist users. This requires a mLearning technical personnel dimension. Further, Experts A, B and R observed that Maina's proposed MLOIF4M had missed reporting on a key component of the knowledge artifacts repository, from which midwives can have real-time access to up-to-date techniques and professional knowledge.

Arising out of the above revelations, a revised Maina MLOIF4M framework should consist of 13 instead of ten (10) stakeholders/dimensions. The additional three (3) stakeholders/dimensions would include: a knowledge repository, a quality assurance mechanism and mLearning technical personnel. The validated framework is shown in *Figure 3* below.



Source: Field Data (2017)

Figure 3: The Validated Maina's Mobile Learning Open Innovation Framework for Midwives

The siever/decipherer

Many technical knowledge artifacts are generated in professional networks. Professional networks afforded by ICTs such as social media can encourage collaborative and cooperative working and sharing of information. Using mobile phones, the knowledge artifacts co-created and shared via a professional network can be deposited in a repository. However, before storage of such knowledge is guaranteed, it has to be quality assured so that the knowledge meets the midwives' expectations, matches with the strategic goals of the government, and fits into international standards, verifiable processes and outcomes. As a result, there are bound to be communications back and forth between the various knowledge developers and the sievers/decipherers.

The mLearning knowledge artifacts repository

This is a database of knowledge artifacts built in an open innovation approach. Here, midwives and other healthcare providers contribute variously to the database. The database can also be searched for different artifacts depending on the need or circumstance, as can be seen in the validated Maina's MLOIF4M.

The mLearning technical personnel

The absence of human resources for mLearning technical support can prohibit access to technical assistance by midwives. These personnel are responsible for the development of the mLearning system and its maintenance. In prior studies, Maina (2017) reported that even when the mLearning system existed, it was attributed invisibly to the insufficiency of highly trained ICT experts in managing health programs and institutions.

If the use and scaling up of mLearning in health programs is to be realized, health programs and institutions need to be made visible and supported by their own network support teams. The few available technical personnel need to be retooled in electronics and blended learning methodologies.

4.7 Conclusion

In this paper, two key concerns are espoused: an open innovation framework for effectively harnessing technical knowledge artifacts from different healthcare practitioners for improved efficiency of midwives using mobile devices and; validation of the same. Successful deployment and subsequent use of the MLOIF4M depends on the interplay between stakeholders in the mLearning ecosystem as well as validation of the framework. Validation is important to take care of any component(s) that would otherwise cause rejection among intended users, thereby increasing its usability.

Some of the stakeholders required to work hand in hand are: midwives themselves, apprentice midwives, the Uganda Nurses and Midwives Council, government, mobile app developers, hospitals, other healthcare service providers and NGOs. Midwives can take resources or ideas from their partners and execute them on their own. In light of the preventable maternal errors that have claimed the lives of mothers and their babies, it is clear that each of the stakeholders has a role to play in building a formidable force of professional midwives ready to apply recommended modern techniques.

If uncommon partners are to contribute meaningfully to mLearning open innovation, a clear and stable policy environment needs to be in place. Government needs to orchestrate this through its ministries, departments and agencies.

Government can also provide connectivity in rural areas where for-profit companies have no motivation to set up. Smartphone sellers can aid mLearning by selling smartphones at cheaper prices. NGOs can be helpful in funding the provision of smartphones or reducing the costs of the subscriptions. Mobile app developers develop apps that are contextualized with midwives' learning needs. Government can have a central role in reducing the prices of all mLearning goods and services by reducing/removing taxes on them. Hospitals, medical schools and other training institutions need to put in place the necessary infrastructure (including courses) and personnel to propel mLearning.

Both midwives and government were seen to be the dual lead partners, albeit the government was observed to have more influence than the midwives. Midwives use an Internet-connected smartphone to collaborate and interact with a range of other healthcare providers, such as physicians, nurses, pharmacists, laboratory technicians and Community Health Workers (CHWs). The maternal mortality challenge can be leveraged. On the other hand, for midwives to collaborate and interact with others for effective knowledge co-creation and sharing, government needs to: subsidize all mLearning goods and services through tax reductions and, where need be, totally scrap the taxes.

They also need to provide a mLearning policy environment by allowing phones in schools and onwards, improving connectivity, especially in rural areas where maternal mortality poses a bigger threat, and helping medical training institutions set up the necessary infrastructure, including courses and providing seed capital for personnel to propel mLearning

All in all, stakeholders need to collaborate in new ways with all relevant partners. Accordingly, validation results revealed that the framework should consist of 13 dimensions/stakeholders, namely: telecoms, hospitals, government, other medical training institutions, mLearning technical personnel, an mL knowledge artifacts repository, a decipherer/siever, other healthcare service providers and NGOs, mobile app developers, mobile phone manufacturers/sellers, apprentice midwives, practicing midwives and their regulator, the Uganda Nurses and Midwives Council.

Appendix 2: Interview Guide for Validating the MLOIF4M

PROJECT TITLE: Mobile Learning as an Innovative Strategy for upgrading Technical skills in developing countries: A case study of mobile learning for midwives in Uganda

Dear Sir/Madam/Dr/Prof

Re: Validation of a Proposed Framework for effectively skilling midwives using mLearning Open Innovation approach

My name is Charles Maina Mungai, a PhD student at Hasselt University, Belgium. One of my outputs is an effective mobile learning (mLearning) open innovation framework for midwives - ***MLOIF4M***. The framework will be vital for contributing to the reduction of high preventable maternal deaths that emanate from short supply of health workers and low levels of knowledge and skills. Their knowledge and skills can be improved without necessarily drawing them from their current work stations.

MLOIF4M is an ecosystem with ten (10) dimensions (stakeholders). These include: telecoms, other healthcare service providers and NGOs, mobile phone sellers, government, mobile app developers, midwives, apprentice midwives, the Uganda Nurses and Midwives Council, hospitals and other medical training institutions.

The validity of this framework has to be measured so as to confirm whether it can be an effective tool for up-skilling midwives. The framework is herewith attached (Figure 2 attached).

As one of the experts in e-learning, blended learning, mLearning, distance education/learning, information systems and IT among others, you have purposively been identified to participate in this exercise so as to help me undertake the validation of my framework. I kindly request you to spare a few minutes for me in this regard. All the responses will be for academic purposes and will remain confidential.

Yours sincerely,

Charles Maina M.
PhD (Open Innovation) Student
Hasselt University

Please see the attached MLOIF4M framework, in which a number of stakeholders have to collaborate and cooperate so as to support midwives gain more knowledge and skills using the mLearning open innovation approach.

From my explanation of the framework,

1. **You are requested to indicate (in table below) your level of agreement if a given stakeholder should be part of the framework (***Tick only one option for each stakeholder).*

Stakeholder (Construct)	**Level of Agreement of stakeholder**				If you wish, please give support for your view
	Strongly Disagree	Disagree	Agree	Strongly Agree	
Telecoms					
Other healthcare service providers and NGOs					
Mobile phone sellers					
Government					
Mobile app developers					
Practicing midwives					
Apprentice (in-service) midwives					
Uganda Nurses and Midwives Council					
Hospitals					
Other medical training institutions					

2. **Further, indicate whether you agree with the entire framework as being an effective framework of supporting continuous professional development for midwives** *(Tick only one option)*

1	I agree that the entire framework is effective	
2	I do not agree	

3. Kindly provide any further support for your opinion in question number 2 above

……
……
……
……

4. In your opinion, who should take lead amongst the stakeholders in the MLOIF4M?

……
……
……
……

I thank you very much for your time

CHAPTER FIVE

5.1 Generalized Conclusion

The aim of this research was to develop a mobile learning open innovation framework to effectively provide healthcare technical skills to midwives with the intention of reducing the maternal mortality burden. Using a mobile device, midwives can efficiently harness technical knowledge artifacts from different healthcare practitioners. The output of this research is a validated mLearning open innovation framework for midwives (MLOIF4M), purposed to enable midwives to effectively harness technical knowledge artifacts from other healthcare providers through a smartphone connected to the Internet. The MLOIF4M spells out the need for hybrid partnerships ranging from inbound, outbound and a mixture of in- and outbound interactions if midwives are to significantly develop and broaden innovations in the health sector. The ten (10) stakeholders established by the MLOIF4M are: practicing midwives, apprentice midwives, their umbrella organization of the Uganda Nurses and Midwives Council, telecoms, hospitals, other medical training institutions, other healthcare service providers and NGOs, mobile app developers, government and smartphone sellers/manufacturers.

The chapter is organized as follows: *Section 5.1.1* gives the technical knowledge artifacts that could be extended to midwives through mLearning using an open innovation approach, while *Section 5.1.2* presents the cost-benefit implications for delivering the mLearning technical knowledge artifacts in *Section 5.1.1* above. In *Section 5.1.3*, the mLearning Open Innovation Framework for Midwives (MLOIF4M) is presented, and lastly, *Section 5.2* provides areas for future research.

5.1.1 Technical knowledge artifacts extendable to midwives through mLearning using an open innovation approach

mLearning as an open innovative strategy has been lauded by midwives due to its potential to provide up-to-date and quick access to information. This state of affairs is in tandem with Uganda's midwifery age structure, which is comprised of relatively young people. Among the young, the desire for social life is great, and there is potential for further training and a high affinity for emerging digital technologies, especially mobile devices as yet less widely experienced professionally. As such, midwives can tap into the expertise and knowledge of specialists who may not be co-located using mobile devices with mixed media affordances. The artifacts identified are: medical literature from books, the Internet and others, medical training simulations, patient diagnostic pictures, support on medical literature from tutors or senior medical officers, dosage administration, day-to-day patient support and real-time patient diagnostic support. However, in order to successfully widen this scope of knowledge to midwives in their workplaces or training institutions in an up-to-date and real-time fashion, the electronic knowledge artifacts should be those that supplement or help midwives to understand the paper-based content. Further, there is a need for great sensitization/awareness and training on mLearning as well as the provision of factors necessary for aiding free access to knowledge artifacts amongst midwives using mLearning in an open innovation approach. Such factors include: a stable hydropower supply, a good mobile network and Internet connectivity, smart mobile phones, policies permitting mLearning in health facilities, mLearning as a supplementary delivery channel to paper-based content and other subsidies of mLearning costs.

5.1.2 Cost-benefit implication of mLearning among midwives using the open innovation approach

Moving from traditional/conventional learning to mLearning or a combination of these two forms of learning can prove costly. This is because it involves a number of stakeholders, thereby making the process of turning it into effective action lengthy and rather expensive in both monetary and nonmonetary terms. While some costs of mLearning innovations are easily quantifiable, others are not. Also, attaching monetary (dollar) values to benefits of mLearning was not tenable as human life is regarded as a "nonmarket good," suggesting that its costs and benefits could best be evaluated in terms of how society members can be happy because of the saving of mothers and their newborns.

Investment in mLearning for midwives is associated with both prohibitive and non-prohibitive costs, with the former necessitating policy directions including, but not limited to, subsidies and/or cost-sharing options from government ministries, departments and agencies. Non-prohibitive costs are within the capability of stakeholders at any given level of action and will therefore necessitate commitment. Some of the costs experienced by midwives include: the cost of smartphones, the cost of airtime, the costs of Internet data, inappropriate use of smartphones on the ward, poor bandwidth and strain on the eyes due to limited screen and keyboard sizes.

As pointed out in the literature, the Ugandan market continues to be flooded with relatively cheaper Chinese smartphones, which, over time, are coming to fit within the means of midwives. Further still, smartphones are increasingly being used to deliver valuable training information on products and services to customers, strategic partners and third-party vendors.

Over time, as several mLearning costs go down, more value for mLearning is bound to be attained in terms of co-development of quality content and making it freely available to access through smartphones. As a result, midwives can reduce the preventable medical errors that mothers experience while in, and/or during, labor as they benefit through: real-time access to patient diagnostic support, real-time day-to-day patient care/support and real-time access to dosage administration procedures. They also get real-time access to continuous professional development, Internet access, the creation of a community of practice among midwives, subsidies from telecoms, subsidies from NGOs and open-access licenses for mLearning apps, among others.

All in all, the success of an open innovation based on mLearning depends on mitigating the costs in the short and long run while maximizing the benefits of mLearning. Such a reduction in mLearning costs can be through judicious use of smartphones to fast-track key policy recommendations (prohibitive costs) on the part of government. This will imply low per capita mLearning costs as benefits to midwives are kept as high as possible.

5.1.3 The MLOIF4M

In order for the MLOIF4M to be active in its envisaged role of providing high-quality maternal care to mothers and their unborn and newly born babies while holding other factors constant (assuming an active existence of the orchestrated invisible hand of the lead player, the government), there is a need to recognize and strengthen each stakeholder's reason for existence. Prominent and non-prominent stakeholders must contribute to the facilitation of the co-creation and sharing of technical knowledge artifacts between midwives and other healthcare practitioners so as to reduce the number of preventable maternal errors.

Through a mLearning technical repository, midwives can take advantage of support from fellow midwives, nurses, doctors and laboratory technicians, among others, whose roles are critical in providing high-quality maternal care.

In order to minimize the rejection of the usability of the MLOIF4M, a 13stakeholder-validated framework was suggested. Successful deployment of the MLOIF4M rests entirely on the interplay between the 13 stakeholders of: telecoms, hospitals, government, other medical training institutions, mLearning technical personnel, the mL knowledge artifacts repository, a decipherer/siever, other healthcare service providers and NGOs, mobile app developers, mobile phone manufacturers/sellers, apprentice midwives, practicing midwives and their regulator, the Uganda Nurses and Midwives Council.

5.2 Directions for further research

Despite the richness of the data, the analysis is restricted to midwives alone. It would be beneficial to encompass other strings of healthcare service providers who are in short supply to get a feel of their attitude towards invoking mLearning as an open innovative strategy to share the scarce resources in their possession.

The stakeholder relationship with other stakeholders at micro levels deserves more attention. Open innovation is bound to succeed in environments where the quality and experience of individuals is unidirectional (somehow points in the same direction). Levels of individual openness for each stakeholder may differ, necessitating further scrutiny to allow an effective MLOIF4M. The usability of the MLOIF4M was only tested using domain expert evaluation. Future work needs to involve a complete mobile learning open innovation environment supported by the MLOIF4M.

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