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Innovative Continuing Education for Maternal and Newborn Health Workers in Low-and Middle-Income Countries: A Feasibility Study

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Abstract

Purpose

The purpose of this dissertation is to explore strategies to improve maternal and newborn health workers' clinical competence and performance, particularly among nurses and midwives, in low-and middle-income countries (LMICs), through innovative continuing educational approaches using priority evidence-based content. A feasibility trial with one such learning approach was implemented with maternal and newborn health providers in a hard-to-reach setting of the Democratic Republic of the Congo (DRC) in order to test one possible response to the continued high maternal and neonatal mortality in that country. The study contributes to the knowledge base on provision of critical continuing education to maternal and newborn health workers in hard-to-reach settings and to the global effort underway to address excess maternal and neonatal mortality in LMICs.

Problems/Aims

Health worker clinical performance is often inadequate in developing countries. Sub-standard delivery and emergency obstetric care (EmOC) in health facilities has been widely documented as a major cause of maternal mortality in health facilities globally. Similarly, studies show that quality gaps are leading to higher rates of neonatal mortality in facility births. A basic strategy for improving health worker practice and strengthening clinical performance is through the promotion of continuing education (CE). However, there are many challenges to organizing CE opportunities for healthcare workers in hard-to-reach LMIC settings.

The aims of this research were 1) to explore potential approaches to continuing education for maternal and newborn health workers in LMICs by examining the

approaches that are currently available worldwide and 2) evaluating one concrete approach using a mobile phone mLearning app. We examined the feasibility and acceptability of the use of mLearning with facility-based maternal and neonatal health workers in one hard-to-reach setting of the DRC. We also evaluated the use of mLearning for a preliminary impact on facility-based health worker Basic Emergency Obstetric & Neonatal Care (BEmONC) self-confidence and clinical knowledge, and on select maternal and newborn outcome trends (as a proxy for evaluating improved health worker clinical behavior/performance). We also sought to refine intervention delivery in the DRC and strengthen study procedures required to conduct a robust future large-scale trial.

Design including theoretical basis

This study design is comprised of two literature reviews on the topic and a feasibility study using a convergent parallel mixed methods and community-engaged pilot cluster-randomized trial design. Our theoretical basis is comprised of complementary theoretical approaches: (1) Benjamin Bloom's Theory of Mastery-Learning and Taxonomy of Educational Objectives; (2) Kirkpatrick's Model of training evaluation; and (3) The Theoretical Domains Framework (TDF).

Findings:

Our literature reviews on CE approaches for facility-based maternal and newborn health workers in low-income countries revealed that conventional and simulation training using varied teaching methodologies can improve provider knowledge, skills, clinical practice, and patient outcomes. However, results are variable and there is limited evidence overall, with minimal use of robust study designs and validated measurement instruments, that document the association between CE and long-term

effectiveness of the interventions with improved patient outcomes. Other creative interventions are being piloted in eHealth / eLearning including mobile phone learning applications (mLearning) and these have shown encouraging results in overcoming some key challenges in providing health workers with evidence-based learning in more remote settings. mLearning was found to be feasible and acceptable to health workers and key stakeholders in the DRC. A trial of one recent mLearning evidence-based app, the Safe Delivery App, increased health worker knowledge and self-confidence on the management of obstetric and newborn emergencies 3 months after introduction and indicated preliminary encouraging impacts on health workers' practices in BEmONC.

Conclusion:

eLearning and mLearning show promise for improving maternal and newborn health worker practice and reducing mortality in low-and middle-income countries, particularly for health workers in more remote settings, where the challenge of maternal and neonatal mortality and quality assurance of emergency obstetric and neonatal care is greatest. Factors such as health worker motivation and self-efficacy, as well as the physical and policy environment, emphasized by Bloom and the TDF, are essential in improving practice and should be considered, along with cost, in designing scalable and comprehensive maternal and neonatal mortality programs for improved outcomes.

Keywords: continuing education, training, mLearning, simulation, maternal health, maternal mortality, newborn health, newborn mortality, health workers, nurses, midwives, Africa, DR Congo, Theoretical Domains Framework

Introduction

Overview

The purpose of this dissertation is to explore strategies to improve maternal and newborn health workers' clinical competence and performance, particularly among nurses and midwives, in low-and middle-income countries (LMICs), through the use of innovative continuing educational approaches using priority evidence-based content.

The research explores how to make priority up-to-date clinical information and guidelines available to the health workers who need these most, in hard-to-reach settings where maternal and newborn mortality are highest. It also explores how, through continuing education, to effectively influence factors that promote provider behavior change, resulting in improved care and improved patient outcomes.

A trial with one such learning approach was tested with maternal and newborn health providers in a hard-to-reach setting of the Democratic Republic of the Congo (DRC). This study evaluated eLearning and mLearning as potential methods to educate health providers related to the continued high maternal and neonatal mortality in that country. The study adds an understanding on how to better provide critical continuing education (CE) to maternal and newborn health workers in hard-to-reach settings, and contributes to the global effort underway to reduce excess maternal and neonatal mortality in LMICs. The research also seeks to render more effective the use of limited resources dedicated to CE as part of maternal and newborn mortality reduction and health systems strengthening efforts.

Background & Problem Statement

1. Disparities

The greatest test of health system function is the ability to provide timely care at birth (1). The reality is that worldwide, approximately 830 women die daily from preventable causes related to pregnancy and childbirth (2). Newborn deaths are closely linked to maternal deaths; almost 2 million newborn babies die in the first week of life every year (3). LMICs accounted for approximately 99% (302,000) of global maternal deaths in 2015, with sub-Saharan Africa alone accounting for about 66% of deaths (201,000), followed by Southern Asia (66,000) (4). A woman's lifetime risk of maternal death (the probability that a 15-year-old woman will eventually die from a maternal cause) is estimated at 1 in 3300 in high-income countries, compared with 1 in 41 in low-income countries (4).

The DRC, the largest country in sub-Saharan Africa, has one of the highest maternal mortality ratios in Africa (846 maternal deaths per 100,000 live births)(5). A woman's lifetime risk of maternal death is estimated to be 1 in 24 in the DRC (4). Neonatal deaths are high at an estimated 30 neonatal deaths (before 28 days of life) per 1,000 live births (3). Disparities in maternal and child health outcomes largely reflect inequalities in access to quality health services (2).

2. Quality of Care

The global shortage of health providers plays a disproportionately important role by affecting primarily low-income countries, notably, Sub-Saharan Africa, which suffers from 25% of the global burden of disease, yet is served by only 4% of the global health workforce (6). Additionally, health worker performance is often inadequate (7-8) resulting in relatively low quality of care (9). Health systems widely

fail to provide safe delivery and newborn care because the quality of care is severely deficient or absent and the available maternal and newborn health providers often lack the requisite skills to deliver evidence-based care (10).

In recent studies, nurses and midwives working in maternal health in LMICs demonstrated low knowledge levels of emergency obstetric and newborn care (EmONC) (despite varying years of provider experience)(11-12), and poor clinical management skills of post-partum hemorrhage (PPH)(13-14). This is of critical importance because PPH is the leading cause of maternal mortality worldwide (15). Low knowledge and confidence in essential newborn care skills have also been documented among neonatal providers (16-17). For babies born in hospitals in South Asia and Africa, staff members are frequently not trained in basic neonatal resuscitation (NR) and equipment is not available (18). Both PPH and NR management are among the seven "signal functions" of Basic EmONC (BEmONC), or key medical interventions that should be provided by all skilled birth attendants if required (10). Deficits in health worker knowledge and skills are linked to suboptimal patient outcomes in many low-resource settings (6,19-20). More specifically, sub-standard delivery and emergency obstetric care (EmOC) has been widely documented as a major cause of maternal mortality in health facilities globally (14). Similarly, studies show that quality gaps are leading to higher rates of neonatal mortality in facility births (16).

These findings are congruent with earlier literature documenting the variable quality of pre-service (basic / pre-licensure) nursing and midwifery education programs in certain countries (21). Variable pre-service educational quality, coupled with a frequent lack of opportunities for CE in LMICs (11, 22) and lack of access to

up-to-date information for self-directed learning (23) result in an “outreach gap”(24). This gap equates with a disparity in the quality of care, wherein health care workers, particularly in peripheral facilities and hard-to-reach areas, are not properly trained to manage obstetric and newborn emergencies (10). Additionally, in low volume settings, emergencies do not occur sufficiently often for providers to become experienced in obstetric and neonatal complication management (25). Improving the quality of care is one method of improving patient health outcomes (22).

3. Importance of CE

WHO suggests that developing capable, motivated, and supported health workers is essential to achieving national and global health goals and noted that the availability of competent health workers is positively associated with maternal survival (26). Nurses and midwives often comprise the largest percentage of national health workforces worldwide and are crucial to strengthening health systems and achieving improved maternal and child health (27-28). The increasing complexity of clinical practice and rapid changes in information and technology make it critically important for nurses and midwives, and all health workers, to retain competency by continuing to learn and develop throughout their careers (29). Enhancing the clinical performance of these cadres is clearly critical to maintaining a quality workforce (27).

A basic strategy for changing health worker behavior and strengthening clinical performance is promoting CE (26), although education alone on evidence-based practice is often insufficient to change behavior (30). However, for many health workers access to relevant up-to-date learning opportunities is difficult or impossible to obtain for a variety of reasons (22), especially in peripheral health facilities, which are generally difficult to reach with conventional training programs. Challenges are

particularly acute for clinicians working in rural and remote areas since there is professional isolation, inadequate communication with peers in the cities, and a lack of appropriate equipment and technologies (31).

CE has also been demonstrated to be a motivating factor for professionals in resource-poor settings (32-33). Health sector performance is critically dependent on worker motivation, with service quality directly mediated by workers' willingness to apply themselves to their tasks (34). Low levels of health worker motivation has been identified as an often-neglected problem and challenge (32), whereas higher levels of motivation have been found to be an important driver for health professionals to maintain their professional competence and continue in the workforce (33, 35).

4. Role of innovative approaches

In terms of approaches and effectiveness of CE, previous literature has documented that dissemination of written guidelines without an additional educational intervention was generally ineffective (7). Additionally, the predominant CE model found in many developing countries of large brief didactic trainings, which are typically centralized at the district or capital city and incentivized by per diem payments, with limited post-training supervision, often have unclear impact on practice (6, 36). Development partners/donors spend large amounts of funding to train health workers to address high priority health problems such as maternal mortality, yet it is unclear whether the training and approaches that are in use are effective, given that key maternal mortality indicators remain high. Training courses have demonstrated effectiveness to improve quality of care and health outcomes, but barriers prevent access by most rural health care workers (10).

Given the challenges of organizing CE opportunities for health workers in hard-to-reach LMIC settings, the use of innovative approaches, such as technology and mobile hand-held electronic devices (phones and tablets), holds promise for new mechanisms to reach these workers with up-to-date information (24). The availability and use of mobile phones is increasing rapidly in LMICs (37), as is learning via mobile devices, referred to as mLearning. The feasibility of mLearning has grown as earlier barriers of bandwidth and the cost of Internet access are falling (38). mHealth and mLearning, which have been linked to expanding mobile phone penetration in LMICs, provide important opportunities for the delivery of health information and services to remote locations, expanding access by remote health workers to current evidence-based learning in order to improve clinical decision-making and management of patients (38-39).

Gaps in knowledge

A number of gaps in knowledge related to this topic were identified during the course of the research:

a. In general, published research on CE among nurses and midwives in developing country settings is limited (9, 28, 38). Some valuable studies exist on the topic, as suggested in the literature reviews that comprise this compendium. However, the effectiveness of CE to positively impact patient outcomes is insufficiently researched in LMICs globally (22, 38). Additionally, the evaluation of effectiveness of CE is also often hampered by inadequate study design and the use of non-validated measurement instruments [40]. Few studies look at longer-term follow-up, as well as cost, in terms of assuring sustainability [40]. Additionally, there is a dearth of studies focused on eLearning, mLearning or other technology-based interventions for

maternal and newborn health workers in LMIC's; in particular, research and evidence on their efficacy and effectiveness are scarce (38-39, 41-44).

b. There is a gap in the literature on how to address the "outreach gap", or how to make CE more accessible both geographically and financially. The term "outreach gap" describes challenges to the quality of emergency obstetric care wherein most deliveries and emergencies in health care facilities take place in hard-to-reach areas, where health care workers often are not properly trained to manage the complexity of obstetric emergencies (10). The lack of access for health workers to CE opportunities and to scientific information for self-directed learning is particularly acute in hard-to-reach settings (11,22) where maternal and newborn mortality are highest (23). Given the high costs and logistical challenges of in-person, conventional CE training programs in LMICs, the healthcare workers who most need support are often the least likely to receive it. Nilsson et al. (24) noted that this "outreach gap" affects the quality of delivery care in sub-Saharan Africa.

Design and method

Given the continued high maternal and newborn mortality in many LMICs and in the DRC, and the limited CE opportunities for nurses and midwives in hard-to-reach settings, this research highlights approaches that warrant further attention including approaches utilizing technology, to bridge the "outreach gap" (24).

This dissertation research is comprised of two literature reviews on the topic of CE for maternal and newborn health workers, as well as a pilot intervention delivery and feasibility study conducted in the DRC. The two literature reviews and the pilot feasibility study are described respectively in the three manuscripts that comprise this dissertation. In our original research, we used convergent parallel mixed methods

design to explore the perspective of health leaders and practicing providers in the DRC on current and future approaches for CE, including mLearning. Simultaneously, we conducted a pilot trial using a cluster-randomized approach, to determine the feasibility, acceptability, and potential impact of a recently developed evidence-based mLearning training tool (Safe Delivery App)(SDA)(25) on knowledge, self-confidence, and practice of facility-based health workers in maternal and newborn health in the DRC.

The SDA reflects current global guidelines for Basic Emergency Obstetric & Neonatal Care (BEmONC) (25). The app allows for training of health providers, as well as use of the app as an on-site job aide, thus reinforcing health worker learning and contributing to the retention of essential maternal and newborn care competencies.

This pilot feasibility study aimed specifically to: (a) evaluate the feasibility and acceptability of adding the SDA to usual CE training approaches widely used in the DRC; (b) determine stakeholder perspectives related to the feasibility and acceptability of mLearning and other CE approaches, and (c) evaluate the mLearning intervention for a preliminary impact on health worker Basic Emergency Obstetric & Neonatal Care (BEmONC) self-confidence and clinical knowledge, select clinical behaviors, and on select maternal and newborn outcome trends (as a proxy for evaluating improved health worker clinical behavior/performance). We also sought to refine intervention delivery in the DRC and strengthen study procedures required to conduct a robust future large-scale trial.

Key concepts/terms

In this compendium we address certain key concepts that warrant definition and clarification:

1. We have stated that health worker clinical performance is often inadequate in developing countries (7) and that with this research we purport to strengthen clinical performance and competence. Health worker *performance* is adherence to an accepted standard or guideline (7). *Competence* is closely linked to level of performance (45) and is a critical component of performance (26). Specifically, competence is defined as the combination of knowledge plus psychomotor, communication, and decision-making skills that enable an individual to perform a specific task to a defined level of performance; *competencies* delineate such skills and professional behaviors (21).

2. *Continuing education* is defined as a "systematic, ongoing, cyclical process of learning" for individuals; it is noted to be a cornerstone of continued fitness to practice and is closely connected to the quality of care and to patient safety (26). *Continuing professional development* (CPD) is the link between learning and professional development wherein health professions are to be able to monitor the attainment and maintenance of essential competencies, and mastery of emerging competencies needed (46).

3. In terms of learning modalities, we explore a number of approaches that warrant clarification.

a. *eHealth* is defined as the transfer of health resources and health care by electronic means using information and communication technology (ICT) and *eLearning* is learning via the same means (47). The use of mobile phone devices to improve health system functions is termed *mHealth* (38) and learning via mobile devices is referred to as *mLearning* (47).

b. *Clinical mentoring* embraces a collaborative approach focused on clinical teaching and coaching during the provision of care to increase the provider's practical

knowledge, confidence, and adherence to guidelines (48).

4. The World Bank currently defines a “low-income” country as a country with gross national income (GNI) per capita of $1025.00 or less; “lower middle-income economies” are those with a GNI per capita between $1,026 and $4,035 (49). There are 31 and 53 such countries listed respectively in the World Bank’s 2018 fiscal year country classification. Until recently, the World Bank classified countries as “developing” and “developed” and many institutions continue to use that nomenclature or variations on those terms.

5. Throughout the dissertation we refer to “motivation” which we define in the work context as an individual’s degree of willingness to exert an effort towards organizational goals (34).

6. “Early neonatal deaths” are those that occur in the first week of life, “neonatal deaths” occur in the first 28 days of life, and “perinatal deaths” are comprised of early neonatal deaths and stillbirths (50).

7. “Signal functions” are key medical interventions that are used to treat the direct obstetric and newborn complications that cause the vast majority of maternal and neonatal deaths around the globe. There are 7 signal functions for BEmONC and 2 additional for Comprehensive EmONC (CEmONC) (51).

8. To measure maternal mortality, normally the “Maternal mortality ratio” is used, which is the number of maternal death per 100,000 live births. A “Maternal death” is the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes (52).

Description and use of theory

In this research we use a mix of three complementary theoretical approaches:

1. The integrative literature review utilizes Benjamin Bloom's Theory of Mastery-Learning and Taxonomy of Educational Objectives (53) as the conceptual framework for evaluating CE approaches for maternal health providers. When analyzing the available literature regarding CE interventions, the lens of Bloom's Taxonomy was applied to identify which of Bloom's domains were reflected in the pedagogical approaches of the various CE initiatives examined. Bloom posits that there are three "domains" of educational/learning objectives or outcomes (54): (1) Cognitive: mental skills (*knowledge*); (2) Affective: feelings or emotional areas (*attitude, motivation, self-efficacy*); and (3) Psychomotor: manual or physical skills (*skills*). The three domains classify intended changes or behaviors produced in leaners as a result of educational interventions. As such, the intended changes are not represented by choice of educational content, but rather by the stated objectives of an educational intervention. Learning objectives suggest instructional approaches, learner assessment strategies, and whether the educational intervention aligns with outcome expectancies (55). Bloom notes that the three domains are constantly interacting with each other and balance between the three is ideal in an educational situation (56).

2. Both literature reviews consider the training evaluation model created by Dr. Don Kirkpatrick to organize results and evaluate training program impact (57). Kirkpatrick's widely used model guides evaluation of training across four levels: (1) Reaction (evaluates how participants assess the training), (2) Learning (measures if participants acquired knowledge, learned skills, or changed attitudes), (3) Behavior

(considers if they are using what they learned at the training on the job), and (4) Results (evaluates if the training positively impacted the organization and/or patient outcomes). Kirkpatrick notes that training evaluation becomes more meaningful as it progresses from levels one to four, with outcome data as the highest level of evidence of training. He posits that ideally, all four levels of any training should be evaluated (40, 57).

3. The Theoretical Domains Framework (TDF) was used to guide the research in the DRC. The TDF positions health professional behavior change as key to increasing the uptake of evidence into healthcare practice (58). The initial aim of the TDF was to simplify and integrate a number of behavior change theories (59) to provide a theoretical lens through which to view the cognitive, affective, social and environmental influences on provider behavior (60). Explanatory constructs from 33 theories of behavior change were reduced and grouped into 14 'theoretical construct domains'; each of which consists of a grouping of theoretical constructs, which are proposed as potential mediators of behavior change (60). The domains each consist of a grouping of theoretical constructs and the domains can be condensed into three core components: capability, opportunity and motivation (61). The TDF provides a useful conceptual basis for assessing implementation problems of evidence-based care and understanding provider behavior-change processes (58). In this research, the TDF influenced the design of interview guides to explore the specific content of these domains in relation to barriers and facilitators with the use of the SDA, mLearning, and CE implementation in the DRC. The TDF was also used as the coding framework for analysis. [**Table 1**: TDF domains and constructs (60).]

Brief description of 3 manuscripts

1. **Manuscript 1**: The purpose of this integrative review was to synthesize and critique the literature on continuing education approaches, content, and effectiveness in LMICs with a particular focus on nurses and midwives and on improving maternal healthcare. The review uses the approach outlined by Whittemore and Knafl, which allows for the simultaneous inclusion of experimental and non-experimental research to gain a greater understanding of a phenomenon of concern (62). This approach prescribes a 5-stage process: (1) problem identification, (2) literature search, (3) data evaluation, (4) data analysis, and (5) presentation. The review uses Bloom's Theory of Mastery-Learning and Taxonomy of Educational Objectives as a framework for analysis (53-55). Additionally, the Kirkpatrick Model is used to consider training program evaluation (57)**.**

2. **Manuscript 2**: The second manuscript is a Scoping Review that synthesizes and critiques the literature on technology-based newborn health learning initiatives for health workers in LMICs, with an emphasis on nurses and midwives. The review was conducted according to the methodological approach outlined by Arksey and O'Malley (63) that utilizes a 5-stage process: (1) identifying the research question, (2) identifying relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing and reporting the results. Kirkpatrick's model for the evaluation of training programs (57) is used as the guiding framework to consider the various training initiatives.

3. **Manuscript 3**: The third manuscript describes research carried out in the Democratic Republic of the Congo (DRC) from April - July 2017 which sought to

determine the feasibility, acceptability, and potential effect of the Safe Delivery App (SDA)(25) on health workers' practices in emergency obstetric and newborn care (EmONC) in the DRC. In this cluster-randomized and mixed methods pilot trial in 2 health zones of central DRC, 8 EmONC facilities were randomized to an mLearning intervention or to standard practice (control). Knowledge in PPH and NR, and provider self-confidence, were assessed at baseline and at 3 months after the intervention among 62 maternal and newborn health care workers at the included facilities. We also conducted 18 interviews with app users and key stakeholders to assess feasibility and acceptability of mLearning and the use of the Safe Delivery App. Maternal mortality was compared pre-and-post intervention in intervention and control facilities using a smartphone-based Open Data Kit (ODK) data application. The Theoretical Domains Framework (TDF)(58-60) guided this study. Quantitative and qualitative data were interpreted and merged together, noting both the quantitative statistical results and qualitative quotes or themes that supported or refuted the quantitative results.

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Table 1: The Theoretical Domains Framework with definitions and constructs

Domain	Construct	Domain (cont'd)	Construct
1. Knowledge (An awareness of the existence of something)	Knowledge (including knowledge of condition/ scientific rationale) Procedural knowledge	**8. Intentions** (A conscious decision to perform a behavior or a resolve to act in a certain way)	Stability of intentions Stages of change model Transtheoretical model / Stages of change
2. Skills (An ability or proficiency acquired through practice)	Skills Skills development Competence Ability Interpersonal skills Practice Skill assessment	**9. Goals** (Mental representations of outcomes or end states that an individual wants to achieve)	Goals (distal/proximal) Goal priority Goal/target setting Goals Action planning Implementation intention
3. Social/ professional role and identity (A coherent set of behaviors and displayed personal qualities of an individual in a social or work setting)	Professional identity Professional role Social identity Professional boundaries Professional confidence Group identity Leadership Organizational commitment	**10. Memory, attention and decision processes** (The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives)	Memory Attention Attention control Decision making Cognitive overload/ tiredness
4. Beliefs about capabilities (Acceptance of the truth, reality or validity about an ability, or talent that a person can put to constructive use)	Self-confidence Perceived competence Self-efficacy Perceived behavioral control Beliefs Self-esteem Empowerment Professional confidence	**11. Environmental context and resources** (Circumstance of a person's situation or environment that discourages or encourages the development of skills / abilities, independence, and adaptive behavior)	Environmental stressors Resources/material resources Organizational culture/climate Salient events/critical incidents Person X environment interaction Barriers and facilitators
5. Optimism (The confidence that things will happen for the best or that desired goals will be attained)	Optimism Pessimism Unrealistic optimism Identity	**12. Social influences** (Interpersonal processes that can cause individuals to change their thoughts, feelings or behaviors)	Social pressure Social / group norms Group conformity Social support Power Group identity Modeling
6. Beliefs about Consequences (Acceptance of the truth, reality, or validity about outcomes of a behavior in a given situation)	Beliefs Outcome expectancies Characteristics of outcome expectancies Anticipated regret Consequents	**13. Emotion** (A complex reaction, involving experiential, behavioral, physiological elements, by which the individual	Fear Anxiety Affect Stress Depression Positive/negative affect Burn-out

		attempts to deal with a personally significant matter /event)	
7. Reinforcement (Increasing the probability of a response by arranging a dependent relationship, between the response and a given stimulus)	Rewards Incentives Punishment Consequents Reinforcement Contingencies Sanctions	14. Behavioural regulation (Anything aimed at managing or changing objectively observed or measured actions)	Self-monitoring Breaking habit Action planning

Continuing Education in Maternal Health for Nurses and Midwives In Low-and-Middle-Income Countries: An Integrative Review of Approaches, Content, and Effectiveness

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Abstract

Background: Sub-standard delivery care has been widely documented as a major cause of maternal mortality in health facilities globally. Improving nurses' and midwives' care competency through continuing education is key to improving patient outcomes, however, the effectiveness of continuing education to increase knowledge and skills, motivate health workers, and positively affect patient outcomes is poorly researched in low-and-middle-income countries (LMICs). Additionally, access by health workers to relevant up-to-date learning opportunities is often difficult to obtain. This review synthesized and critiqued the literature on continuing education approaches, content, and effectiveness with a particular focus on nurses and midwives in LMICs and on improving maternal healthcare.

Methods: The approach utilized in this integrative review prescribes a 5-stage process: (1) problem identification, (2) literature search, (3) data evaluation, (4) data analysis, and (5) presentation. A literature review was conducted from multiple databases including PubMed, EBSCO Host Platform, SCOPUS and POPLINE. Articles selected for analysis consisted of studies published in peer-reviewed journals over the last ten years, from 2007 - 2017. Bloom's Theory of Mastery-Learning and Taxonomy of Educational Objectives was used as a framework for analysis of CE approaches. The Kirkpatrick Model was used to evaluate training programs**.**

Results: Fifteen studies were identified, grouped into three approaches: (1) short training courses; (2) longer-term educational interventions; and (3) eHealth. Conventional trainings using varied teaching methodologies can improve provider

knowledge, skills, clinical behavior or practice, and patient outcomes, however, there is limited evidence using robust study designs linking CE to long-term improved patient outcomes. Other creative interventions were piloted in eHealth and guideline adaptation that showed positive results and were motivating for participants.

Conclusion: eHealth and other creative approaches to continuing education hold promise for engaging health professionals, including in remote areas, where maternal and newborn mortality are the highest. Approaches with high priority content and demonstrated effectiveness must be tested using rigorous research methods and validated measurement instruments to determine long-term effectiveness on patient outcomes and to evaluate feasibility and cost-effectiveness in different contexts and priority areas.

Keywords: education, training, professional development, nurses, midwives, maternal, obstetric, low-and-middle-income countries

Background

Worldwide, approximately 830 women die daily from preventable causes related to pregnancy and childbirth [1-3]. The World Health Organization (WHO) [4] identified the development of capable, motivated, and supported health workers as essential to achieving national and global health goals and noted that the availability of competent health workers is positively associated with maternal survival. In reality, there is a global shortage of health providers, notably, Sub-Saharan Africa suffers from 25% of the global burden of disease, yet is served by only 4% of the global health workforce [5]. Additionally, health worker performance is often inadequate [6, 7] and deficits in health worker knowledge and skills have been reported to negatively impact patient care [5-9]. Sub-standard delivery and emergency obstetric care (EmOC) has been widely documented as a major cause of maternal mortality in health facilities globally [10], and post-partum hemorrhage (PPH), which is largely preventable and treatable through established interventions, is the number one cause of maternal death worldwide [3].

Nurses and midwives often comprise the largest percentage of national health workers worldwide; thus enhancing clinical performance of these cadres is critical to maintaining a quality workforce [11]. Increasing complexity of clinical practice and rapid changes in information and technology make it critically important for workers to retain competence by continuing to learn and develop throughout their careers [12]. Continuing education (CE), defined as an ongoing process of learning, is a cornerstone of continued competence, and is closely connected to the quality of care and patient safety [4]. CE has also been demonstrated to be a motivating factor for professionals in resource-poor settings [13, 14]. Health sector performance is

critically dependent on worker motivation, with service quality directly mediated by workers' willingness to apply themselves to their tasks [15]. Motivation in the work context is related to an individual's degree of willingness to exert an effort towards organizational goals [15].

Yet for many nurses and midwives, access to relevant up-to-date learning opportunities is difficult or impossible to obtain [16-18], especially in peripheral health facilities. This "outreach gap" describes the situation wherein most health facility deliveries and obstetric emergencies take place in peripheral health facilities, yet these areas are generally difficult to reach with conventional training programs [19]. Additionally, low health worker motivation has been identified as an often-neglected problem and challenge [13], whereas higher motivation has been found to be an important driver for health professionals to maintain their professional competence and continue in the workforce [14, 20].

An integrative review was conducted to identify and review CE approaches, content, and effectiveness for nurses and midwives with a particular focus on improving the provision of delivery and emergency obstetric care in LMICs.

Theoretical Framework

Benjamin Bloom's Theory of Mastery-Learning and Taxonomy of Educational Objectives constitute the conceptual framework for evaluating CE approaches for maternal health providers. Additionally, the Kirkpatrick Model [21-22] is used to assess the level of training program evaluation utilized in the study or the level at which the effectiveness of the training is measured.

Bloom posits that there are three "domains" of educational/learning objectives or

outcomes [23-25]: (1) Cognitive: mental skills (*knowledge*); (2) Affective: feelings or emotional areas (*attitude, motivation, self-efficacy*); and (3) Psychomotor: manual or physical skills (*skills*). The three domains classify intended changes or behaviors produced in leaners as a result of educational interventions. As such, the intended changes are not represented by choice of educational content, but rather by the stated objectives of an educational intervention (or they may be inferred from instructional methods or evaluation measures after instruction). The choice of learning objectives is based on questions about the learners such as: their present level of development, their needs, activities they are expected to perform or problems they are likely to encounter, and their context [23]. Learning objectives suggest instructional approaches, learner assessment strategies, and whether the educational intervention aligns with outcome expectancies. Bloom notes that the three domains are constantly interacting with each other and balance between the three is ideal in an educational situation [24]; the goal of the learning process is to attain mastery of the subject matter.

Kirkpatrick's widely used model guides evaluation of training across four levels: (1) Reaction (evaluates how participants assess the training); (2) Learning (measures if participants acquired knowledge, learned skills, or changed attitudes), (3) Behavior (considers if they are using what they learned at the training on the job), and (4) Results (evaluates if the training positively affected the organization and/or patient outcomes). Kirkpatrick notes that training evaluation becomes more meaningful as it progresses from levels one to four, but that ideally, all four levels of any training should be evaluated [22, 26].

Methods

Approach

This integrative review used the approach outlined by Whittemore and Knafl, which uses 5 stages and allows for the simultaneous inclusion of experimental and non-experimental research to gain a greater understanding of a phenomenon of concern: (1) problem identification, (2) literature search, (3) data evaluation, (4) data analysis, and (5) presentation. [27].

Search Strategy

The author searched the electronic, academic peer reviewed journals for studies published over the last ten years, from 2007-2017. Multiple electronic databases were searched including: PubMed, EBSCO host platform [including Cumulative Index of Nursing and Allied Health Literature (CINAHL), Medline, ERIC, Education Full text and PsycINFO], Scopus, and POPLINE. Key search terms are presented in **Table 1**. Bibliographies of included papers were also manually searched.

Table 1. Search terms

Nurse(s)	Training	Maternal health	Low income countries
Midwife(s)	Education	Obstetric emergency	Middle income countries
	Learning		Developing countries
	Continuing education		Low-resource countries
	Continuing professional development		
	On-the-job training		

Inclusion/exclusion criteria

Articles were included in this review if they addressed nurses or midwives' training or CE interventions, in a LMIC, targeting the clinical management of labor or emergency obstetric care. We included only those articles published in English language literature. Studies were excluded that focused on specialized health problems (cancer, HIV etc.), preventive care (such as cervical cancer screening), descriptions of undergraduate curricula, and studies describing training of traditional birth attendants or community health workers only. Editorials, opinions, and reviews were excluded unless they included direct results of training.

Data evaluation and analysis

The database search identified 675 papers. Duplicates were removed and papers were screened by title and abstract, leaving 85 papers. After full-text review 70 papers were excluded and 10 studies remained. An additional five studies were identified through bibliographic ancestry review, leaving fifteen studies for analysis in the final review. Search results are found on the accompanying PRISMA diagram (Figure 1.0). The lens of Bloom's Taxonomy was applied to identify which of Bloom's educational domains were reflected in the pedagogical approaches of the CE initiatives examined either overtly as an objective of the learning intervention or strongly suggested by the description of the intervention (or the outcomes or evaluation measures as noted above). Kirkpatrick's Model was used to assess the level of training program evaluation used in the intervention.

Results

Fifteen studies were included in this review. Most studies were conducted in sub-Saharan Africa (n = 11). Studies were primarily conducted using quantitative methods (n=12); two studies used qualitative methods only [28, 29], while one study used mixed methods [30].

The interventions collectively addressed all three of Bloom's learning domains, although only one study [29] explicitly referenced a learning theory, the Mastery-learning approach, in which trainees were required to achieve "mastery" in selected skills [31]. The studies collectively addressed all four of Kirkpatrick's training evaluation levels. A number of the studies specifically noted the use of Kirkpatrick's model. **Table 2** presents the application of respective Bloom and Kirkpatrick levels in the learning interventions' objectives, approaches and their training evaluation methods. All fifteen interventions addressed the cognitive learning domain, whereas all but one addressed the psychomotor domain [28], and the majority (n = 10) addressed the affective learning domain.

Content

Teaching-learning content was categorized into two topics: (1) Emergency obstetric (EmOC) (n= 12) [10, 19, 29-36, 38-39], and (2) General maternal care including partogram use (n = 3) [28, 37, 40]. There was a particular emphasis in these studies on PPH prevention and management, which is a key component of EmOC, and a number of the studies (n=7) looked specifically at PPH related outcomes (either knowledge, skills or patient outcomes)[10, 19, 29, 35-36, 38-39].

Effectiveness

In terms of assessing the effectiveness of the interventions, there was significant

heterogeneity within these studies. Not all of the studies reported statistical results; only a few reported the p-values and none of the studies reported an effect size. Many of the studies utilized non-validated measurement instruments. Additionally, certain in-service training programs were delivered as one component of a larger maternal health intervention; therefore, it was difficult to specifically attribute a change in outcomes to training alone [41]. Where training programs were evaluated, the focus was assessment of health provider competency before and/or after training; few studies evaluated the effect on change in practice and/or health outcomes.

Approach to Continuing Education

When viewed through the lens of approaches to CE, the interventions described fall into three main categories: (1) Short training courses, under a week in length and primarily in EmOC (n = 6) [10, 30, 32, 36-37, 39], including courses with low-tech simulation emphasis; (2) Longer educational interventions of variable duration (n = 5) [31, 33-35, 38]; and (3) eHealth initiatives (defined as the use of information and communication technologies (ICT) for health) [42] (n = 4) [19, 28-29, 40]. **Tables 3-5** present the studies utilizing the 3 approaches respectively. It should be noted that many of the interventions incorporated aspects from more than one of these categories.

(1) Short training courses (n = 6)(**Table 3**)

Short-term trainings lasted from a half-day [36] to a four-day training [30]. A total of 1156 health workers, mostly nurses and midwives, were trained across the five studies in different aspects of basic delivery and EmOC, primarily through validated training packages such as “Helping Mothers Survive – Breathing After Birth” (HMS-BAB), Advanced Life Support in Obstetrics (ALSO©), and Liverpool School of Tropical

Medicine-Royal College of Obstetricians and Gynecologists "Life Saving Skills – Essential Obstetric Care" (LSTM-RCOG LSS-EOC & NC). The most comprehensive training packages were competency-based and team-based multidisciplinary trainings, grounded in adult learning principles, that used approaches such as lectures, discussions, case studies, "hands-on" skills training, role-plays, scenario teaching and discussions [10, 30, 32, 36]. One study specifically examined the effect of a training intervention on the use of the partogram for labor monitoring [37]. Most studies put a particular emphasis on the use of low-cost and low-tech simulation technology using birthing simulator mannequins specifically aiming to improve PPH prevention and management [10, 30, 32, 36, 39]. Results from these six studies reported significant improvements in pre-and-post test knowledge, skills, provider behavior and patient outcome results, notably partogram completion [37], PPH incidence [10] and EmOC provision [30].

(2) **Longer educational interventions** (n = 5)(**Table 4**)

Longer-term trainings lasted from 3 weeks [31] to 2 years [33]. These studies examined interventions that were more heterogeneous across studies than the short courses, ranging from a conventional training course that measured BEmONC knowledge pre-and-post [31] to a longer training that evaluated provider behavior change via completion of resuscitation logbooks post-training as an audit mechanism [34]. One complex study [35] conducted pre-intervention observational studies of patient records in 17 hospitals as a means to motivate hospital staff to consider and adapt their own clinical guidelines to prevent PPH in their respective facilities, by increasing the use of active management of the 3rd stage of labor (AMSTL) and other methods to reduce maternal mortality. In this study, observational facility studies

were carried out at 3-and 12 months after adopting new guidelines to document impact and found a significant drop in PPH. Ellard et al. [33] reported on a prospective study in Tanzania that included an over 2-year package of clinical training, clinical guidelines and leadership training plus post-training mentoring and supervision at the workplace. This study showed a non-significant downward trend in maternal deaths. The researchers suggested that the relative lack of impact may have been related to the poor working conditions including lack of availability of running water, functioning toilets, ambulance availability, basics for infection/hygiene control (soap) and the provision of oxygen. Walker et al. [38] reported on a simulation training that used a simulator worn by a patient actress to simulate obstetric emergencies ("PartoPants"), made from modified recycled surgical scrub pants. This training emphasized PPH, eclampsia and shoulder dystocia management and measured knowledge and self-efficacy change pre-and-post intervention.

(3) eHealth (n = 4)(**Table 5**)

Studies focusing on eHealth with interventions for health workers targeting labor and obstetric emergencies utilized the following approaches: (1) Mobile phone short message service (SMS) (n = 1)[40], (2) Video instruction using computers (n = 1) [19], (3) Computer-based clinical decision support systems (CDSS)(n = 1)[28], and (4) Computer Simulation (n = 1)[29].

Attwell et al. [40] described a simple sms intervention for midwives in South Africa, wherein text messages containing information from the "Maternal Care" textbook and a link for more information were sent each week over six months. The intervention was evaluated via a short questionnaire administered to the message recipients. Lack of access to the Internet, or failure to utilize the link provided to

obtain additional information, indicated that limitations existed in internet-based distance education in South Africa, especially in the public sector. Nilsson et al. [19] tested a hands-on training program (with instructors) for PPH management versus a non-interactive video training on computers (with no instructors). No significant differences were observed between the groups in either pre-training test scores ($p = 0.852$) or post-training test scores ($p = 0.367$). Both groups had significant increases in "Objective structured clinical evaluation" (OSCE) skill performance scores comparing pre-to-post training results.

Two studies in this review administered educational interventions via computer [28 - 29]. Zachane et al. [28] used qualitative interviews to assess perceived needs and attitudes among healthcare workers to accessing WHO guidelines using a clinical decision support system (CDSS) in maternal and neonatal care in rural Burkina Faso. The study utilized a quasi-experimental design and trained intervention participants on use of the computer and the CDSS, whereas the control group did not receive such training. Health workers in the intervention group expressed some hesitation and fear about using the system but also expressed a fascination for and a willingness to adapt and use modern technologies like computers in the workplace. Taekman et al. [29] tested a multiplayer screen-based simulation experience aimed at improving PPH management by health workers. The PPH software was built on the Epic Games platform, the technology behind many commercial video games, and ran on inexpensive computers with Internet connections. Epic technology was repurposed to develop a healthcare learning activity, customized to reflect available resources in Uganda. A pre-and-post test self-assessment survey on PPH management was administered before and after the intervention; participant scores increased

significantly overall following the simulation experience.

Discussion

The purpose of this review was to examine peer-reviewed studies of continuing education interventions for nurses and midwives working in emergency obstetric care in LMIC's. In this review, we found a relatively limited number of studies, primarily concentrated in Africa. The content of the interventions focused primarily on EmOC and on PPH management. This focus on PPH and EmOC reflects the reality of continued high maternal mortality in LMIC's, particularly in sub-Saharan African countries, where PPH is the most important cause of maternal death.

Most studies in this review described established training courses, using a variety of educational methodologies such as lecture, team-based approaches, scenario teaching, video viewing, role-plays, demonstrations, and case discussions. Most studies also employed some form of hands-on simulation with birthing mannequins and simulated situations of obstetric emergencies; one study used patient actresses combined with the use of a birthing simulator [38]. Some studies integrated post-training mentoring and supervision, whereas others integrated leadership training. One guideline adaptation intervention used experts to teach about guidelines and guideline adaptation rather than teaching EmOC content [35]. eHealth studies were heterogeneous, using sms [40], video [19], CDSS [28] and a computer-based multiplayer screen-based PPH simulation [29].

Kirkpatrick's model outlines four levels of training evaluation: reaction, learning, behavior change and results, and notes that evaluation becomes more meaningful as the levels rise. As per Kirkpatrick, patient or organizational change

results are the most meaningful in evaluating trainings. The studies in this review primarily utilized one-group pre-and-post designs, measuring changes in provider knowledge and skills; few documented Kirkpatrick level 4 results. Additionally, few utilized robust study designs, such as randomized controlled trials. Lack of evidence of the effectiveness of CE in LMIC's to increase knowledge, motivate health workers, and positively affect patient outcomes via robust study designs and measurement of patient outcomes has been noted to be deficient in the literature [20-21]. In addition to more robust study designs, long-term follow-up and the use of validated measurement instruments to evaluate intervention effects would render the evaluations robust [21].

Collectively all of the studies addressed Bloom's three learning domains: cognitive, affective and psychomotor, however most studies focused on measuring cognitive (knowledge) and psychomotor (skills) outcomes. Affective outcomes such as motivation was referenced in certain papers but rarely measured as an outcome. In Figueras et al., the intervention was noted to specifically target health worker motivation through active involvement of health professionals in drafting their own facility clinical guidelines. This intervention resulted in a substantial drop in maternal mortality in these facilities [35]. Zachane et al. [28] identified motivation of staff as one of their qualitative findings related to staff use of CDSS technology to access WHO guidelines. The literature notes the critical importance of motivation and affective outcomes to provider behavior, particularly in sub-Saharan Africa, where staffing is a critical issue and motivation has a particularly important impact on attracting and retaining staff [13].

A notable gap identified in the studies in this review was the lack of attention to strategies to make continuing education more accessible - geographically and

financially - to health workers in hard-to-reach areas, where the challenge of high maternal mortality and quality assurance of emergency obstetric care is the greatest [1, 19]. Short-term EmOC courses are often a feasible way to train a relatively large number of staff in a short time [10]; however, in many settings, standard short-or medium-term training courses are difficult to carry out in hard-to-reach settings. None of the studies in this review included costing estimates or mentioned logistical challenges for their interventions. Nilsson et al.'s [19] simple intervention study to improve PPH management skills compared an interactive hands-on PPH training versus a non-interactive video training for PPH management and found no difference in skill results between the two groups post-training. This suggests that there are other approaches to providing continuing education to health workers that may not come with the high cost and logistical requirements of conventional training. This also suggests that newer technologies may one response to the "outreach gap" in sub-Saharan Africa's rural areas as they may potentially be less costly and could facilitate access to clinical providers in remote locations [19]. In contrast to the Nilsson study, Zachane's intervention utilizing a CDSS to access WHO guidelines at the point of care held great appeal among healthcare workers, however, health workers noted challenges related to lack of confidence and skills needed to use the IT equipment [28]. Additionally, in many remote locations, electricity sources and lack of system maintenance might be a barrier to the use of CDSS [28].

Sustainability was also not addressed in these studies but is equally important, including keeping costs low and assuring long-term impact of interventions, such as the retention of knowledge and skills by health workers. Few studies addressed longer-term follow-up, providing a need for future research and evaluation of

sustainability[21, 39].

Our identification of studies was defined by our selected databases and search terms, which may have resulted in relevant studies being missed from different databases or associated key terms. Additionally, we were limited to analysis of the results reported in the studies that made comparisons between learning interventions difficult due to lack of comparable data. Future research must therefore emphasize robust study designs, using valid and reliable measurement instruments, and measuring higher-level outcomes such as behavior change and patient results. Additionally, we recommend addressing the role of motivation in future research, as suggested by Bloom's educational domains. Feasibility in remote areas to determine if a certain approach is viable for the specific context or country as well as costing analyses should be included in future analyses.

Conclusion

Health worker performance is a complex issue that has many potential influencing factors, however knowledge, skills, and affect, including factors such as self-efficacy, attitude, and motivation are essential to competence and to performance. In the current context of rapid change, information overload, and continued high maternal mortality, accessible CE for nurses and midwives in the neediest settings can keep them abreast of best practices and level the playing field for differing levels of basic and professional education. eHealth and other creative approaches to continuing education hold promise for engaging health professionals, including in remote areas, where maternal and newborn mortality are the highest. Research is needed on continuing education approaches with high priority content and demonstrated

effectiveness, using rigorous research methods and validated measurement instruments to determine long-term effectiveness on patient outcomes and to evaluate feasibility and cost-effectiveness in different contexts and priority areas

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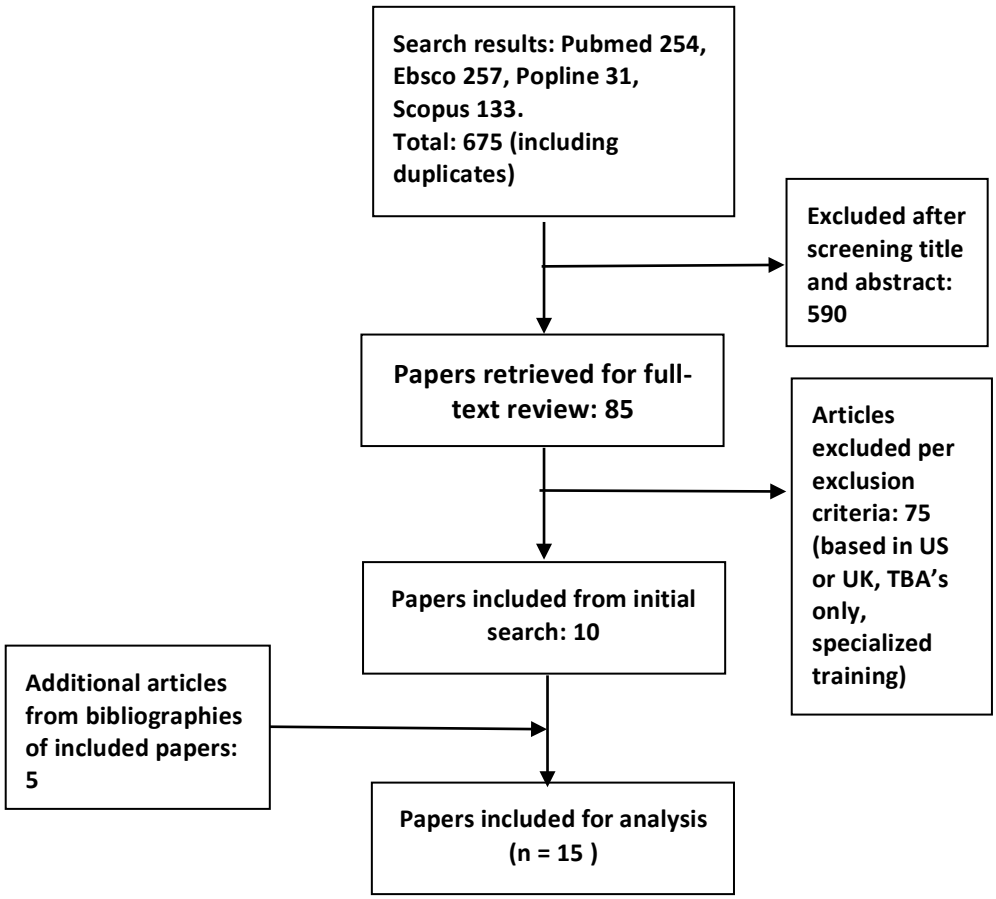
MS1. Figure 1.0 Integrative Review: PRIMSA Flow Diagram



MS1 Table 2 – Bloom & Kirkpatrick levels measured

First Author, Year	*Measures*	*Bloom's learning domains* *(specific affective characteristic)*	*Kirkpatrick level*
Short Training Courses (n = 6)			
Grady [32] 2011	**Reactions & Affective:** Questions scored 1 – 10 for training usefulness and participant enjoyment. **Knowledge & Skills**: MCQ's results analyzed by country for group mean differences pre-and-post. Pre-specified scoring guidelines for skills test modules, rated by a facilitator.	1. Cognitive 2. Affective (enjoyment) 3. Psycho-motor	1: Reaction 2: Learning
Ameh [30] 2012	**Reactions & Affective:** Likert scale. **Knowledge & Skills**: MCQ's results analyzed with SPSS for group mean differences pre-and-post. Skills assessments carried out using obstetric, newborn, skill mannequins and checklists. **Behavior change:** Qualitative assessment ssessed via 6 Focus groups & 9 Interviews post training. **Institutional change**: Assessed via HCW interview, inspection of facility records, and facility observation.	1. Cognitive 2. Affective 3. Psycho-motor	1: Reaction 2: Learning 3: Behavior 4: Results
Fatusi [37] 2008	**Reaction to training:** Respondents' assessment of the training measured (Likert scale). **Behavior:** 242 partograms of women in labor plotted by staff post-training: completion of partogram, technical accuracy of completion, appropriateness of action based on the partogram.	1. Cognitive 2. Affective 3. Psycho-motor	1: Reaction 3: Behavior
Sorensen [10] 2012	**Behavior:** Staff performance to prevent, detect, and manage PPH using a structured observation scheme. **Results**: Measurement of pre & post training blood loss (PPH ≥500ml)(severe PPH blood loss ≥1000ml) and	1. Cognitive 3. Psycho-motor	3: Behavior 4: Results
Nelissen [36] 2013	**Reactions & Affective:** Assessed by questionnaire **Knowledge & Skills**: Knowledge was assessed by a written 26-item pre & post-test, developed and validated by nonprofit Jhpiego. T tests used to compare before and after for matched cohorts. Skills assessed pre & post using simulated scenarios and a skills checklist for 38 learners (due to logistics). Essential items were identified in order to pass the test (5 items for basic delivery, and 8 items for management of PPH).	1. Cognitive 2. Affective (self-efficacy) 3. Psycho-motor	1: Reaction 2: Learning

First Author, Year	*Measures*	***Bloom's learning domains*** *(specific affective characteristic)*	***Kirkpatrick level***
Evans [39] 2014	**Reactions & Affective:** Acceptability of materials & methods was assessed using a 5-point Likert scale. Confidence was assessed pre-and-post-training via oral questionnaires. **Knowledge & Skills**: Knowledge was assessed pre-and-post-training via oral questionnaires. Skills were assessed immediately after training using 3 OSCEs (on simulators) on prevention of PPH, and management of retained placenta and severe PPH.	1. Cognitive 2. Affective (confidence) 3. Psycho-motor	1: Reaction 2: Learning
Longer Educational interventions (> 1 week)(n = 5)			
Mirkuzie [31] 2014	**Reactions:** Trainees asked to evaluate the course in 8 areas using Likert scale. **Knowledge**: Immediate post training & 6 months post assessment of knowledge- based mastery on 9 major topics using 36 MCQ tool.	1. Cognitive 2. Affective 3. Psycho-motor	1: Reaction 2: Learning
Zafar [34] 2009	**Behavior**: Logbooks verified which noted the following: demographic data, principal illness or injury, type of patient, skills used, drugs used, complications, outcomes.	1. Cognitive 3. Psycho-motor	3: Behavior
Ellard [33] 2016	**Results:** A predesigned instrument was used to capture data from monthly/annual summary reports stored at each of 16 facilities covering the project time period; there were no control facilities.	1. Cognitive 3. Psycho-motor	4: Results
Figueras [35] 2008	**Results:** Observed data collected from clinical records of patients at baseline and 3-and-12 months post intervention. Changes between baseline and post were interpreted using hypothesis testing.	1. Cognitive 2. Affective: motivation 3. Psycho-motor	4: Results
Walker [38] 2015	**Knowledge & Skills:** Study measured average change in participant pre-and-post training EBP knowledge and self-efficacy (confidence in their own ability to perform key skills) scores for each training topic area.	1. Cognitive 2. Affective: motivation 3. Psycho-motor	2. Learning
eHealth Interventions (n= 4)			
Attwell [40] 2012	**Reactions:** Midwives were contacted by an independent consultant, and asked to answer 7 short questions; each question had 3 possible answers ranging from positive to negative.	1. Cognitive	1: Reaction

First Author, Year	***Measures***	***Bloom's learning domains*** *(specific affective characteristic)*	***Kirkpatrick level***
Nilsson [19] 2014	**Knowledge & Skills:** Competency assessment before & after training for both groups using ALSO structured observation instrument and standardized test scenario.	1. Cognitive 2. Psycho-motor	2: Learning
Zakane [28] 2014	**Reactions:** Open-ended questions explored the informants' needs of information and equipment in the workplace and attitudes to CDSS in maternal care.	2. Affective: motivation	1: Reaction
Taekman [29] 2017	**Reactions:** A fifteen-question self-assessment administered before and after the intervention, consisting of 4 psychomotor, 6 cognitive, and 5 affective questions targeted at management of PPH	1. Cognitive 2. Affective 3. Psycho-motor	1: Reaction

Table 3. Short training courses (n = 6)

Citation	Study Design	Participants	Intervention	Key Findings
Grady K et al. 2011 [32]	Prospective intervention study with one group pre & post, to assess the effectiveness of in-service training "Essential Life Saving Skills – Emergency Obstetric and Newborn Care" (LSTM-RCOG LSS-EOC & NC).	Nurse-midwives, doctors, clinical officers n= 600 Setting: 7 African countries	3-day training in LSS-EOC & NC. (Competency and team-based training package based on adult learning principles).	**Knowledge & Skills:** Knowledge for 8 EmONC topics significantly increased ($p < 0.001$) with some differences noted both between modules and countries. Mean scores for 8 skills test increased significantly ($p < 0.001$).
Ameh C et al. 2012 [30]	Prospective intervention study with one group pre & post, using qualitative & quantitative plus facility visits, to assess the effectiveness of in-service training (LSTM-RCOG LSS-EOC & NC) & availability of EmONC services.	Nurses & midwives (67%), MD's (33%) n= 222 Setting: Somalia	4 days of training using adapted LSS-EOC & NC using methodologies noted in Grady et al.	**Knowledge & Skills:** significant improvement in 50% of knowledge and 100% of skills modules ($p < 0.001$). **Behavior**: BEmOC facilities provided 100% of expected functions, compared with 43% at baseline.
Fatusi et al. 2008 [37]	Prospective intervention study with one group post-test only (no pre-test), to assess correct application of the partogram in routine practice undertaken for a 7-month period.	5 nurses/midwives, 50 CHW's, 1 MD n= 56 Setting: Nigeria	3 day training on partogram use with didactic sessions and practical examples. Supervision for 2 weeks post-training during phase-in of use of partogram in maternities.	**Behavior:** 242 partograms were correctly charted in 76.9% of cases, technical accuracy in plotting was achieved in 64.9% and appropriate action was taken (based on partogram plotting) in 93.4% of cases.
Sorensen et al. 2011 [10]	Prospective intervention study, with one group of HCW's and women admitted for delivery pre & post, to evaluate the impact of Advanced Life Support in Obstetrics (ALSO) training on staff performance and the incidences of PPH.	16 midwives, 8 Medical Officers, 2 MDs (n = 26) Sample: 510 women who delivered before the training and 505 after. Setting: Tanzania	2-day ALSO training course. (Uses lectures, workshops, case discussions, hands-on & teamwork training using mannequins in simulated situations of obstetric emergencies.)	**Results:** The incidence of PPH was significantly reduced from 32.9 to 18.2% [RR 0.55 (95% CI: 0.44–0.69)], severe PPH from 9.2 to 4.3% [RR 0.47 (95%CI: 0.29–0.77)]. [Note: Measurement of pre & post-training blood loss (PPH ≥500ml)(severe PPH blood loss ≥1000ml).]

Nelissen et al. 2013 [36]	Prospective intervention study, with one group pre & post, to evaluate "Helping Mothers Survive Bleeding After Birth" (HMS BAB), a simulation-based training.	Nurse-midwives, medical attendants, and ambulance drivers involved in maternity care. (n = 97) Setting: Tanzania	Half-day simulation-based training, focused on basic delivery care, active management of third stage of labor, and treatment of PPH using a low-cost, low-tech birthing simulator.	**Knowledge & Skills:** Mean scores on knowledge test increased significantly for 84 learners from 74% to 80% ($p < .001$). Significant increases found in mean skill scores for 3 scenarios: basic delivery, PPH management, and bimanual compression.
Evans et al. 2014 [39]	Prospective intervention study, with one group pre & post, to validate "Helping Mothers Survive Bleeding After Birth" (HMS BAB), a simulation-based training.	Midwives, Clinical officers, medical assistants, MD's, orderlies. (n = 155) Setting: India, Malawi and Tanzania	One-day, facility-based training that emphasizes simulation of scenarios related to prevention, detection, and management of PPH; an apron-style simulator used, consisting of an abdominal "skin" containing a uterus holding a fetal mannequin, postpartum size uterus and blood tank.	The proportion of providers with passing knowledge scores increased significantly from pre- to post-training among all cadres except for those already high at baseline. On three post-training skills tests the overall proportion of individuals with a passing score ranged from 83% to 89%.

Table 4: Longer Educational interventions (> 1 week)(n = 5)

Citation	Study Design	Participants	Intervention	Key Findings
Mirkuzie et al. 2014 [31]	Prospective intervention study, one group with test immediately post-training & 6 months post (for knowledge retention), to evaluate collaborative training intervention project conducted by Ethiopian Midwifery Association.	Midwives and nurses working in 10 randomly selected public health centers (HCs). (n = 82) Setting: Ethiopia	3-week long mastery-learning training approach using theoretical sessions on BEmONC complemented with demonstration, videos, case studies & role-plays plus skills training using low-cost and low-tech simulation with mannequins.	**Knowledge:** Results comparing immediate post test and 6 month post-test on 9 topics showed no significant decay in providers' knowledge over the six-month period following the training a the mean difference of 2.9% (95% CI 0.6, 5.7).
Zafar S. et al. 2009 [34]	Cross-sectional study, to evaluate a training program, Essential Surgical Skills -Emergency Maternal and Child Healthcare (ESS-EMCH), via the completion of logbooks documenting resuscitation attempts post-training.	Nurses & MD's n = 120 Setting: Pakistan	6 five-day (total 30 days) training given over one year. Following the trainings, participants provided with logbooks to document the actual resuscitation of mothers, infants and children.	**Behavior:** 1123 resuscitation attempts documented by 63 of the 120 participants (response rate 53%). The authors concluded that logbooks should continue to act as a feedback and audit mechanism to measure provider behavior/outcomes.
Ellard et al. 2016 [33]	Prospective intervention study of maternal and neonatal health indicators at 16 facilities (no control facilities), to explore the impact of ETATMBA training on health outcomes in facilities where trainees were based.	16 nurse midwives/nurses, 9 AMO's, & 1 CO (n= 26) Setting: Tanzania	2 year plus package using clinical training, clinical guidelines and leadership training plus post-training mentoring and supervision at workplace (exact training duration not specified).	**Results:** Maternal deaths show a non-significant downward trend over the 2 years (282–232 cases/100 000 live births). No significant differences in maternal, neonatal and birth complications across the time-points.

Figueras et al. 2008 [35]	Prospective intervention study, (GIRMMAHP Initiative) with four phases: 1. Pre-intervention observational study from 2247 patient records of pregnant women who delivered in 17 hospitals to characterize delivery care. 2. Followed by writing/ adaptation of clinical practice guidelines in each facility. 3 & 4. Two observational post-intervention studies of patient records at 3 & 12 months post.	Midwives, nurses, residents, MD's (staff of each facility obstetrics ward) Setting: 17 hospitals in 5 countries: Argentina, Dominican Republic, Guatemala, Nicaragua & Peru	3-month-long educational workshop included: comparison of observed baseline results with EBP guidelines, discussions, and adapting EBP guidelines. Initiative was designed to describe the actual delivery care and to educate and motivate clinical staff to implement their own clinical practice guidelines to prevent PPH.	**Behavior:** The proportion of active management increased from 23% at baseline to 72% of deliveries at 3 months and 59% at 12 months ($p < 0.05$). **Results:** The proportion of women who had PPH decreased from 12.7 % at baseline to 5 % at 12 months after the intervention ($p < 0.05$).
Walker et al. 2015 [38]	Prospective intervention study with one group pre & post, to evaluate the impact of PRONTO, a low-tech, low-cost simulation-based obstetric and neonatal emergency and team-training program. Note: Simulation via "PartoPants", a simulator worn by a patient actress to simulate obstetric emergencies, made from modified recycled surgical scrub pants. http://prontointernational.org/partopants-birth-simulator-2/	MD's, nurses and auxiliary nurses. Clinic directors chose training participants from the clinic staff doing deliveries. n = 219 from 15 clinics (intervention clinics only) of a larger, pair-matched, cluster randomized controlled trial in 30 clinics. Setting: Guatemala	15 PRONTO trainings conducted: consists of two modules 2-3 months apart covering topics of teamwork, communication, PPH, NNR, eclampsia & shoulder dystocia. Sessions comprised of interactive team-building exercises, case-based learning, targeted skill sessions, simulation of obstetric emergencies, video-guided debriefings and goal setting sessions for facility clinical improvement.	**Knowledge & Skills:** Knowledge in all subject areas improved significantly ($p < 0.001$) following the training intervention. Self-efficacy changes were similar to knowledge improvements and were all significant at $p < 0.001$. Both were positively correlated for all topics at training completion as trainees with high self-efficacy were also found to have high knowledge scores.

Table 5: eHealth Interventions (n= 4)

Citation	Study Design	Participants	Intervention	Key Findings
Attwell et al. 2012 [40]	Survey questionnaire administered post-intervention to one group, to explore whether the use of cell phone text messaging to improve access to continuing education is acceptable to midwives.	Midwives (n = 50) Setting: South Africa	Essential lessons from the Maternal Care book (South African textbook) were delivered via text message to over 2,500 midwives each week for a period of 6 months.	**Reaction:** 86% enjoyed and learned from the weekly text messages, 72% believed that the messages improved their clinical practice, and 68% regularly shared and discussed the messages with their colleagues.
Nilsson et al. 2014 [19]	Quasi - Experimental design – pre-and post test for two intervention groups (hands-on role play training vs. video), to compare two teaching methods for PPH management: interactive hands-on training and non-interactive video training.	Senior nursing, assigned to one of two groups based on rotation schedule. (n = 27) Setting: Kenya Competency assessment pre & post training for both groups using ALSO structured observation instrument and standardized scenario.	Hands-on group: 30 min PowerPoint presentation on prevention & management of PPH and 60 min hands-on-role-play with team approach Video group: 12 min PowerPoint presentation and 11 min video on prevention & management of PPH	**Knowledge & Skills**: Both intervention groups significantly increased in skill scores after receiving training: Hands-on: 40% (95% CI 29.5–47.0) and video training: 34.5% (95% CI 25.0–42.0). There were no significant differences in either pre-training test scores (p = 0.852) or post-training test scores (p = 0.367) between the intervention groups.
Zachane et al. 2014 [28]	Qualitative interviews as part of quasi-experimental cluster-matched trial using districts as unit, to explore and describe perceived needs and attitudes among healthcare workers to accessing WHO guidelines using clinical decision support system (CDSS) in maternal and neonatal care in rural Burkina Faso. Part of Quality of Maternal and	Nurses, nurse assistants, midwives, and midwife assistants. n = 45 I = 23 C= 22 Setting: 12 rural healthcare facilities, Burkina Faso Note: CDSS system is able to run on any hardware.	Treatment group: 3-day demonstration and training workshop prior to interview about the concept and handling of the computer and CDSS. Control group: Prior to the interview, had been informed about the planned CDSS project.	**Reaction:** There are four main findings: (a) a fascination among HCW's for and willingness to adapt and use modern technologies like computers in the workplace, (b) a positive attitude to easy access to guidelines and implementation of decision-support using computers, (c) a fear that the CDSS requires more working time, and (d) that CDSS is

	Neonatal Care study (QUALMAT).			complicated and requires substantial computer training and extensive instructions.
Taekman et al., 2017 [29]	Quasi-experimental design: one group pre-and-post-intervention survey, to assess whether a multiplayer screen-based PPH simulation experience with VOIP would increase learner confidence in their ability to manage PPH as a team. (VOIP enables audio communication over the internet.)	Midwifery, Obstetrics, & Anesthesiology (n= 48) Settting: Mulago Hospital, Uganda	Nine 1-hour sessions over a 5-day period with 2-10 learners. Learners participated in similar simulations, consisting of a 30-min screen-based facilitator-lead simulation followed by a debrief with faculty.	**Reaction**: Self-confidence scores increased significantly overall following the simulation experience (pre = 7.83 ± 1.55, post = 8.95 ± 1.42, $p < 0.001$) and individually in each of the three categories of Bloom's Taxonomy: affective, cognitive, and psychomotor.

Technology-based newborn health learning initiatives for nurses and midwives in low-and-middle income countries: A scoping review

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Abstract

Purpose: Given high neonatal mortality in many low-to-middle-income countries (LMICs), and the potential of simple interventions to prevent intrapartum-related neonatal deaths, enhancing the quality of newborn care provided by nurses and midwives is critical. However, access to relevant up-to-date learning opportunities is often difficult for health providers to obtain. The use of technology holds promise for new learning and performance support initiatives. This Scoping Review synthesizes and critiques the literature on technology-based newborn health learning initiatives for nurses and midwives in LMIC's. Kirkpatrick's Model is used to organize the analysis of training program evaluation.

Methods: The approach applied in this Scoping Review utilizes a 5-stage process: (1) identifying the research question, (2) identifying relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing and reporting the results. A literature review was conducted from multiple databases including PubMed, EBSCO Host Platform, and SCOPUS. Articles selected for analysis consisted of original research studies published in peer-reviewed journals over the last five years, from 2012 – 2017.

Results: Twelve studies were included in this review and fell into two main categories: (1) Simulation training in routine neonatal care and neonatal resuscitation via Helping Babies Breathe courses (n= 6) and other training programs (n = 3), and (2) eLearning initiatives (n = 3). The majority of studies in this review evaluated health provider knowledge and skills before and/or after training (n = 9); fewer studies evaluated the effect on change in provider practice (n = 3) and/or patient

health outcomes (n = 5), representing Kirkpatrick levels 3 and 4. Few of the included studies utilized robust study designs and validated measurement instruments.

Conclusion: Learning approaches emphasizing simulation training and eHealth/eLearning initiatives for facility-based maternal and newborn health workers in LMICs hold promise for identifying potentially scalable approaches towards establishing better coverage of skilled birth attendants proficient in essential newborn care and neonatal resuscitation. However, existing simulation literature demonstrates that translation of knowledge gained during simulation into improved clinical outcomes in real births is difficult and variable. Additionally, the volume of peer-reviewed evidence demonstrating the potential benefit of mHealth strategies, especially in the neonatal period, is limited. This review provides an overview of the state of the science and recommendations for future research with the goal of reducing neonatal mortality globally.

Keywords: nurses, midwives, technology, newborn, neonatal, low-and-middle income countries, education, training, learning, eLearning, mLearning, and neonatal resuscitation.

Background

The greatest test of health system function is the ability to provide timely care at birth [World Health Organization (WHO), 2005]. The reality is that worldwide, of the 140 million babies born each year (WHO, 2017), almost 1 million newborn babies die on their first day of life each year and close to 1 million die during their first week of life [United Nations Inter-Agency Group for Child Mortality Estimation (UN IGME), 2017]. An estimated 99% of these deaths occur in low-to-middle-income countries (Lawn et al, 2009a). Although some regions have made progress in decreasing neonatal mortality, the highest mortality regions have seen little progress in the last decade. “Early neonatal deaths” are those that occur in the first week of life, and “neonatal deaths” occur in the first 28 days of life, while “perinatal deaths” are comprised of early neonatal deaths and stillbirths (Lawn et al., 2009b). Neonatal deaths account for an increasing proportion of under-5 mortality, as post-neonatal mortality (mortality in children under 5 years of age) has decreased dramatically over the past 15 years globally, while there has been slower progress in reducing the neonatal mortality rate (NMR)(Lawn et al., 2009a). The share of neonatal deaths is projected to increase from 45 percent of under-five deaths in 2015 to 52 percent in 2030 (IGME, 2017).

The time of greatest risk of mortality and morbidity for both the mother and baby is at birth. The three major causes of perinatal deaths are preterm birth complications, intrapartum-related “birth asphyxia”, and infections, contributing approximately one-third each (Lawn et al., 2009a). Intrapartum-related neonatal deaths, formerly referred to as “birth asphyxia” (i.e. failure to initiate spontaneous respirations and/or 5 min Apgar score <7), are closely linked with maternal complications and death (Lawn et

al., 2009a). In reality, the vast majority of neonatal deaths can be prevented or treated by relatively straightforward, effective interventions practiced by health workers (UN IGME, 2017; Chandrasekaran, Thukral, & Deorari, 2014) starting with primary prevention such as skilled attendance at birth, and early recognition and timely management for obstetric complications. Secondary prevention focuses largely on early neonatal care and neonatal resuscitation (NR) (Lawn et al., 2009a; Erdsal & Singhal, 2013).

The WHO estimates that while 5–10% of newborns worldwide do not breathe immediately at birth and require some level of assistance to initiate respirations, 3–6% require basic NR, consisting of simple initial steps and assisted ventilation via bag-mask or face-mask ventilation (FMV) (WHO, 1997). Less than 0.1% of neonates require advanced resuscitation techniques such as chest compressions and vasoactive medications (Wall, 2009). Simple immediate newborn care includes warming, drying, stimulation, hygiene and thermal care. Providing these immediate steps to newborns in all settings is essential newborn care, and can be performed by family members (Wall et al., 2009). Basic NR training can be effectively performed by a wide range of health providers [from traditional birth attendants (TBA's), community health workers (CHWs), nurses, and midwives to physicians] resulting in reductions in intrapartum-related mortality in both the facility and home settings. Evidence from several observational studies show that facility-based basic NR alone may avert 30% of intrapartum-related neonatal deaths in full-term babies, plus 5-10% in pre-term babies (Wall et al., 2009).

One key impediment is the lack of skilled birth attendants (BA's) and newborn care providers proficient in essential newborn care and NR in LMIC's (Wall et al.,

2009; Ersdal & Singhal, 2013). The coverage gap of skilled birth attendance is widest in certain regions, namely Sub-Saharan Africa and South Asia, where baseline coverage is lowest globally and progress to reaching universal skilled attendance is slow (Lawn et al., 2009a). NR is one of the "signal functions" of emergency obstetric and newborn care (EmONC) that must be provided by all skilled BA's (Lund et al., 2016). In reality, low knowledge and confidence in NR skills among neonatal providers has been documented, and lack of initial/ refresher training has been identified as a key contributor (Rule et al., 2017; Subbiah, Sarin, Jeeva, & Geetanjali, 2012). For babies born in hospitals in South Asia and Africa, staff often lack training in resuscitation and equipment is not available. In assessments in six African countries, only 2–12% of personnel conducting births in facilities had been trained in neonatal resuscitation and only 8–22% of facilities had equipment for newborn respiratory support. About half of the babies born in Africa are not born in facilities (Wall et al., 2009), and clearly they are at higher risk. One of the key challenges is how to seize the missed opportunity to ensure adequate provision of essential newborn care and basic resuscitation in facility settings, including equipment and competent personnel (Wall et al., 2009). Key constraints include cost, availability of competent trainers, and the rapid pace of change of information, technology, and clinical recommendations (Chandrasekaran et al., 2014; Klunklin, Viseskul, Sripusanapan, & Turale, 2010)

Nurses and midwives are crucial to strengthening health systems, and achieving improved maternal and child health (WHO, 2011a; Bell, Rominski, Bam, Donkor, & Lori, 2013). However, particularly in rural areas, where there is the lowest coverage of skilled care at birth and neonatal mortality is highest, access to relevant up-to-date

learning opportunities is difficult or impossible to obtain (WHO, 2006; Hudspeth, Curry, Sacks, & Surena, 2015). Given the challenges of organizing learning opportunities for health workers (HWs) in remote settings, the use of technology holds promise for new mechanisms to reach these HWs with up-to-date information (Nilsson, Sorensen, & Sorensen, 2014), yet published robust research on newborn health learning initiatives is limited (Chandrasekaran et al., 2014; Amoakoh et al., 2017).

The purpose of this scoping review is to explore what is known from the existing research literature about technology-based newborn health learning initiatives for health workers in LMICs with an emphasis on nurses and midwives. Kirkpatrick's model for the evaluation of training programs (Kirkpatrick, 1996) is used as the guiding framework to consider the various training initiatives.

Methods

Approach

The approach applied in this Scoping Review utilizes a 5-stage process as outlined by Arksey and O'Malley (2005): (1) identifying the research question, (2) identifying relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing and reporting the results.

Search Strategy

The author searched the electronic, academic peer reviewed journals for studies published over the last five years, from 2012-2017, in order to limit findings to more recent papers. Multiple electronic databases were searched including: PubMed, EBSCO host platform [including Cumulative Index of Nursing and Allied Health Literature (CINAHL), Medline, ERIC, Education Full text and PsycINFO], and

Scopus. Key search terms are presented in **Table 1**. Bibliographies of included papers were also manually searched.

Table 1. Search terms

Nurse(s)	Training	Maternal health	Technology	Low income countries
Nursing	Education	Newborn health	e Health	Developing countries
Midwifery	Learning	Neonate	m Health	Low-resource countries
Midwife(s)	Continuing education	Neonatal	Digital health	Asia
	Professional development		Mobile phones	Africa
	Performance support		Computers	
			Electronic	
			Simulation	

Inclusion/exclusion criteria

Articles were included in this review if they addressed nurses, midwives', or other health workers' technology-based training or learning interventions, in a LMIC, targeting the clinical management of newborn care. Studies were excluded that focused on research protocols, multi-intervention quality improvement projects, descriptions of undergraduate curricula, and studies on training of TBA's or CHW's only. Editorials, opinions, and reviews were excluded unless they included direct results of training.

Data evaluation and analysis

The database search identified 576 papers. Duplicates were removed and papers were screened by title and abstract, leaving 36 papers. After full-text review 27 papers were excluded and 9 studies remained. An additional three studies were identified through

bibliographic ancestry review, leaving 12 studies for analysis in the final review. Search results are found on the accompanying PRISMA diagram (Figure 1.0). Kirkpatrick's Model was used to assess training program evaluation in the interventions reviewed (Kirkpatrick, 1996) (**Table 2**). Kirkpatrick considers evaluation of training programs across four levels: (1) Reaction (evaluates how participants assess the training); (2) Learning (measures if participants acquired knowledge, learned skills, or changed attitudes), (3) Behavior (considers if they are using what they learned at the training on the job), and (4) Results (evaluates if the training positively impacted organization and/or patient outcomes). Kirkpatrick notes that training evaluation becomes more meaningful as it progresses from level one to four, but that ideally, all four levels of any training should be evaluated.

Results

Twelve studies are included in this review. Studies were conducted in India (n= 5)(Subbiah et al., 2012; Goudar et al., 2012; Vail et al., 2017; Thukral et al., 2012; Prakash et al., 2016), sub-Saharan Africa (n= 4)(Msemo et al., 2013; Erdsal et al., 2013; Eblovi et al., 2017; Lund et al., 2016), both India and Africa (n = 2)(Bang et al., 2016; Bellad et al., 2016), and one study was conducted in Honduras (Seto et al., 2015). All twelve studies were published in English. Studies were all conducted using quantitative methods with the exception of one study that used mixed methods (Prakash et al., 2016). The studies collectively addressed all four of Kirkpatrick's training evaluation levels and a number of the studies specifically noted the use of Kirkpatrick's model as part of their research approach. The majority of studies evaluated health provider knowledge and skills before and/or after training (n = 9); fewer studies evaluated the effect on change in provider practice (n = 3) and/or patient

health outcomes (n = 5) (Kirkpatrick levels 3 and 4). Table 2 presents the application of respective Kirkpatrick levels in the learning interventions' training evaluation methods. Only a few of the included studies utilized more robust study designs, such as randomized controlled trials (RCT) and validated measurement instruments.

The interventions included in this review fall into two main categories: (**Table 3 & 4**): (1) Simulation training in routine neonatal care and NR, via Helping Babies Breathe (HBB) courses (n= 6) (Msemo et al., 2013; Erdsal et al., 2013; Seto et al., 2015; Bang et al., 2016; Bellad et al., 2016; Eblovi et al., 2017) and other training programs (n = 3)(Subbiah et al., 2012; Goudar et al., 2012; Vail et al., 2017), and (2) eHealth / eLearning initiatives (defined as the use of information and communication technologies (ICT) for learning)(n = 3) (WHO, 2011b)(Thukral et al., 2012; Prakash et al., 2016; Lund et al., 2016). Tables 3 - 4 present the studies per these categories respectively.

The studies are presented by category of teaching-learning approach:

(1) Simulation training with HBB and related training programs (n = 9)(Table 3)

Duration of trainings based on HBB and other training programs were from one to five days. Two of these studies reported on training using Essential Newborn Care (ENC)(WHO) and NRP programs (NRP)[American Academy of Pediatrics (AAP)] (Subbiah et al., 2012; Goudar et al., 2012).[1] One training utilized the (*Programa de*

[1] HBB, launched in 2010 by the American Academy of Pediatrics (AAP), in collaboration with WHO and other global partners, is an evidence-based curriculum in basic neonatal care and resuscitation, utilizing simulation-based training, to educate large numbers of birth attendants in LMIC's in order to reduce global neonatal mortality (Ersdal et al., 2013). ENC and NRP were later incorporated into the training program that became HBB, although both are still being used. HBB is centered on basic care for all babies (warmth, drying, stimulation and suctioning) and ventilation within the important 'Golden Minute' of life (Rule et al., 2017). This is accomplished through hands-on learning and practice using the "NeoNatalie" newborn simulator. HBB promotes active learning using hands-on skills practice with the newborn simulator, paired learning, self-reflection, and group discussion. Immediately following the training, learners are tested with four formative assessments to determine

Rescate Obstétrico y Neonatal: Tratamiento Óptimo y Oportuno) PRONTO Program, and was implemented for 1 week per month for 8 months (Vail et al., 2017). Over 3,000 HW's, mostly nurses and midwives, were trained across the nine studies in different aspects of basic newborn care and NR. All nine studies utilized low-cost and low-tech simulation technology with birthing simulator mannequins specifically designed for NR demonstrations and evaluations.

Subbiah et al. (2012) reported an increase in knowledge and skills among nurses in India subsequent to training with ENC and NRP. Goudar et al. (2012) reported on the results of a prospective community-based RCT in rural India. They found a significant decrease in perinatal mortality after provider ENC training. Randomization to NRP or refresher ENC training was done after the initial ENC training and no further reduction in mortality was noted in NRP designated facilities.

Implementation of HBB training in select rural Tanzanian hospitals was reported on in two studies. Ersdal et al. (2013) reported on data collected 7 months after HBB training in one hospital, where they found significantly increased skill scores for both routine newborn care and NR compared with pre-training scores. In contrast, in terms of provider behavior, neonatal management in the delivery room during the corresponding time period did not improve; the number of babies being suctioned

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learner competence and performance: a multiple-choice questionnaire, a bag-mask ventilation skills checklist, and two validated simulation evaluation tools called "Objective Structured Clinical Examinations" (OSCEs). The educational kit includes an action plan, a culturally adopted flip-over facilitator guide, and a student workbook; course material is largely pictorial with simple text. Though aimed at midwives, the curriculum can also be adapted for CHW's and TBA's with limited literacy. Supplemental oxygen, intubation, chest compressions, and medications do not enter the algorithm since these actions are not relevant for most of the babies requiring assistance (Ersdal & Singhal, 2013). Recently, HBB has been updated and incorporated into a suite of evidence-based training programs, "Helping Babies Survive" (HBS), which includes the HBB 2nd edition, "Essential Care for Every Baby" (ECEB) and "Essential Care for Small Babies" (ECSB) to address the other leading causes of newborn death (http://globalhealth.org/helping-babies-survive/)

and/or ventilated at birth did not change from pre-to-post training, and the use of stimulation in the delivery room paradoxically decreased after HBB training. Msemo et al.'s (2013) study in 8 facilities in Tanzania (including the one facility reported on by Ersdal et al.), reported that in the 2 years after HBB training, the frequency of stimulation and suctioning increased overall in the 8 hospitals and there was an associated sustained 47% reduction in Early Neonatal Mortality (ENM) within 24 hours of birth and a 24% reduction in fresh stillbirths.

Seto et al. (2015) tested HBB in one hospital in Honduras and reported that participants demonstrated statistically significant improvements in post-test scores for MCQ's, bag-mask ventilation, and "Objective structured clinical evaluation" (OSCE) B (complex resuscitation scenario). However, although participants achieved high scores on the knowledge test, they improved from 27.9 % pre-test to only 42.4% post-test ($p = 0.02$) for ventilation by the "Golden Minute". The 'Golden Minute'® is a term to denote the critical first minute after birth during which neonates should begin breathing spontaneously or receive assistance with adequate and effective bag-mask ventilation.

Research on HBB trainings conducted in 71 facilities in the National Institute of Child Health and Human Development (NICHD) Global Network research sites in India and Kenya found immediate post-training results for knowledge and skills to be significantly higher than at pre-training. However, at 6 – 7 months post-training, knowledge scores remained high (at 99%) while skill scores dropped by 20% on average (Bang et al., 2016). Noteworthy is that initial skill scores were only 5% on average out of 100% for 2,227 BA's including nurses, midwives, and medical doctors (MDs). Thus, the starting point was low in terms of provider competence. Bellad et

al. (2016) did an analysis of registered births in the local population, before and after HBB training in the same geographic clusters tested in the Bang et al. study. In this study, however, the researchers examined all births registered in the local population in the study areas - including non-facility births. Training was not associated with significant reductions in perinatal mortality, stillbirth, or neonatal mortality. Similar to Bang et al., Eblovi et al. (2017) found that immediate post HBB training skill scores waned when tested after 4 months, but scores rebounded to post-initial training levels after a refresher training.

Vail et al. (2017) reported on an in-situ simulation training in Bihar, India with primarily auxiliary nurses and midwives from 80 primary care facilities using PRONTO training over an 8 month period. The focus of the PRONTO training is on teaching providers to simultaneously manage maternal and neonatal complications rather than focusing on NR skills in isolation; trainings are conducted in resource-limited facilities where providers actually work, rather than in classrooms. The researchers video-recorded providers' NR simulations and coded for pre-defined clinical skills, with increasing clinical complexity of the simulated scenario (from the simplest scenarios requiring only NR to complex situations requiring simultaneous management of neonatal & maternal complications) (Vail et al.; 2017). The researchers measured time to completion of key steps in the NR algorithm as complexity increased and found that as complexity of simulations increased, the time elapsed between delivery and key NR steps decreased, although not significantly.

(3) eHealth / eLearning interventions (n = 3)(Table 4)

Studies focusing on eHealth/eLearning interventions for newborn HW's utilized the following approaches: (1) Internet-based distance learning in conjunction with local

hands-on skill enhancement (n = 1)(Thukral et al., 2012), and (2) mLearning initiatives (n = 2)(Lund et al, 2016; Prakash et al, 2016).

Course modules in Thukral et al. (2012) were delivered via distance learning over 5 weeks to nurses at 7 health facilities in India and the Maldives, and were moderated by online tutors. Participants managed case scenarios, participated in discussion forums and synchronous chat sessions. Local tutors at the partnering health facilities administered skill learning. Participants expressed favorable reactions to the training and scored significantly higher in knowledge and skills scores post-training as compared to pre-training.

In terms of MLearning initiatives, Prakash et al. (2016) evaluated the efficacy of a training and point of care tool, an Android-based mobile phone app, the "All India Institute of Medical Sciences (AIIMS) -WHO Collaborating Center Standard Treatment Protocols (STPs)", on the knowledge, skill scores, and satisfaction among Special Newborn Care Unit MDs in district hospitals managing sick neonates. The participants received a one-day training on four key topics related to key causes of neonatal mortality: hypothermia, seizures, shock, and nutrition for low birth weight babies and they were trained on how to access the treatment algorithms for these conditions on the app. Participants reported overall satisfaction and found the app to be user-friendly. Mean knowledge and skill scores for participants differed significantly from pre-to-post-training scores.

In a recent cluster-randomized controlled trial, the Safe Delivery App (SDA), designed as a training and point-of-care mobile phone resource to improve the management of obstetric and neonatal emergencies in low-income countries, was tested with rural healthcare workers in Ethiopia. The purpose of Lund et al.'s (2016)

study was to determine the effects of training and use of the SDA on health care workers' knowledge and skills in NR and on newborn perinatal survival. Use of the SDA was associated with statistically significant increases in knowledge and skill scores related to NR at both six and twelve months post-training and with a non-significant lower perinatal mortality in intervention clusters compared with control clusters.

Discussion

The purpose of this scoping review was to explore what is known from the existing research literature about technology-based newborn health learning initiatives for nurses and midwives in LMICs. In this review, we identified a number of studies focusing on simulation training for facility-based health workers using evidence-based training programs such as ENC, NRP, HBB and PRONTO. Additionally, we identified a limited number of studies utilizing eLearning initiatives, such as Internet based online learning and mobile phone apps. The content of the initiatives focused primarily on essential newborn care including basic neonatal resuscitation; one paper tested an app targeting interventions for sick newborns (Prakash et al., 2016). Collectively these interventions target facility-based prevention and treatment of the major causes of neonatal deaths, particularly perinatal deaths in the intra-partum period and during the first week of life, where intra-partum related "birth asphyxia" takes a heavy toll.

Results reported from simulation training programs (HBB, ENC, NRP) in this review varied widely, both in terms of skill acquisition and retention, and in terms of provider behavior and patient outcomes. Some studies reported positive and negative results within the same study. The variable results suggest that while short simulation

programs improve short-term knowledge and skills and may improve longer-term practice in the simulated setting, the training may be insufficient to enable HWs to integrate and translate those skills into clinical practice. Results also suggest that performance decreases significantly over time and requires refresher training (Bang et al., 2016; Eblovi et al., 2017). These finding are consistent with other literature on the topic (Erdsal & Singhal, 2013), which highlight the importance of programs targeting ongoing refresher training and local mentoring for skill retention in order to impact clinical management and patient outcomes and to increase sustainability. However, supervised practices for skill retention can be challenging and costly in resource-limited settings (Rule et al., 2017).

This review identified a dearth of studies focused on eLearning or other technology-based interventions, which points to the relative lack of studies on eLearning and mLearning interventions for newborn health workers in LMIC's, which is consistent with findings reported elsewhere (Chandrasekaran et al., 2014; Agarwal & Labrique, 2014). Thukral et al. (2012) demonstrated that online training is feasible and effective in increasing knowledge and skills and can be blended with skill learning in partnering institutions. Findings suggest that this blended approach might be an economical and expeditious way to cover a wide geographical region with uniform standardized education.

mHealth initiatives provided updated information to health workers through a training and point-of care algorithm-based app for Androids (Prakash et al, 2016) and through the Safe Delivery App, a learning resource for training providers on EmONC and for point-of-care use (Lund et al., 2016). Prakash et al. (2016) measured changes in knowledge and skill levels with MD's while Lund et al (2016) carried out a cluster

randomized controlled trial and measured changes and retention in birth attendants' knowledge and skill levels, demonstrating that the use of mobile phones is feasible for health care workers, irrespective of their educational level or prior training. Lund et al.'s study also found a non-significant lower perinatal mortality rate in intervention clusters compared with control clusters subsequent to SDA use.

Simulation training is generally an increasingly utilized methodology for training healthcare providers to manage obstetrical and newborn emergencies such as birth asphyxia (Vail, 2017). Simulation-based initiatives in this review primarily used mannequin-based simulation, which has grown in healthcare education and training as a method of teaching, learning, and performance evaluation (Taekman et al., 2017). The advantages of simulation training are that it provides concrete learning opportunities within "realistic" and reproducible contexts (Fuchs, Miller, & Berkowitz, 2009) and it engages providers to synthesize and apply knowledge and tasks according to a scenario, thereby promoting theoretical, cognitive, technical, and behavioral skills (Ersdal et al., 2013). Simulation is suitable for both pre-and in-service settings, thereby providing a continuum of training throughout a professional career (Nelissen et al., 2014). Additionally, simulation allows learners to practice new skills at their own pace, since scenarios can be slowed down to adapt to the needs of the learner. Scenarios can be used to train learners to prepare for emergency situations in a setting where no patient will be harmed from the initial attempts of performing a procedure unfamiliar to the learner and /or in situations that are too rare, serious, or expensive to re-create in real life (Stitely, Cerbone, Nixon, & Bringman, 2011). The disadvantages of simulation training are that it can be costly and requires specific equipment, learners to be physically present, and capable trainers, which may not be a

practical option for reaching health workers in the most remote settings.

Challenges are particularly acute for clinicians working in rural and remote areas since there is professional isolation, inadequate communication with peers in the cities, and a lack of appropriate equipment and technologies that hinder timely and appropriate quality obstetric and neonatal care (Ellard et al., 2016). mHealth and mLearning, which have been linked to expanding mobile phone penetration in LMICs, provide important opportunities for the delivery of health information and services to remote locations, expanding access by remote health workers to current evidence-based information in order to improve clinical decision-making and management of patients (Obasola et al., 2015; Agarwal & Labrique, 2014).

Evidence from systematic reviews and other studies suggest that mHealth initiatives can contribute to improving maternal and newborn health in a variety of ways. mHealth interventions can help by directing health prevention information to women, community workers and the public, expediting referrals for management of obstetric and newborn health emergencies, monitoring patient adherence to treatment regimens and conducting surveillance (Obasola et al., 2015; Lund et al., 2012; Lund et al, 2014; Amoakoh-Coleman et al., 2016; Lee et al, 2016). Advantages of mHealth initiatives are many, including reduced program cost, practicality in contexts where there are insufficient numbers of available instructors to provide quality training (Thukral et al., 2012), and ease of collaboration with individuals in remote locations at flexible times. Apps are also easy to share and can be updated easily as clinical practice guidelines evolve (Prakash et al., 2016). An additional benefit of mLearning and online learning is self-paced learning with standard course delivery and monitoring, allowing the learner to tailor their own learning objectives and giving the

learner control over content and pace of learning. The findings from Lund et al. (2016) support those of other studies, that providers perceive the use of mobile tools as a promising opportunity for health care workers' self-improvement with effects on their motivation, self-efficacy, and enthusiasm, in contrast to passive learning models (Chandrasekaran et al., 2014; Labrique, Vasudevan, Kochi, Fabricant, & Mehl, 2013).

The feasibility of mLearning has advanced beyond earlier barriers of bandwidth and the cost of Internet access (Obasola et al., 2015). However, despite the rapid growth of mHealth and eHealth programs, research and evidence on their effectiveness are scarce. (Agarwal, Perry, Long, & Labrique, 2015; Tomlinson, Swartz, Rotheram-Borus, & Tsai, 2013; Sondaal et al, 2016; Batavia & Kaonga, 2014). More specifically, there is a lack of trials of mobile phone and other eHealth interventions in LMIC's that have health outcomes, or level 4 Kirkpatrick findings, as a primary outcome (Obasola et al., 2015, Lund et al., 2016). One review hypothesized that the lack of evidence related to mHealth may be because organizations piloting mHealth projects in the field are perhaps more focused on implementation of mHealth tools and are opting to publish open-source grey literature and white papers, rather than peer-reviewed papers (Batavia & Kaonga, 2014).

Our identification of studies was defined by our selected databases and search terms, which may have resulted in relevant studies being missed from dfferent databases or associated key terms. Additionally, we were limited to analysis of the results reported in the studies that made comparisons between learning interventions difficult due to lack of comparable data. Future research on simulation training and mHealth/eHealth must therefore emphasize robust study designs, using valid and reliable measurement instruments, and measuring higher-level outcomes such as

behavior change and patient results, as well as examining standardized evaluation techniques for mHealth (Amoakoh-Coleman et al., 2016, Chandrasekaran et al., 2014). Feasibility studies in remote areas are needed to determine if certain technology-enhanced approaches are viable for the specific context or country, as well as cost analyses, to identify potentially scalable approaches leading to better coverage of skilled birth attendants (BA's) proficient in essential newborn care and neonatal resuscitation.

Conclusion

Given the high costs and logistical challenges of in-person training programs in low-income settings, the healthcare workers who most need support are often the least likely to receive it. Studies examined here propose innovative technology-based learning initiatives as a way to address gaps in resource-poor locations. Learning approaches emphasizing simulation training and eHealth initiatives for facility-based maternal and newborn health workers hold promise for identifying potentially scalable approaches towards establishing better coverage of skilled birth attendants (BA's) who are proficient in essential newborn care and neonatal resuscitation. This is especially critical for health workers in more remote areas, where maternal and newborn mortality are the highest. However, existing simulation literature demonstrates that translation of knowledge gained during simulation into improved clinical outcomes in real births is difficult and variable. The volume of evidence demonstrating the potential benefit of mHealth strategies, especially in the neonatal period, is limited. Learning initiatives with high priority content and demonstrated effectiveness should be tested using rigorous research methods to determine long-term effectiveness and to measure cost-effectiveness in different contexts and priority

areas, however mHealth and blended learning initiatives combining distance learning and simulation training hold many advantages. Future research is suggested documenting patient outcomes due to technology-based learning interventions, in order to enhance the quality of care of nurses and midwives in maternal and newborn health.

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MS 2, Figure 1.0 Integrative Review: PRIMSA Flow Diagram

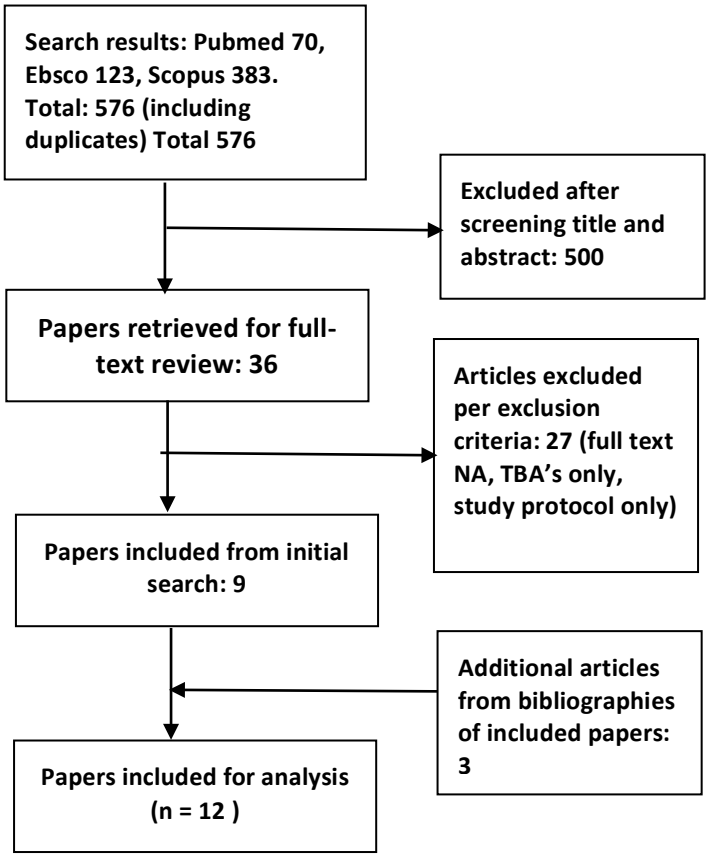

Table 2.0 – Kirkpatrick levels measured

First Author, Year	*Measures*	*Kirkpatrick level*
Simulation training with HBB course (n = 6) and other training methodologies (n=3)		
Subbiah et al., 2012	**Knowledge & Skills**: Structured knowledge questionnaire on NNR. Observational checklist on routine care and NNR.	2: Learning
Goudar et al., 2012	**Results:** Birth, 7-day and 28-day neonatal outcomes	4: Results
Msemo et al., 2013	**Behavior:** Use of stimulation, suctioning and FMV was monitored in pre-and post intervention births. **Results:** The primary outcomes were a reduction in early neonatal deaths within 24 hours and rates of fresh stillbirths (FSB).	3. Behavior 4: Results
Ersdal et al., 2013	**Skills:** Two simulation scenarios, "routine care" and "neonatal resuscitation", were performed by 39 providers 7 months before (September 2009) and 27 providers 7 months after (November 2010) the HBB training in April of 2010. Two independent raters scored the videotaped scenarios for "pass/fail" performance and different skills. **Behavior:** Observational data was collected in the delivery room during 7 months pre (n = 2745) and 7 months post (n = 3116) the HBB training (April 2010) by observing all hospital births during the same period.	2: Learning 3. Behavior
Seto et al., 2015	**Reaction to training:** Pre-and post confidence levels, post-course satisfaction **Knowledge & Skills test**: MCQ's pre-and-post for NNR knowledge. Bag-mask ventilation skills checklist (a 7-item checklist of skills to perform effective ventilation) and 2 OSCE's (A - one for routine newborn care)(B - one complex resuscitation scenario). Pre-specified scoring guidelines for skills tests and 2 raters for OSCE B.	1: Reaction 2: Learning
Bang et al., 2016	**Knowledge & Skills:** Compared pass rates for skills and knowledge pre- and post- initial HBB training and following refresher training among BAs. OSCE B tested resuscitation skill retention by comparing post-initial training performance with pre-refresher training performance.	2: Learning
Bellad et al., 2016	**Results**: Comparison of pre & post fresh stillbirth rates (FSR) and numbers of fresh stillbirths (FSBs) and 7- day neonatal mortality rate (NMR) giving composite PMR, among all live registry births and registry births in HBB-trained facilities.	4: Results
Eblovi et al. 2017	**Skills:** Trainee skills were evaluated by OSCE at three time points: immediately and 4 months after training, and four months after the refresher training. **Behavior**: Midwives recorded in logbooks the highest level of NNR performed newborns delivered for one year. **Results:** The rate of mortality in the first 24 hours of life documented by the midwives during the one-year study period was compared with nationwide estimates of first 24 hour mortality in Ghana from 2007–	2: Learning 3. Behavior 4: Results

First Author, Year	*Measures*	*Kirkpatrick level*
	2013.	
Vail et al., 2017	**Skills test**: Skills evaluated by clinical complexity of the simulated scenario, which ranged from level 1, requiring NNR without a maternal complication, to level 3, requiring simultaneous management of neonatal & maternal complications. Simulations were video-recorded and coded for pre-defined clinical skills using "Studiocode" as part of training protocol.	2: Learning
eHealth / eLearning interventions (n = 3)		
Thukral et al., 2012	**Reaction:** Participants satisfaction evaluated on a five-point Likert scale **Knowledge & Skills:** Knowledge and skill changes were evaluated by administering online multiple-choice test questions (MCQs) and on-site objective structured clinical evaluation (OSCE) stations before and after completion of the course.	1: Reaction 2: Learning
Lund et al., 2016	**Knowledge & Skills:** Knowledge and skills in NNR were assessed at baseline and at 6 and 12 months after the intervention. Knowledge & skills assessed via questionnaire and objective structured assessment tools of technical skills respectively, using simulated scenarios with scoring on skills performance on mannequins. **Results:** Perinatal mortality was defined as a composite of a stillbirth or an early neonatal death. Outcome was recorded at delivery.	2: Learning 4: Results
Prakash et al., 2016	**Reaction:** Participants satisfaction evaluated on a five-point Likert scale **Knowledge & Skills:** Knowledge and skill changes were evaluated by administering online multiple-choice test questions (MCQs) and on-site objective structured clinical evaluation (OSCE) stations before and after completion of the course. baseline knowledge and skill scores of pediatricians working in SNCUs in the state of Tamil Nadu, India (n = 32) were assessed by 25 multiple choice questions (MCQs) and by five Objective Structured Clinical Examination (OSCE) skill stations.	1: Reaction 2: Learning

Table 3. Simulation training with HBB course (n = 6) and other methodologies (n=3)

Citation	Study Design	Participants	Intervention	Key Findings
Subbiah et al. 2012	Prospective intervention study, with one group pre & post, to assess the effectiveness of NRP educational intervention in terms of knowledge and skill of nurses; modules developed by National Neonatology Forum, India.	Nurses working in nursery, labor room, postnatal ward of secondary and tertiary hospitals across the country. n= 71 Setting: India	5 day NRP workshop on routine neonatal care and NNR using lecture, discussions and demonstrations followed by hands on training using mannequins.	**Knowledge & Skills:** Mean difference in knowledge from pre-to-post was 11.6 out of 45 ($p < .001$). Skills mean difference 7.8 out of 33 ($p < .05$).
Goudar et al. 2012	Study was part of a multi-country prospective, community-based cluster RCT, to evaluate the effect of WHO ENC* course and the AAP NRP training on perinatal mortality in rural India.	All women with pregnancies greater than 28 weeks. n = 25,096 births Setting: 26 study communities in Karnataka, India	Mortality rates pre & post ENC training were collected prospectively and then communities were randomized to either receive (NRP) training or refresher newborn care training in the control clusters. Trainings were 1 – 5 days.	**Results:** Perinatal mortality for infants ≥500 g decreased from 52 to 36/1000 after ENC training (RR 0.7; 95% CI 0.5, 0.9); Mortality was not reduced further with NR training.
Msemo et al. 2013	Prospective intervention study, with one group pre & post, to determine if implementation of the HBB educational and training program would reduce Early Neonatal Mortality (ENM) on day 1 (within 24 hours of birth) by 50% and reduce by 25% the rates of fresh stillborns (FSBs).	Births in 8 pilot hospitals over 2 months prior to HBB training in Sept. 2009; post-implementation data collection was initiated after the initial training of providers in each hospital until March 2012. n = pre (n = 8124) and post (n = 78,500) Setting: Tanzania	2 days training of 40 master trainers from 8 pilot hospitals, then a 1-day training of HWs (primarily midwives) at each hospital progressively over a 9 month period. A simulator was placed in the labor and delivery suite where every provider documented application of basic skills including FMV before starting a shift.	**Behavior:** Use of stimulation increased from 47% to 88% (RR 1.87; 95% CI 1.82–1.90; $p < .0001$) and suctioning from 15% to 22% (RR 1.40; 95% CI 1.33–1.46; $P < .0001$). **Results:** Implementation associated with a sustained 47% reduction in ENM and a 24% reduction in fresh stillbirths after 2 years.

Ersdal et al. 2013	Prospective intervention study, with one group pre & post, to (1) determine the effect on practical skills and clinical management seven months after HBB training, and (2) describe neonatal management in the delivery room during the pre-and-post time period.	Midwives, nurses, and ward attendants (assistants without any formal medical education). n = 39 (pre) and 27 (post) Setting: Tanzania, in one rural hospital from above sample	The one-day HBB training was conducted in April 2010. The course methodology focused on hands-on practice using a simulator mannequin, emphasizing the very first basic steps; drying, stimulation, suction, warmth, and initiation of FMV within the "Golden Minute**® after birth.	**Knowledge & Skills:** Providers who "passed" the simulated "routine care" & "NR" scenarios increased from 41 to 74% ($p = 0.016$) and from 18 to 74% ($p \leq 0.0001$) respectively. **Behavior:** The number of babies being suctioned and/or ventilated at birth did not change from pre-to-post, and the use of stimulation in the delivery room decreased after HBB training.
Seto et al. 2015	Prospective intervention study with one group pre & post, to assess the acquisition of knowledge and skills following HBB training; emphasis on the "Golden Minute"* following birth.	Nurse-midwives, MD's n= 70 (39 nurses, 31 MD's) Setting: Honduras, Hospital Enrique Aguilar Cerrato (HEAC)	One-day, 8-hour workshop using the Spanish HBB translation and action plan, newborn simulators, and bag-mask ventilation.	**Knowledge & Skills:** Statistically significant improvements in post-test scores for MCQ's, bag-mask ventilation, and OSCE B. Achievement of ventilation by the "Golden Minute" improved from 27.9 % pre-test to 42.4% post-test ($p = 0.02$).
Bang et al. 2016	Prospective intervention study, with one group pre & post initial and refresher training to explore the impact of initial HBB training followed by refresher training a mean of 6.7 (SD 2.49) months (in the 71 facilities) after the initial training, on the knowledge and skills of the birth	BA's (midwives, nurses, MD's) trained (n = 2227) across 71 facilities & 52 geographical clusters n = 2,227 in initial training; n= 835 in refresher training Setting: Nagpur and Belgaum, India and	Three-day HBB trainings conducted in 71 facilities in the NICHD Global Network research sites (Nagpur and Belgaum, India and Eldoret, Kenya). Daily bag and FMV practice, equipment checks and supportive supervision were stressed as part of training.	**Knowledge & Skills:** The pass percentage for knowledge tests improved from 74 to 99% ($p < 0.001$) post initial training.Ventilation training test improved from only 5% to 97% post-initial training ($p < 0.0001$). During pre-refresher training evaluation, 99% passed knowledge test, but successful completion rate for

	attendants in facilities.	Eldoret, Kenya		the OSCE B fell 99% (post-initial training) to 81%.
Bellad et al. 2016	Prospective population-based registry study pre & post HBB program implementation, to explore whether facility-based implementation of (HBB) reduces neonatal mortality at a population level in LMIC's.	BA's (same as above) n= 70,704 births >1500 g in 52 clusters (35,000+ pre and 35,000+ post)(46% of registry births in the 71 sites) Setting: Kenya & India (same as above)	HBB training as above and monitoring to selected facilities included training, direct supervision, accountability measures for delivery room record-keeping, bag & mask ventilation practice, resuscitation debriefings, death audits, site visits, etc.	**Results:** HBB training of facility BAs was not associated with significant population reductions in perinatal mortality, stillbirth, or neonatal mortality among all neonates ≥1500 g; however, in the Kenyan facilities, the PMR and FSBR decreased. The pre-post changes in mortality in the HBB trained facilities in India were not significant.
Eblovi et al. 2017	Prospective intervention study, with one group post intervention only at 3 points in time, to determine the impact of HBB trainings provided to rural Ghanaian midwives on their skills retention. They also had midwives record births post-training in logbooks, to examine first 24-hour mortality of the newborns they served for a year.	Midwives n= 48 Setting: Ghana, rural health clinics	AAP trained Master Trainers provided two 2-day HBB trainings (n= 24 each) and 2-day refresher courses one year later; initial sessions including introduction of the material, discussion, hands-on instruction, and repetitive practice of resuscitation techniques using NeoNatalie® mannequins with various clinical scenarios.	**Skills:** OSCE scores decreased from immediately after training (94.9%) to 4 months later (81.2%, $p < 0.001$). Four months following refresher course, scores improved to same level attained initially (92.7%, $p = 0.001$). **Behavior:** 5.0% of newborns required FMV; % consistent with global estimates. **Results:** 0.71% of neonates did not survive, compared with a nationwide first 24-hour mortality estimate of 1.7%.
Vail et al. 2017	Quasi-Experimental design – one group post-test only at various points in time (weeks 3, 5,	Nurses and midwives at 80 primary health facilities: 89% Auxiliary Nurses/Midwive	Training 1 week per month for 8 months implemented by trained nurse mentors.	**Skills:** 298 videos requiring NNR simulation were analyzed; as simulation complexity increased,

	and 7) to assess the impact of an in-situ simulation training program (PRONTO) on NNR skills of nurses in Bihar, as part of PRONTO focus on simultaneous care of the mother-infant dyad.	s (ANM's), 11% General Nurses/ Midwives (GNM's). n= 658 Setting: Bihar, India	* Skills evaluated by clinical complexity of the simulated scenario, which ranged from level 1, requiring NNR without a maternal complication, to level 3, requiring simultaneous management of neonatal & maternal complications. Simulations were video-recorded and coded for pre-defined clinical skills using "Studiocode"	% simulations in which nurses completed key steps of NNR did not change, suggesting that they were able to maintain key skills despite higher clinical demands. As simulation complexity increased from level 1 to 3, time to completion of key NNR steps decreased non-significantly.

* ENC includes evidence-based guidelines for routine care and initial management of neonates following birth and during the first week after birth, including routine neonatal care, initiation of breathing and resuscitation, thermoregulation, early and exclusive breastfeeding, skin-to-skin care, care of the small baby, counseling on baby care and danger signs, and recognition and initial management of complications.

**The 'Golden Minute'® is a term to denote the critical first minute after birth during which neonates should begin breathing spontaneously or receive assistance with adequate and effective bag-mask ventilation.

Table 4: eLearning Interventions (n= 3)

Citation	Study Design	Participants	Interv ention	Key Findings
Thukral et al. 2012	Prospective intervention study with one group pre & post, to evaluate the efficacy of internet-based distance learning in conjunction with local hands-on skill enhancement in improving knowledge and skills of essential newborn care among in-service nursing health professionals.	Nurses from seven health facilities (n = 98) Setting: India & Maldives	Delivery of course material over 5 weeks (2 lessons per week), moderated by online tutors. Participants managed case scenarios, and participated in discussion forums/ synchronous chat sessions. Local tutors at the partnering health facilities administered skill learning.	**Reaction:** 79% completed the evaluation and 100% of respondents expressed satisfaction **Knowledge & Skills:** There was a significant increase in knowledge and skills scores: MCQ test: mean difference: 6.4 (95% CI: 5.6–7.17, $p < 0.001$), OSCE: mean difference: 15.4 (95% CI: 12.7–18.1, $p < 0.001$).
Lund et al. 2016	Cluster-randomized clinical trial with the facility as the unit of randomization, to determine the effects of the safe delivery app (SDA) on perinatal survival and on health care workers' knowledge and skills in neonatal resuscitation (NR). The SDA is a training tool in emergency obstetric and neonatal care that uses visual guidance in animated videos with clinical instructions for management.	Women in active labor (n = 3601) were included at admission and followed up until 7 days after delivery to record perinatal mortality. Health workers (n= 176) n = 70 health care facilities: 35 intervention / 35 control Setting: Ethiopia (5 rural districts)	HW's in intervention facilities received a smartphone with the SDA and a 1-day introduction to use of the smartphone / SDA with group video viewing. At control facilities, the HW's provided standard care without the assistance of the SDA.	**Knowledge & Skills:** Knowledge change corresponded to 39% and 38%, respectively at 6 & 12 months, above the control level. Skills change corresponded to 80% and 107%, respectively, above controls. **Results:** Use of the SDA was associated with a non-significant lower perinatal mortality of 14 per 1000 births in intervention clusters compared with 23 per 1000 births in control clusters (odds ratio, 0.76; 95% CI, 0.32-1.81).

Prakash et al. 2016 [35]	Prospective intervention study with one group pre & post, to evaluate the efficacy of a point of care tool- Android based App- "All India Institute of Medical Sciences (AIIMS) - WHO CC Standard Treatment Protocols (STPs)" on the knowledge, skill scores, and satisfaction among Special Newborn Care Unit (SNCU) physicians managing sick neonates.	Pediatricians (n = 32) Setting: Tamil Nadu, India	The training of participants on four modules: (1) Hypothermia, (2) Seizures, (3) Shock, and (4) Feeding of the low birth weight baby, was done in a one day workshop with presentation of the algorithmic management of the respective clinical conditions on the "App", followed by interactive discussions and group video viewing with demonstration.	**Reaction:** The median (IQR) satisfaction score with the course was 4 (out of 5) (Likert's scale). Focus group discussion revealed that participants were satisfied with the teaching methodology. **Knowledge & Skills:** Mean knowledge scores [19.4 vs. 10.7 out of 25, mean difference 8.7 (95 % CI 7.6 to 9.9)], and the composite mean skill scores [55.2 vs. 42 out of 75, mean difference 13.2 (95 % CI 10.4 to 15.9)] improved after training.

mLearning in the DR Congo:

A Mixed Methods Feasibility and Pilot Cluster Randomized Trial

using the Safe Delivery App

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Abstract

Background: Sub-standard delivery care has been widely documented as a major cause of maternal mortality in health facilities globally**.** The availability and use of mobile phones is increasing rapidly in low-income countries, as is learning via mobile devices, referred to as mLearning; however, there is little evidence of mLearning effectiveness. This study sought to determine the feasibility, acceptability, and potential effect of the Safe Delivery App (SDA)© on health workers' practices in basic emergency obstetric and newborn care (BEmONC) in the Democratic Republic of the Congo (DRC). The Theoretical Domains Framework was used to guide this research.

Methods (Design, Setting, and Participants): In a cluster-randomized and mixed methods pilot trial in 2 health zones of central DRC, 8 facilities were randomized to either an mLearning intervention or to standard practice (control) from April - July 2017. Knowledge in post-partum hemorrhage and neonatal resuscitation, as well as provider self-confidence in managing obstetric complications were assessed at baseline and at 3 months post-intervention among 62 maternal and newborn health care workers at the included facilities. The research team conducted 18 interviews with app users and key stakeholders to assess feasibility and acceptability of mLearning and the use of the SDA in the context of central DRC. Maternal mortality was compared pre-and-post intervention between intervention and control facilities using a smartphone-based Open Data Kit (ODK) data application designed for this study.

Interventions: Health workers in intervention facilities were trained on the use of a smartphone, the SDA, and the ODK data collection instrument. The SDA is a training

resource for emergency obstetric and neonatal care with visual guidance using animated videos and clinical management instructions. The French translation of the SDA was tested in this study. One smartphone with SDA and ODK was entrusted to each intervention facility for the study period, whereas control facilities received smartphones with ODK only.

Main Outcomes and Measures: Primary outcomes were provider knowledge of clinical signs and management of post-partum hemorrhage and of neonatal resuscitation, and self-confidence on the provision of BEmONC services, before the intervention and after 3 months. Secondary outcomes included maternal mortality and other key outcome data in the facilities, and qualitative interview findings. Eighteen qualitative interviews were coded using the Theoretical Domains Framework.

Results: The quantitative analysis included 62 heath workers. Knowledge scores for post-partum hemorrhage and neonatal resuscitation increased significantly from baseline among intervention group participants compared with controls at 3 months post-intervention (mean difference, 17.4 out of 100; 95% CI, 10.7-24.0 and 19.4; 95% CI 11.4-27.4 respectively). Self-confidence scores on 12 essential BEmONC procedures also significantly improved among intervention group participants compared with those of controls at 3 months (mean difference, 4.2 out of 48; CI 0.7 – 7.7). Increases were unaffected by health worker cadre, previous smartphone use, or provider gender. Qualitative interviews with 18 SDA users and key stakeholders supported the feasibility and acceptability of the SDA and mLearning, and the potential for it to impact maternal and neonatal mortality in the DRC, particularly in terms of making evidence-based, up-to-date global BEmONC guidelines available to health workers via an exciting mLearning app.

Conclusion: SDA use and mLearning was feasible and acceptable to health workers and key stakeholders in the DRC. The app supported increased health worker knowledge and self-confidence in the management of obstetric and newborn emergencies 3 months after introduction, and it indicated preliminary encouraging effects on health workers' BEmONC practices.

Keywords: mLearning, Congo, obstetric, newborn, continuing education, low-income countries, Theoretical Domains Framework

Introduction

Health worker clinical performance is often inadequate in low-and middle-income countries (LMICs).[1] Sub-standard delivery and emergency obstetric and newborn care (EmONC) has been widely documented as a major cause of maternal and newborn mortality in health facilities globally.[2] Worldwide, approximately 830 women die daily from preventable causes related to pregnancy and childbirth[3], and almost 2 million newborns die in the first week of life every year.[4] LMICs accounted for approximately 99% (302,000) of global maternal deaths in 2015, with sub-Saharan Africa alone accounting for about 66% of deaths (201,000).[5] The Democratic Republic of Congo (DRC), the largest country in sub-Saharan Africa, has one of the highest maternal mortality ratios in Africa (846 maternal deaths per 100,000 live births).[6] A woman's lifetime risk of maternal death, or the probability that a 15-year-old woman will eventually die from a maternal cause, is estimated to be 1 in 24 in the DRC, compared with 1 in 3,300 in high-income countries.[5] Neonatal deaths, or deaths before 28 days of life, are estimated at 30 per 1,000 live births in the DRC.[4] Worldwide, disparities in maternal and child health outcomes largely reflect inequalities in access to quality health services.[3]

Deficits in health worker knowledge and skills are linked to suboptimal patient outcomes in low-resource settings.[7-9] Maternal care providers demonstrate low knowledge levels of EmONC, despite varying years of provider experience, and poor clinical management skills of post-partum hemorrhage (PPH).[2,10-12] PPH is the leading cause of maternal mortality worldwide[13], and PPH management is one of the seven "signal functions" of Basic EmONC (BEmONC), or key medical interventions that must be provided by all skilled birth attendants. An outreach gap exists wherein health

workers in peripheral health facilities are not properly trained to manage obstetric emergencies.[14] Additionally, in low delivery settings, emergencies do not occur sufficiently often for providers to become experienced in obstetric complication management.[15]

A basic strategy for changing health worker behavior and strengthening clinical performance is promoting continuing education (CE) or continuous professional development.[16] However, for many health workers, access to relevant up-to-date learning opportunities is difficult or impossible to obtain, particularly in hard-to-reach or peripheral settings where maternal and newborn mortality are highest.[10, 17-18] The availability and use of mobile phones is increasing rapidly in LMICs[19], as is learning via mobile devices, referred to as mLearning. Given the costs and logistical challenges of providing in-person, conventional CE training programs peripherally, the use of mobile phones and other mobile electronic devices holds promise as new mechanisms to reach more remote health care workers with up-to-date information.[20] However, there is little evidence of mHealth effectiveness as most of the studies examining mLearning are of poor methodological quality, and few have evaluated the effects on client health outcomes. [21-23]

This mixed methods feasibility and pilot cluster randomized controlled trial (RCT) sought to determine the feasibility, acceptability, and potential impact of a recently developed evidence-based mLearning training tool known as the Safe Delivery App (SDA)© on knowledge, self-confidence, and practice of facility-based health workers in maternal and newborn health in the DRC. The trial also sought to refine intervention delivery in the DRC and strengthen study procedures required to conduct a robust future large-scale trial. The Theoretical Domains Framework (TDF) guided

this study, which views health professional behavior change as key to increasing the uptake of evidence into healthcare practice.[24]

Methods

Study design

This feasibility pilot study was a cluster-RCT with the health care facility as the unit of randomization, which followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines for reporting pilot and feasibility trials.[25] Using mixed methods convergent parallel design[26], the principal investigator (PI) conducted qualitative semi-structured interviews with app users and key stakeholders.[27] Additionally, select patient outcomes were compared pre-and-post intervention. The DRC Institutional Review Board (IRB) housed at the Protestant University of Congo (UPC) provided ethical clearance for the study in April 2017. Medical University of South Carolina (USA) IRB also approved the study in April 2017.

Setting

The study took place over three months (April – July 2017) in two Health Zones (Kindu, Alunguli) in the Province of Maniema, an under-resourced area in central DRC with weak infrastructure and some of the poorest maternal and newborn health outcomes in the country.[6] Ten health care facilities constituted sites eligible for cluster randomization owing to their being accessible by vehicle and being designated as EmONC centers supported by the Access to Primary Health Care Project (ASSP) project. ASSP, led by international non-governmental organization (NGO) IMA World Health (IMA), is a health systems strengthening and primary care redevelopment project funded by the UK government. The project is carried out in

collaboration with the Congolese government and an array of local and international partners to revitalize the country's health system in targeted health zones, fight disease, and improve key health indicators, particularly related to maternal and child mortality.[28] As designated EmONC centers, the ten facilities (one hospital and four health centers per zone) have received EmONC commodities and equipment, and personnel have participated in EmONC trainings.

Randomization

Identified facilities were stratified by type into hospital or health center categories (Figure 1 – Consort Diagram). In the hospital category, one facility was selected randomly, using an urn filled with labeled papers, from the matched group of two facilities. One health center was excluded due to being non-functional. In the health center category, three centers were chosen randomly from among the seven matched health centers for intervention and three for control, giving a total of four intervention and four control facilities (n = 8).

Participants

Medical Doctors (MDs), nurses, and midwives working in the selected facilities who manage deliveries and newborn care were invited to participate in the study. The study population included 64 health care workers at the 8 selected health care facilities (**Figure 1**). Attrition included two individuals (MDs) in the Intervention group who completed the pre-test but were unable to participate in the post-test due to ill health. For this mixed methods study, the PI conducted qualitative semi-structured interviews with two categories of professionals for a cumulative total of eighteen (18) interviews: (1) ten key stakeholders in Kinshasa (national capitol) and Kindu (capitol of Maniema Province); and (2) eight app users. For key stakeholders, the researcher

utilized “snowball sampling”, which relies on the personal networks of the persons the researcher taps into for referrals to other key persons.[29] Key stakeholders included educational, policy and program leaders, and health service leaders in the field. App users owere identified as a convenience sample from among users trained on the app from the study facilities in Kindu.[26] All study participants provided verbal consent after they were informed about the purposes of the study during a site visit by the research team and were given IRB approved written information (“Information for Participants Sheet”), assuring the confidentiality of all information obtained during the study and informing them of their right to withdraw from the study at any time without any effect on their employment status. The study participants and the clinic staff were not masked because the intervention required overt participation. Facilities were randomized rather than individuals to avoid contamination among health care workers in the same facility, such as health care workers showing the application and animation videos to the control group.[14]

Intervention

The SDA© is a training tool and job aide developed by the Maternity Foundation, University of Copenhagen, and the University of Southern Denmark. It was designed to reinforce the capability and confidence of health care workers in low-income countries on how to manage basic obstetric and neonatal emergencies**.** The content of the app is based on global clinical BEmONC guidelines and has been validated by an international group of global health experts.[15] The SDA can be downloaded free of charge for iPhone at the App Store or for Android: https://play.google.com/store/apps/details?id=dk.maternity.safedelivery.

The SDA conveys knowledge and skills via animated videos and instructions on key procedures. It also contains information on essential drugs for BEmONC. All features and functions are designed for low-literacy, low-income settings and work completely offline once downloaded. The 10 instruction films include the seven signal functions of BEmONC as well as three additional essential procedures (infection prevention, management of infection in newborns and active management of the third stage of labor). The French version of the SDA was pre-downloaded to the study Android smartphones, due to poor Internet connectivity in the region, and one smartphone was allocated per facility. A specially designed Open Data Kit (ODK) data collection instrument was also loaded onto the smartphones to collect information on BEmONC vital statistics and signal function execution, to be entered manually by facility staff daily.

Staff in participating facilities received explanation of the nature and purpose of the trial. Intervention health care workers received a half-day training session on the use of the smartphone, SDA, and ODK, with joint app video viewing and discussion. At the non-intervention health care facilities, the health care workers provided standard care without the assistance of the SDA. However, training was conducted for the smartphone-based ODK data collection, as data was collected at control facilities in the same manner as at intervention facilities during the study period. To ensure equal possibilities to provide standard care, the availability of a minimum package of drugs and equipment was ensured by the ASSP project in both groups of facilities. For the 3-month study period, the smartphone with SDA was available to all maternity providers at the intervention facilities. Solar panel battery chargers were given to all 8 facilities with the smartphones to ensure consistent ability to charge.

Providers were instructed to use the SDA as often as they wished and that the phone should be made available to the team on duty at all times. Ministry of Health supervisors were tasked with visiting intervention and control facilities weekly to remind providers to use the app and /or the ODK.

Theoretical Framework

The Theoretical Domains Framework (TDF) was used to guide this research. The TDF positions health professional behavior change as key to increasing the uptake of evidence into healthcare practice.[24] The initial aim of the TDF was to simplify and integrate a number of behavior change theories to provide a theoretical lens through which to view the cognitive, affective, social and environmental influences on provider behavior.[30-31] Explanatory constructs from 33 theories of behavior change were reduced and grouped into 14 'theoretical construct domains'; each of which consists of a grouping of theoretical constructs, which are proposed as potential mediators of behavior change. [30-31] The TDF provides a useful conceptual basis for assessing implementation problems of evidence-based care and understanding provider behavior-change processes.[24] In this research the TDF influenced the design of interview questions to explore the specific content of these domains in relation to barriers and facilitators with the use of the SDA, mLearning, and CE implementation in the DRC. The TDF was also used as the coding framework for analysis. (Table 1 for TDF domains, definitions and domain constructs.)

Outcomes & Measures

The primary outcomes of the pilot SDA trial were self-confidence and knowledge scores by the health care workers. Self-confidence and knowledge data collection instruments were developed, tested (in English) and translated into French by the

Maternity Foundation in Copenhagen. Reliability and validity measures have not yet been published for these measures; this study will contribute to the assessment of the measures. Self-confidence scores were assessed for twelve essential BEmONC services. Knowledge scores were assessed for two key BEmONC services, management of PPH and neonatal resuscitation (NR) at baseline and at 3 months post-intervention. Additionally, baseline demographic characteristics were collected for the health workers in intervention and control groups.

Births, maternal deaths, obstetric complications, and execution of BEmONC signal functions was assessed in intervention and control clusters post intervention using a smartphone-based Open Data Kit application designed for this study by the researchers and piloted with the SDA, as part of an examination of study procedures for a future adequately powered randomized-controlled trial. ODK-generated data was compared with hand collected statistical data from health facility registers and with HIS data.

Feasibility and acceptability of the SDA was assessed through qualitative semi-structured interviews with app users. Additionally, key stakeholder perspectives were assessed on the use of mLearning more broadly in the DRC.

Data Collection

Data collection was conducted in parallel in the intervention and control facilities using the same methods at baseline and 3 months after the training intervention. Measures were taken prior to the training of facility-based providers on the SDA and included 1) demographic data of participant health workers, 2) provider self-rated self-confidence in handling twelve essential services of BEmONC, and 3) provider knowledge of two key BEmONC services: management of postpartum hemorrhage

(PPH) and neonatal resuscitation (NNR). All data were collected on paper in a classroom setting; knowledge scoring was provided by the SDA. Results were entered in Excel and subsequently transferred and analyzed in SPSS (version 23; SPSS Inc). Three months after the SDA introduction, self-confidence and knowledge were measured a second time in the classroom using the same data collection instruments.

The PI developed two qualitative interview guides for the two qualitative target groups (SDA users and key stakeholders) using the theoretical construct domains of the Theoretical Domains Framework (TDF)[24] to guide the questions (**Table 1**). Semi-structured interviews were audio recorded by the PI with eight SDA users and ten key stakeholders after the 3-month study period. SDA users were asked about the feasibility and acceptability of using the SDA and barriers and facilitators to its use. Key stakeholders were asked about the feasibility and acceptability of the use of mLearning and CE in the DRC more broadly, as well as barriers and facilitators to the implementation of CE.

Facility-based reporting of select health outcomes collected with the use of the ODK was compared with data reported in the District Health Information System (DHIS - 2)(to be referred to as HIS), and with data collected by hand-review of health facility registers by the PI. Data was collected by hand at baseline for the 3 months prior to the intervention and at 3 months post-intervention for comparison. The ODK app was developed for this research study and piloted during the study period in the eight intervention and control facilities. The ODK data were entered by the health workers into mobile phones provided by the project immediately post-delivery/event and were available immediately online for consultation from any location.

Statistical Analysis

Descriptive summary statistics were analyzed on demographic data including age, gender, profession, educational level, years of experience, number of deliveries performed in the past month, and previous use of smartphone. Given that this was a feasibility study, power calculations were not made in choosing the sample size for the pilot trial focused on health care workers' EmONC self-confidence and knowledge. However, the study team did gear the sampling strategy to achieve a minimum sample size of n= 30 for both intervention and control groups in order to be able to use parametric statistical tests.

T-tests examined within-subject differences on test scores "pre" and "post" intervention, (where the dependent variable (DV) is scores on self-confidence and KFQ test within the intervention and control groups) and between-group differences in change in self-confidence and knowledge (where the DV is the mean difference in change on scores for the two groups). Confidence intervals and effect size were calculated. To test for potential confounding, between-group differences were calculated to examine the role of gender on test scores and the role of previous smartphone use. One-way analysis of variance (ANOVA) was used to examine test scores analyzed by the three health professional cadres (nurses, midwives and MDs) across both intervention and control groups. The criterion for significance for all analyses was set at $p < .05$. All data was entered into Excel and analysis was performed using SPSS (v. 23).

Qualitative Analyses

Data coding for both target groups was carried out deductively by the PI, using the 14 TDF domains as the coding framework for content analysis, in order to interpret

meaning from the content of the qualitative data.[30] Responses for SDA users were coded to 8 out of 14 domains: '*knowledge*', '*skills*', '*belief about capabilities*', '*reinforcement*', '*intentions*', '*emotion*', '*memory/attention/decision processes*' and '*environmental context and resources*'). Key stakeholder responses were mapped to these same 8 domains, plus two additional domains ('*social/professional role and identity*', '*beliefs about consequences*'), since the discussion took into account the broader issues and context of CE in the DRC. The scope of analysis was limited to the above domains. Quantitative and qualitative data were interpreted and merged together, noting both the quantitative statistical results and qualitative quotes or themes that support or refute the quantitative results.[27]

Results

Quantitative Data

The analysis included 62 health care workers: 32 in intervention and 30 in control groups. **Table 2** shows that the participating health care workers included 26 clinical nurses and midwives (81.2%) in intervention groups and 20 (66.6%) in control groups; the remaining workers were medical doctors (18.8% intervention and 33.3% control respectively). The average age was similar, 41.3 and 44.2 in the intervention and control groups respectively. Twenty-six intervention workers were women versus eleven women in the control group (81.3% vs. 36.7%, respectively). The control groups had less recent experience than the intervention groups, with 13 workers (43.3%) conducting 5 or fewer deliveries during the previous month and 10 (33.3) conducting more than 10 deliveries, in comparison to 5 (15.6%) and 21 (70.0%) workers, respectively, in the intervention groups. Similarly, 12 workers (40%) had

over 10 years of experience in the profession in the control groups, compared with 17 (53.1%) in the intervention groups. Eighteen intervention health care workers (43.8%) and 9 control health workers (30.0%) had tried using a smartphone before the study.

Mean knowledge scores for PPH management were similar at baseline for health workers in the intervention and control groups at 47.75 ±16.8 and 47.5 ±14.7, respectively, out of 100 total points. Similarly, self-confidence mean scores were similar at baseline in intervention and control groups at 30.3 ± 8.7 and 31.3 ± 10.8 respectively, out of 48 total points. In contrast, mean baseline NNR knowledge scores were lower among health care workers in the intervention group (40.8 ± 17.5) compared to the control group (50.9 ±16.6)(out of 100 points).

We found a significant association between the intervention and health care workers' knowledge on both PPH and NNR, and on BEmONC self-confidence after 3 months from baseline (**Table 3**). The mean increase in PPH knowledge from pre-to-post was statistically significantly larger in the intervention group as compared to the control group (18.9 ±16.6 vs 1.6 ±11.4, respectively, p= < .001). Similarly, the mean increase in NNR knowledge from pre-to-post in the intervention group was statistically significantly larger compared to the increase in the control group (16.8 ±14.6 vs -2.5 ±16.9, respectively, p= < .001), despite lower baseline scores in the intervention group. Overall self-confidence scores on 12 essential EmONC procedures also significantly improved compared with those of controls at 3 months (mean difference, 4.2 out of 48; CI 0.7 – 7.7). Significant differences in intervention participant self-confidence were found pre-and-post on five essential BEmONC services out of 12 (**Table 4**): Manual Vacuum aspiration (MVA), pre-eclampsia/ eclampsia, prolonged labor, PPH, and manual placenta removal.

In exploring potential confounders, comparison of PPH and NNR mean scores by provider gender showed that there were significant differences along gender lines in the pre-test for both PPH and NNR, however there were no differences between men and women for either post-test (**Table 5**). Mean pre-test knowledge scores for men across both groups (Intervention & Control) were statistically significantly higher for both pre-PPH and pre-NNR (53.9±13.8 and 53.6±15.9, respectively) compared to the women (43.4 ±15.6 and 40.3 ±16.9)(p=0.008 for PPH and p=0.003 for NNR). In contrast, men in the post-test had similar mean scores compared to those of the women on both tests. The mean increase in PPH knowledge from pre-to-post among women was statistically significantly larger compared to the increase among men (13.8 ±17.3 vs 5.7 ±11.8, respectively, p= .046). Similarly, the mean increase in NNR knowledge among women was statistically significantly larger compared to the increase in the control group (12.0 ±19.0 vs 0.8 ±15.7, respectively, p= .017).

Analysis of test scores by previous smartphone experience (Table 5) showed significant differences for mean PPH scores only on both pre-and-post tests across both groups (intervention & control), wherein people with previous smartphone experience scored statistically significantly higher on the PPH pre-and-post tests ($p < 0.05$). Although providers who had smartphone experience scored slightly higher on the NNR pre-and post-tests, there was no significant difference. Similarly, there was no significant difference in mean change in PPH and NNR knowledge from pre-to-post among those experienced with smartphones and those who have never used them.

One-way Analysis of variance (ANOVA) tests were employed to examine differences in test score results by health professional cadre using a breakdown of all

participants into 3 cadres (nurses, midwives and MD's) across both groups together (**Table 6**). The ANOVAs indicated significant group mean differences for the three cadres only for the NNR pre-test. For both NNR and PPH pre-tests, MDs had the highest scores, followed by midwives and then by nurses. In both post-tests, nurses scored higher than midwives, with MDs scoring the highest. This difference reflects positively on the internal validity of the measurement instruments to distinguish differences.

In terms of patient outcome data, birth and maternal mortality figures were collected by register review of hand-entered data in the 8 study facilities. This was triangulated with data collected by mobile phones using the Open Data Kit application (ODK) and the monthly HIS reporting. ODK generated data corresponded well with hand-collected register data, however the HIS data differed from the ODK and register data. Patient adverse events were too few to compare, given the small number of facilities and months in the study period, as well as infrequent occurrence of maternal death. Obstetric complication data and BEmONC signal function execution data was piloted with the ODK, but is not collected systematically by the facility registers and it is not captured by the HIS reporting. Therefore it was not possible to triangulate. Since the ODK was only introduced with the intervention (in May of 2017), we were not able to compare ODK data pre-and-post.

Qualitative data

Interview data indicated that the SDA and mLearning could contribute positively to BEmONC provider behavior change, resulting in improvement in the quality of care and reductions in maternal and neonatal mortality through impacting the domains of '*knowledge*', '*skills*', '*belief about capabilities*', '*reinforcement*', '*intentions*',

'*emotion*', and '*memory/attention/decision making*'. The biggest barriers to provider behavior change in using the SDA, mLearning, and CE were reported in relationship to deficiencies in the '*environmental context and resources*', as well as '*social/professional role and identity*' and '*beliefs about consequences*' (**Tables 7-8**).

Interviews with SDA users (Table7)

Interviewees discussed how use of the SDA was feasible and acceptable and they perceived a positive effect on their '*knowledge*', '*skills*', '*belief about capabilities/confidence*', '*intentions*', '*memory/attention/decision processes*', and '*emotion*'. Many noted that it helped to "hear and see (the information) at the same time," "When we see and hear at the same time it teaches a lot," "The visual images or auditory information help participants to remember." One respondent said "We did things blindly before with what we learned in school and it wasn't enough."

Respondents reported changes in their '*intentions*', '*belief about capabilities*' and '*memory/attention/decision processes*', which led them to change their management of BEmONC, including now taking vital signs, using uterine massage and bimanual compression in PPH, using controlled cord traction during the 3rd phase of labor, giving IV fluids and misoprostol for PPH, and using the partogram. One respondent said, "It changed our old habits." They discussed observed changes in patient outcomes as a result of SDA use and how this has reinforced their new practices, such as: "there are no more deaths from PPH now." "All the children are saved with using the Ambu Bag for NNR." "Now we see less fever in children after NNR when we give antibiotics." "PPH resolves if you use what is in the video." "With info in the video for NNR, you see the newborn coming back. It's really encouraging."

In terms of '*emotion*' one participant said: "(The videos) are amusing and relaxing. It's good for educating adults. There is variety." Another said: "The animated graphics were interesting. Other trainings they talk and talk." The interviewees stated that they consulted the app frequently ('*reinforcement*'), both as a learning tool and in various obstetric and neonatal emergencies as a job aide. The app topic most consulted by the respondents was post-partum hemorrhage management (n = 8). Participants preferred watching the animated videos, as compared with written app features, and many of the providers interviewed had not consulted the other features in the app.

In terms of barriers to implementation of the SDA and BEmONC guidelines, participants cited the '*environmental context and resources*', particularly the poor practice environment, lack of consistent meds, equipment, electricity, and poor salary. One respondent said: "We earn nothing. Put yourself in our place. We work hard for nothing."

Interviews with key stakeholders (Table 8)

Data from semi-structured interviews with ten key stakeholders mapped to all of the same TDF Domains noted above, plus an additional two domains ('*social/professional role and identity*' and '*beliefs about consequences*'. Respondents supported the feasibility and acceptability of mLearning and the potential for it to have an impact on maternal and neonatal mortality. Many respondents noted that often health workers have no access to CE and that often the same people are selected many times for training. One respondent reported: "There is a poor distribution of opportunity to get CE. There is limited training for hard-to-

reach areas and for lower professional cadres." Another interviewee noted that: "eLearning can train more people at lower cost."

Respondents noted that current trainings offered are often too theoretical, are not necessarily relevant to the daily work of health workers, are not of interest, and don't do a good job of enhancing '*knowledge*', '*skills*', or changing '*belief about capabilities*', or '*intentions*' to change behavior. One respondent said: "Generally, there is a weak development of competence of personnel with current continuing education." Another said: "We must change training approaches to those that facilitate learning. Approaches aren't adapted to the current era, using written modules and lectures. People don't read the modules and the trainings don't allow participants to gain knowledge or competencies." One service leader said, "Trainings are too theoretical via lectures; the essential notions aren't mastered and trainees aren't able to apply the knowledge to a case." To combat infrequent access to training or self-directed learning opportunities, mLearning was noted to provide the opportunity for '*reinforcement*' of learning and to be more interesting ('*emotion*', '*memory/attention/decision processes*'): "New technology fascinates people and they want to try it. It responds to a need or desire for learning." "New technology should be encouraged, especially for remote areas." "Audiovisual makes it more interesting and one can experience it alone or in a group. Approaches must change from written info to interactive self-learning options."

In terms of barriers to mLearning or CE, responses centered on the domain '*Beliefs about consequences*', and noted the lack of incentives or requirements for CE, amidst the general lack of national and regional planning and tracking capacity for CE. One interviewee noted: "There is no link between CE and career progression."

"We need an accreditation system for CE, so that people have to take CE with a systematic plan of courses required for different fields." One respondent noted that: "mLearning should be linked with post-training monitoring and supervision and it should be connected to performance contracts." Interviewees also noted that many deficiencies centered on the domain '*Environmental context and resources*', highlighting the contextual gaps that result in poor care such as lack of accountability for poor practice, insufficient remuneration for health workers, lack of drugs, equipment, and supervision.

Mixed Methods Integration

Qualitative interviews identified many positive benefits to the use of the SDA and mLearning in the DRC context, particularly in terms of making evidence-based, up-to-date global BEmONC guidelines available to health workers via an exciting mLearning app. Access to information was noted to be especially critical to those who are often devoid of learning opportunities such as those in remote areas and lower level cadres. However, interviews noted that even for those who have been trained in the past, the SDA and mLearning offer the opportunity to learn important knowledge and skills and change behavior via the use of a more modern, more captivating approach that appeals to all health personnel. This reinforces our quantitative results of significantly increased knowledge and self-confidence scores (which directly mirror two TDF domains '*knowledge*' and '*beliefs about capabilities*') across all three health professional cadres (MDs, nurses, midwives) after 3 months of SDA use. The increases were unaffected by previous smartphone use or gender, reinforcing that mLearning can be used to train any health worker.

Qualitative responses further elucidated barriers to mLearning and CE that are well known to key stakeholders in the DRC such as environmental and contextual barriers and lack of resources. The policy context including lack of accountability measures ('*beliefs about consequences*') and gaps in '*professional identity*' mutually reinforce the '*environmental context and resource*' gaps, contributing substantially to poor quality of care by health providers and high mortality indicators for mothers and newborns.

Discussion

Learning via the SDA was feasible and acceptable for health workers in the context of the Democratic Republic of the Congo. mLearning more broadly, was assessed by our sample of key stakeholders in the DRC, to be feasible and acceptable, and a potential solution to problems of access by health workers to up-to-date learning resources in hard-to reach settings. A pilot trial with the French language version of the SDA in central DRC led to a significant increase in health care workers' knowledge scores for post-partum hemorrhage and neonatal resuscitation management and in BEmONC self-confidence scores in intervention as compared with control participants, irrespective of the gender, previous smartphone use, or professional cadre of the health worker.

This study supported findings by Lund et al.[14] regarding the significant effect of the use of the SDA with skilled birth attendants in Ethiopia in terms of significantly increased knowledge and skill scores of health workers on neonatal resuscitation, and a non-significant 24% reduction in perinatal mortality. This trial did not test BEmONC skill scores given the smaller nature of the feasibility study. Similarly, this

trial was unable to determine the impact of the SDA on patient outcomes with sufficient power, given the small sample size and short duration of the study combined with relatively infrequent occurrence of maternal death. However, the research team did assess the feasibility of study procedures for a future larger well-powered study in the DRC.

Despite being unable to demonstrate two key needs identified in systematic reviews for trials on mHealth in LMIC's [21-23], namely (1) trials with patient outcomes as a primary outcomes and (2) longer term trials, the study (1) assessed the feasibility, acceptability and potential efficacy of using the SDA to improve the quality of BEmONC in the largest Francophone African country; and (2) proposed a potential means of addressing the challenge of inadequate access to up-to-date evidence-based training and reference materials for health workers in hard-to-reach areas and for health worker cadres that often miss out on training opportunities in the DRC. The advantages of the SDA are that it is self-explanatory, is free of charge for download, and, once installed on the mobile device, does not need network coverage to funtion.

Conventional training of skilled birth attendants in BEmONC has proved effective to improve health care outcomes[11, 32-33] However, health care workers in hard-to-reach settings, are often not able to participate in such trainings and are unable to access other learning resources.[10, 17-18] Systematic reviews on mHealth show that mobile phone applications are increasingly being used in LMICs to disseminate information to health care workers.[34] Other pilot studies have shown related eLearning strategies to be potentially as effective as traditional training strategies.[20] These findings also support those of other studies that the use of electronic tools is perceived as an opportunity for improving health worker quality of care with effects on health

care workers' motivation[35], self-efficacy[36] and enthusiasm.[37] The Theoretical Domains Framework proposes domains of influences or constructs for health worker behavior change that mirror these concepts, noting the domains such as '*belief about capabilities*', '*intentions*' and '*emotion*'[30] as being critical determinants of behavior change.

The small sample size of this study limited findings by reducing the power of the study. In terms of design limitations, 8 facilities were randomized in this study, rather than individuals, to avoid contamination of the intervention group to the control group[14], and researchers did note disparities between the intervention and control groups in the gender, professional cadre composition, and previous experience of the health workers. Additionally, blinding of intervention and control clusters was impossible owing to the nature of the intervention, which increased the risk for information bias. It is possible, however, that some control participants accessed the SDA in intervention facilities, since the facilities were all in relatively close geographic approximation. Other limitations included that the study team was unable to consistently track SDA use during the study, given that this capability was not completely developed at the time of intervention. Access to such data will enrich results and analysis of the association between SDA use and changes in measures in future research.

Lessons learned from this feasibility study to improve future study procedures suggested that future trials of mLearning in the DRC would benefit from an additional means of data collection for mortality and other critical BEmONC data, such as through the use of the ODK data collection instrument designed for this study or dedicated data collection staff on-site. Researchers found that data collected by hand-

review of health facility registers and ODK data collected daily via mobile phone were comparable, but differed from monthly HIS reporting. Although not the primary question in our research, interview data revealed possible explanations for discrepancies in data collected from these different sources including deliberate under-reporting of mortality in the HIS by health workers for a variety of reasons, which would clearly complicate the measurement of patient outcomes in an eventual follow-up study. Future work could also benefit from the recently updated version of the SDA, which incorporates additional features to measure learning and to motivate the user through video game-like features, where learners must gain a certain number of points to move to the next learning level and are certified once they achieve the top score. These features might exponentially increase the benefits of the SDA intervention by further tapping into certain TDF domains such as '*emotion'*, *'reinforcement'* and '*belief about capabilities*' by providing incentives and rewards, and promoting motivation and self-empowerment.

The implications of this study are that the SDA and other mLearning interventions should be considered to increase the ability of health workers to provide improved quality of care during obstetric and neonatal emergencies as well as improved routine obstetric and newborn care. Evolving policies for continuing education in the DRC and similar context countries should consider the integration of mLearning as an approach for training and as a job aide for EmONC in order to reduce maternal and newborn mortality, as well as considering the integration of mLearning tools for other priority and emergent health problems.

Conclusion

The SDA and mLearning was found, through both qualitative and quantitative

methods, to be feasible and acceptable to health workers and to key stakeholders in the largest Francophone African country, the DR Congo. SDA use was associated with increased health worker knowledge on PPH and NR management 3 months after introduction and increased health worker self-confidence overall in the management of obstetric and newborn emergencies. These results contribute to the growing body of knowledge on mHealth in low-income countries where the quality of care is challenged by lack of continuing education programs. Lessons learned for a future adequately powered study on the effect of mLearning on quality health care provision for reduced maternal and newborn mortality in the DR Congo are discussed.

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CONSORT
TRANSPARENT REPORTING of TRIALS

Figure 1: CONSORT Flow Diagram

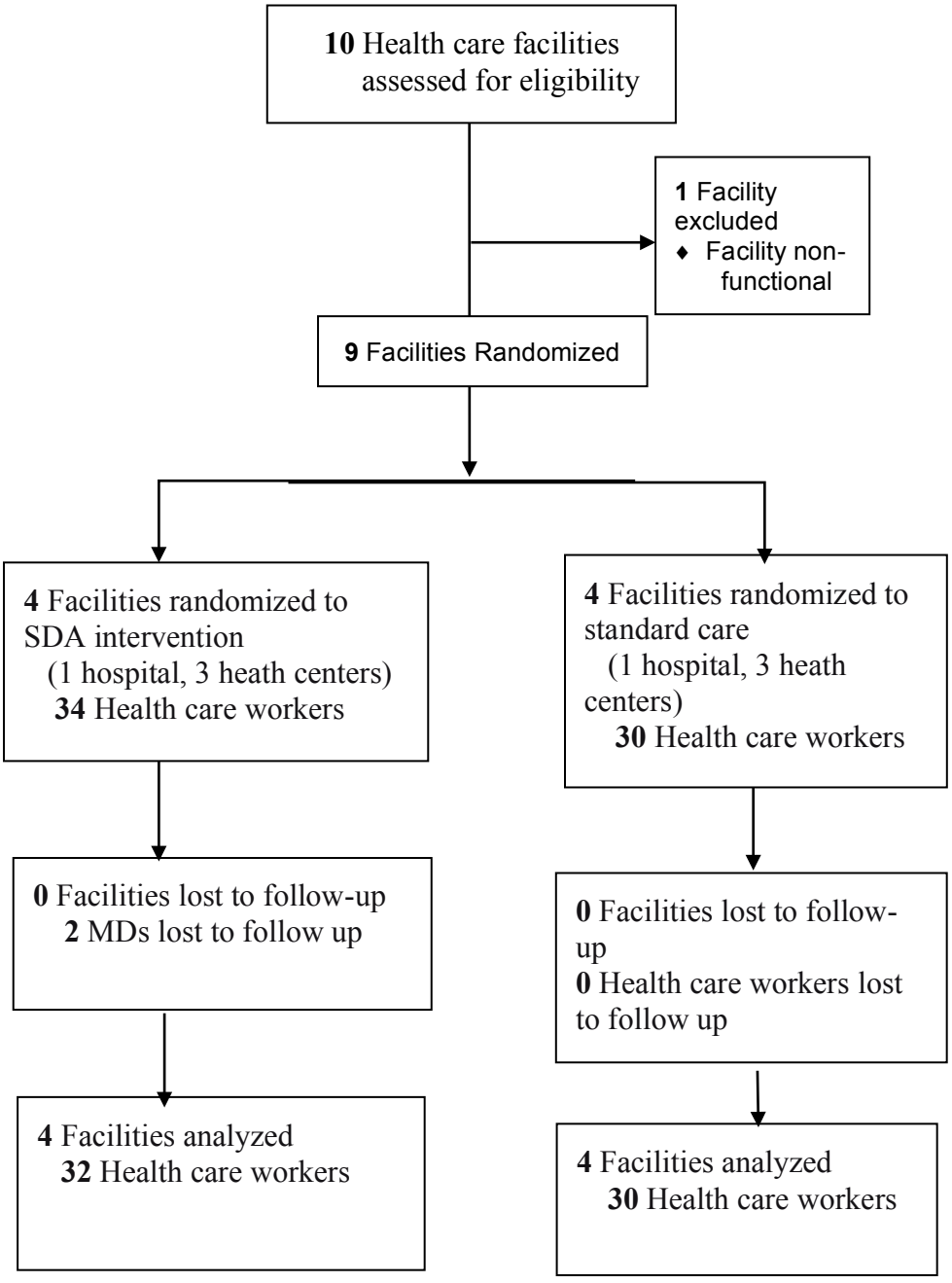

Table 1: The Theoretical Domains Framework with definitions and constructs			
Domain	**Construct**	**Domain (cont'd)**	**Construct**
1. Knowledge (An awareness of the existence of something)	Knowledge (including knowledge of condition/ scientific rationale) Procedural knowledge	**8. Intentions** (A conscious decision to perform a behavior or a resolve to act in a certain way)	Stability of intentions Stages of change model Transtheoretical model / Stages of change
2. Skills (An ability or proficiency acquired through practice)	Skills Skills development Competence Ability Interpersonal skills Practice Skill assessment	**9. Goals** (Mental representations of outcomes or end states that an individual wants to achieve)	Goals (distal/proximal) Goal priority Goal/target setting Goals Action planning Implementation intention
3. Social/ professional role and identity (A coherent set of behaviors and displayed personal qualities of an individual in a social or work setting)	Professional identity Professional role Social identity Professional boundaries Professional confidence Group identity Leadership Organizational commitment	**10. Memory, attention and decision processes** (The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives)	Memory Attention Attention control Decision making Cognitive overload/ tiredness
4. Beliefs about capabilities (Acceptance of the truth, reality or validity about an ability, or talent that a person can put to constructive use)	Self-confidence Perceived competence Self-efficacy Perceived behavioral control Beliefs Self-esteem Empowerment Professional confidence	**11. Environmental context and resources** (Circumstance of a person's situation or environment that discourages or encourages the development of skills / abilities, independence, and adaptive behavior)	Environmental stressors Resources/material resources Organizational culture/climate Salient events/critical incidents Person X environment interaction Barriers and facilitators
5. Optimism (The confidence that things will happen for the best or that desired goals will be attained)	Optimism Pessimism Unrealistic optimism Identity	**12. Social influences** (Interpersonal processes that can cause individuals to change their thoughts, feelings or behaviors)	Social pressure Social / group norms Group conformity Social support Power Group identity Modeling
6. Beliefs about Consequences (Acceptance of the truth, reality, or validity about outcomes of a behavior in a given situation)	Beliefs Outcome expectancies Characteristics of outcome expectancies Anticipated regret Consequents	**13. Emotion** (A complex reaction, involving experiential, behavioral, physiological elements, by which the individual	Fear Anxiety Affect Stress Depression Positive/negative affect Burn-out

		attempts to deal with a personally significant matter /event)	
7. Reinforcement (Increasing the probability of a response by arranging a dependent relationship, between the response and a given stimulus)	Rewards Incentives Punishment Consequents Reinforcement Contingencies Sanctions	14. Behavioural regulation (Anything aimed at managing or changing objectively observed or measured actions)	Self-monitoring Breaking habit Action planning

Table 2: Demographic Characteristics of Study Groups

Characteristic	**Study Groups: 4 health care facilities in each group**	
	Intervention (n = 32)	**Control** (n = 30)
Average age	41.3	44.2
	No. (%)	
Gender		
Male	6 (18.8)	19 (63.3)
Female	26 (81.3)	11 (36.7)
Professional cadre		
Nurses	22 (68.8)	14 (46.6)
Midwives	4 (12.5)	6 (20)
MD's	6 (18.8)	10 (33.3)
Years of experience in profession		
1 – 5	3 (9.4)	6 (20)
6 – 10	12 (37.5)	12 (40)
>10	17 (53.1)	12 (40)
No. Deliveries past month		
0 – 5	5 (15.6)	13 (43.3)
6 – 10	6 (18.8)	7 (23.3)
>10	21 (65.6)	10 (33.3)
Experience with smartphone		
Tried using one	14 (43.8)	9 (30.0)
Never tried using one	18 (56.3)	21 (70.0)

Table 3: Within and between-subject differences Pre-and-Post Intervention

	Intervention: Mean scores (n= 32)	Control: Mean scores (n= 30)	Pre-Post Difference	95% CI	p-value	Cohen's d
PPH-Pre (out of 100)	47.8 ± 16.8	47.5 ± 14.7	0.3	(-7.8, 8.3)	.951	
PPH-Post	66.7 ± 14.8	49.1 ± 15.6				
PPH-Pre-Post-Difference	18.9 ± 14.6	1.6 ± 11.4	17.4	(10.7, 24.0)	< .001	1.6
95% CI	(13.7, 24.2)	(-2.6, 5.8)				
p-value	< .001	.457				
Cohen's d	1.2					
NNR-Pre (out of 100)	40.8 ± 17.5	50.9 ± 16.6	- 10.1	(-18.7, -1.4)	.024	- 0.6
NNR-Post	57.7 ± 15.3	48.3 ± 17.3				
NNR-Pre-Post-Difference	16.8 ± 14.6	- 2.5 ± 16.9	19.4	(11.4, 27.4)	< .001	1.2
95% CI	(11.6, 22.1)	(-3.8, 3.8)				
p-value	< .001	.419				
Cohen's d	1.0					
Confidence-Pre (out of 48)	30.3 ± 8.7	31.4 ± 10.8	- 1.1	(-6.1, 3.9)	.655	
Confidence-Post	34.0 ± 8.9	30.9 ± 8.7				
Confidence-Pre-Post-Difference	3.8 ± 6.6	- 0.4 ± 7.2	4.2	(0.7, 7.7)	.019	0.6
95% CI	(1.4, 6.2)	(-8.6, 2.3)				
p-value	.003	.744				
Cohen's d	0.4					

* PPH = Post=partum hemorrhage, NNR = Neonatal resuscitation

Table 4. Provider self-confidence scores (on a scale of 4 points) on management of the following procedures for Intervention group participants:

Procedures	Pre-intervention	Post-intervention	Mean difference	p-value
MVA	2.1 ± 1.3	3.0 ± 1.2	0.88	.003
D & C	2.7 ± 1.2	2.6 ± 1.3	- 0.03	.899
Pre-eclampsia/ Eclampsia	2.0 ± 1.2	2.4 ± 1.4	0.41	.030
AMSTL	3.5 ± 0.7	3.7 ± 0.5	0.22	.090
Prolonged labor	2.7 ± 1.1	3.1 ± 0.8	0.47	.007
Vacuum extraction	1.7 ± 1.4	1.8 ± 1.3	0.19	.447
PPH	2.6 ± 1.2	3.1 ± 0.9	0.50	.030
Manual placental removal	2.8 ± 1.0	3.1 ± 1.1	0.31	.039
Septicemia	2.2 ± 1.2	2.5 ± 1.3	0.34	.078
NNR	3.0 ± 0.8	3.0 ± 0.9	0.00	1.000
Danger signs in newborns	2.6 ± 1.0	2.9 ± 1.0	0.31	.106
Severe infection of newborn	2.4 ± 1.1	2.6 ± 1.0	0.19	.311

Table 5. Within & between group difference analyzed by Gender and Smartphone experience

	Men: (n= 25)	Women: (n= 37)	Pre-Post Difference	95% CI	p-value	Cohen's d
PPH-Pre (out of 100)	53.9 ± 13.8	43.4 ± 15.6	10.5	(2.8, 18.3)	.008	0.72
PPH-Post	59.6 ± 15.3	57.2 ± 18.9				
PPH-Pre-Post-Difference	5.7 ± 11.8	13.8 ± 17.3	8.1	(0.1, 16.0)	.046	0.56
95% CI	(0.9, 10.6)	(8.0, 19.5)				
p-value	< .023	< .001				
Cohen's d	0.37	0.80				
NNR-Pre (out of 100)	53.6 ± 15.9	40.3 ± 16.9	13.3	(4.8, 21.9)	.003	0.81
NNR-Post	54.4 ± 14.8	52.3 ± 18.3				
NNR-Pre-Post-Difference	0.8 ± 15.7	12.0 ± 19.0	11.2	(2.1, 20.4)	.017	0.66
95% CI	(-5.7, 7.2)	(5.6, 18.3)				
p-value	0.811	< .001				
Cohen's d		0.68				
	Never used Smartphone (n = 39)	**Experienced Smartphone (n= 23)**	**Pre-Post difference**	**95% CI**	**p-value**	**Cohen's d**
PPH-Pre (out of 100)	43.0 ± 14.5	55.6 ± 14.6	12.6	(5.0, 20.3)	.002	.87
PPH-Post	53.8 ± 17.2	65.6 ± 15.7	11.8	(3.0, 20.5)	.009	.72
PPH-Pre-Post-Difference	10.9 ± 17.8	10.0 ± 11.6	0.85	(-7.5, 9.2)	.839	
95% CI	(5.1, 16.6)	(5.0, 15.0)				
p-value	.001	.000				
Cohen's d	0.69	0.66				
NNR-Pre (out of 100)	43.9 ± 17.5	48.7 ± 18.0	4.7	(-4.6, 14.0)	.313	
NNR-Post	51.5 ± 17.8	55.9 ± 15.0	4.3	(-4.5, 13.2)	.332	
NNR-Pre-Post-Difference	7.6 ± 19.4	7.2 ± 17.0	.40	(-9.4, 10.2)	.935	
95% CI	(1.3, 13.9)	(-0.1, 14.6)				
p-value	.019	.054				
Cohen's d	0.43	0.44				

Table 6. Test scores examined by Health worker Cadre						
	Nurses' Mean scores (n= 36)	**Midwives' Mean scores (N = 10)**	**MD's Mean scores (n=16)**	**Total Mean scores**	**F**	**p - value**
PPH pre-test	44.4 ± 16.8	48.8 ± 14.1	54.1 ± 12.3	47.6 ± 15.7	2.197	.120
NNR pre-test	41.1 ± 18.5	47.5 ± 11.8	54.9 ± 15.5	45.7 ± 17.7	3.747	.029
PPH post-test	56.9 ± 17.6	53.2 ± 17.5	64.1 ± 16.7	58.2 ± 17.5	1.428	.248
NNR post-test	53.4 ± 15.1	42.8 ± 21.2	59.0 ± 15.6	53.2 ± 16.9	3.046	.055

Test scores by Cadre	**Paired Comparisons***		
	Nurses-Midwives	Nurses – MDs	Midwives – MDs
PPH pre-test	-	-	-
NNR pre-test	-	p = .023	-
PPH post-test	-	-	-
NNR post-test	-	-	p = .043

*Significant for Tukey's HSD test

Table 7: Qualitative Interview results with SDA users in Intervention facilities

Domains	Interview	Content	
1. Knowledge	4	App understandable. "We saw and heard the information"	
	2	"When we hear and see at the same time it teaches a lot"	
	6	"We felt better taking knowledge test after using the app (on post-test)."	
	8	"We did things blindly before with things we learned in school and it wasn't enough"	
2. Skills	4	"Training was sufficient to use app"	
	1	"Training gave us the skills to use the app."	
4. Beliefs about capabilities	5	"We see that Misoprostol is effective (for PPH)."	
	1	"There are no more deaths from PPH now"	
	2	"Had many PPH deaths before"	
	7	"All the children are saved with using Ambu Bag for NNR" "Now we see less fever in children after NNR when we give antibiotics"	
	8	"PPH resolves if you use what is in the video" "With info in the video for NNR, you see the newborn coming back. It's really encouraging."	
7. Reinforcement	4	"Watched videos every few days alone or with nursing & mw students."	
	1	"Watched every 4 – 5 days together at the Maternity if there was no work or with an emergency situation"	
	3	Also watched once during an emergency (NNR)." "One can re-watch the video"	
	2	"Watched videos every few days alone or with maternity team."	
	6	"Watched videos about every 3 days during free time at maternity. Also used during a case of manual removal of placenta and MVA."	
	5	"Watched videos at the maternity about every 4 days."	
	7	"Videos were the most helpful" "Watched during free time and during a PPH case"	
		Which videos? AMSTL – 5 PPH – 8 NNR – 4 Eclampsia – 2	Septicemia – 1 MVA – 1 Manual extraction of placenta – 1 Newborn care – 2 Prolonged labor – 1

8. Intentions	4	"Consulted other features (Action cards, Practical modalities, Medications)"
	1	1. "Now we take Vital Signs during delivery." 2. "Now we do uterine massage after delivery"
	3	1. "Before for AMSTL they put the baby off to the side; Now we put baby skin-to-skin and encourage breastfeeding" 2. "Now we start an IV for PPH and run the solution fast"
	2	"It changed our old habits" 1. "Before we didn't do uterine massage or use misoprostol or IV fluids for PPH management; Now we use massage, miso and IV fluids. "We didn't look for the source of bleeding before" 2. "Before we didn't follow the partogram; Now we use the partogram" 3. "Before we aspirated the newborn systematically; Now we only do if needed" 4. "Before we held the baby upside down after delivery and gave mouth-to-mouth brutally if needed; Now we use the Ambu bag, which gives a good result; we learned that they
	5	must position the baby & the mask in order to do NNR"
	6	1. "Before we didn't use misoprostol; Now we give rectally and orally for PPH." 2. "Before we aspirated all babies; Now only aspirate when we need to" 3. Before we pushed the uterus down during 3rd stage; Now we support the uterus and use controlled traction on the cord"
	7	1. "Before we didn't use miso, now we do with good results"
	8	1. "Before we gave miso sub-lingual; Now we give it orally or rectally" 2. Before we gave iron for 1 month with severe PPH; Now we give for 3 months". 3. "Before – for respiratory distress we did mouth to mouth and gave Hydrocortisone IM, no antibiotics, saw high rate of fever; Now – use Ambu bag and give ab's, and we see less fever 4. Before – they told the mom not to push, Now use controlled traction w mother pushing."
		1. "Before –we aspirated all the babies, now only when needed 2. Now – with HPP do uterine massage & urinary catheter, see the uterus contracts. 3. Now with Premature rupture of membranes – we give antibiotics. 4. Before – told Mom not to push, Now tell mom to push a little, turn membranes"
10. Memory, attention and decision processes	4	"mLearning with the app is good, the learner sees the information, hears it and then can do it themselves. It helps participants to remember the visual images or auditory information."

11. Environmental context and resources	6	"We have needs for certain materials to carry out work properly: long gloves, lights (maternity has no power), oxytocin. Only two of us were trained back in 2012 but need others to be trained, and need formative supervision more often."
	8	"Availability of material would help us to manage better: uniforms, tops, shoes, eye protective equipment, aprons, soap. We work in our own clothes and shoes, we risk to contaminate our children." "We earn nothing – 12,700 Francs per month. Put yourself in our place. We work hard for nothing."
13. Emotion	4	"It's amusing and relaxing. It's good for educating adults. There is variety." "App should be made more widely available – in pediatrics and the OR."
	2	"Animated graphics were interesting" "Others trainings they talk and talk".
	8	"We are very happy with the intervention. It's very encouraging"

BEmONC – Basic Emergency Obstetric and neonatal care
PPH – Post-partum hemorrhage
NNR – Neo-natal resuscitation
AMSTL – Active management of the 3rd stage
MVA – Manual vacuum aspiration

Table 8: Qualitative Interview results with Key Stakeholders (Feasibility & Acceptability of mLearning and vision of CE more broadly)

Domains	Interview	Content
1. Knowledge	2	"CE is too theoretical. CE should incorporate adult learning principles where participants share experiences as equals and draw on their experience, brainstorm, watch videos. And it should be continuous / regular." "Hospital/workers are often "subjected" to trainings that they haven't planned.... should be included in planning in response to priority needs."
	3	"Trainings are theoretical, not applied. Must present things that are relevant to what they do – where they have the equipment. Must be modernized – not just theoretical – where they get practical info and can see the gestures."
	7	"Make trainings less theoretical and more hands-on so that it makes a real change. Must determine key competencies and address these.
	5	"Trainings too theoretical – held in classrooms. For remote settings, eLearning interesting – self-directed learning, and should measure if they acquire competencies / can be certified, and put in place a system for them to be encouraged to do this. New technology should be encouraged, especially for remote areas (where no library or specialist). In DRC people used to a teacher who lectures....students become receivers of info.
	9	Approaches aren't adapted to current era, use written modules and lecture, and don't reach objectives/don't allow participants to gain knowledge or competencies. Isn't possible to evaluate any change. Training not based on identified gaps or learning needs. Must change training approaches to approaches that facilitate learning. People dont read the training modules. Trainings are general, not specific to providers or targeted and dont change behavior. Could project (info/videos) and discuss – effective and feasible, self-learning and in groups. Could program 1x/month and monitor the programming and resultant learning.
2. Skills	1	"Providers were able to put into practice new things learned such as using the side of the hand for manual extraction (of the placenta) and bimanual compression for PPH" SDA renders learning operational."
	4	"mLearning also teaches people how to use technology."
	5	"Should train people in their workplaces for better skill acquisition, not take them out. Send trainers there"

		"Doesn't address clinical gaps, should address clinical skills in clinical setting"
	8	Trainings too theoretical, unclear if they lead to a change in behavior or practice/how they will apply information. Objectives of change in practice unclear. Trainings should be theoretical and clinical at same time. Should be conducted in real work conditions/context to combat the gap between what one knows and what one does. Care has become mechanized and based on memorized protocols, so they have a difficult time analyzing situations. Efficacy of trainings not measured, more focused on number of participants rather than actually looking for changes, rarely analyze any data or think about the meaning of the number (of trainees). Reinforce even very basic practices, cant assume people have basic skills. Basic education often deficient for all categories of professionals.
	10	There is a weak development of competence of personnel.
3. Social/ professional role and identity	4	"Depends on how people were educated/raised and values, ethics. If children don't learn to read themselves, adults will expect to be given information. Adults use what they have to treat patients, but they are not going to look something up or get additional info.
	5	"Reading and writing not encouraged in basic education in DRC. Values have changed – not important who you are but what you have – people no longer value excellence. Young people look for money. Before people had motivation to learn, to do well, to make contacts. Now people only want $. The economic situation is unstable and people seek to get as much money as possible quickly. In past the student paid the master, now people want to be paid to learn. Must create a way for people to share information. Maybe form a club (to discuss / project) with an animator/ trainer. If the program is personalized, even better – get points, get certificate (must be linked to employer).
4. Beliefs about capabilities	4	"Must show people (must make apparent) the benefits of training" Imposing CE is only of limited value, when the boss isn't there ...they wont do it. Inspiring them to the benefits of CE would be more motivating then sanctions. Important to show health workers the importance so that they understand. One can take the model of a leader who inspires."
	6	"Must reinforce that money isnt the only objective"

6. Beliefs about Consequences	1	"Accountability related to malpractice could help. Providers often cause complication or don't refer in order to earn $." "No accountability related to malpractice"
		"Requirements for CE are needed; could be made clear at hiring in job descriptions" (Employers or Ministry should have tracking capability related to CE to be able to identify persons in need of training and needed training"
	4	"Work is mechanical. People don't actually care." "Accountability is needed. Remuneration based on participating in CE would be helpful (results based financing).
	6	"CE should be obligatory to improve practices and incentives should be put in place, as well performance-based financing linked to promotions and salaries....People have lost their sense of obligations and results."
	7	"CE Regulations/requirements are where the country needs to go to make a change"
	5	Must assure career path for HW's based on regular evaluation.
	8	Must encourage HW's to do better instead of punishing. Must create a better relation – confidence between parties.
		Hard to put in place regulations when the context varies so much in the country.
7. Reinforce ment	1	"mLearning interesting to reinforce learning since the tool is available at all times and the provider can view the information many times."
	3	"SDA – can re-listen to many times, even at home." "SDA should be made available in all health zones with post-training supervision...would decrease maternal & neonatal mortality"
	7	"Supervision needs to have clear goals for it to be effective. Supervision should be an outside person who shows interest in work/results.
	5	eLearning must have trainers to do follow-up. Ideal if someone follows the process to enrich the application (give retro-information and ensure that needs are covered in the app), and to answer questions.
	8	Need real accompaniment with learner, where trainer values the experiences and competences of learner and uses leaner's knowledge as basis for adding new information (ie must identify their knowledge gaps).
	9	Follow-up post training not done to see if they have adapted/changed practices or can practice autonomously. No measurement is done.

8. Intentions	2	"I consulted other features (Action cards, Practical modalities, Medications)"
	4	"mLearning isnt in the culture. Young people like it but not for work. They like the physical presence of trainers."
	6	"People wont do self-directed learning – they think they have made it and that they dont need it."
	5	"Must be defined who participates (in CE) and what one gets from it. CE has to meet a need/ fill a gap. Must lead to a change in employment status / have a concrete change.
10. Memory, attention and decision processes	1	"The images allow people to learn with more stimulation and attention. The visual memory can fix the memory of the information for longer." "Trainings are theoretical via lectures. They teach too many things at the same time and they rush through the material. Learners have trouble prioritizing and leave with confusion; meanwhile the essential notions aren't mastered and they aren't able to apply the knowledge to a case. Providers have been trained before but it's as if they have never been trained. It would be better to have more practical training."
	3	"When time passes after a training, when you have no equipment, you forget"
	7	"If people are motivated they may retain info better"
	8	Regarding local guideline adaptation, this is important, people must rely on the protocols not on memory/improvisation
11. Environ-mental context and resources	2	"Challenges are linked to logistics: electricity, equipment"
	6	"Must improve working conditions – hygiene, equipment, minimum salary; and put in place non-financial incentives"
	3	"Often there is no written literature and no equipment. Are areas with no telephone coverage so info / images should be downloaded on CDs or available on apps."
	4	"The right people aren't necessarily chosen for trainings." "CE not well structured...not based on needs" "Take same people for all trainings" "Biggest barrier to CE is poverty – people prefer to spend time for per diem" "Better working conditions (salaries, supervision, environment) would push people"
	7	"Need accreditation system: so that people have to take CE, systematic plan of courses that are required for different fields, even if no funding they need a plan that projects could buy into and support it.
	5	"No clear CE policy. Who choses the subjects? And must be

		defined who participates and what one gets from it. Needs a clear policy, training should programmed and budgeted...so that employers recognize the training and has it planned/budgeted for their facility. Important that employees are being trained in topics that employers have identified as needs. For CE, programs/partners decide subject, may repeat subjects already covered, same people always go to the trainings and are missing from work
	5	eLearning can train more people at lower cost.
	8	Difference between what people are taught and the reality of the environment.
	9	CE Subjects planned by partners rather than based on needs in the field or by facilities. Subjects "fall from the sky from the top to the bottom". This explains why the same providers can be trained multiple times in the same period on the same subjects. Situation is driven by the funding/per diem involved No coordination by MoH – dont know who has been trained on what. No coordination locally of multiple partners to make sure providers have been trained on a variety of subjects or to reinforce competencies. Providers are absent from work during the trainings at frequent intervals for long periods of time. Length linked to not knowing the profile of workers who will be trained and not knowing the learning gaps so the trainers train them on everything "fishing net approach" (gather everything).
	10	Basic education weak. Poor distribution of opportunity to get CE training. Limited training for hard-to-reach areas and for lower cadres (A3, A2). No link between CE and salary/career progression.
13. Emotion	1	"Seeing the images is more interesting than just talking theoretically"
	4	"Young people are not stimulated at school and adults are not stimulated at work."
	5	People are capable especially if they are stimulated – but requires personal discipline
	9	AV (eLearning) makes it more interesting and can experience alone or in a group. Approaches must change from written info to interactive self-learning options (videos, illustrated info)(such as SDA that can serve as self-learning and memory aide). What can push people – through CE – to be engaged? It must respond to a need or desire for learning. New technology fascinates/attracts people and they want to try it; it responds to a need.

		Training approaches havent changed and dont interest people (written modules). On-line training - people ready to work to master new things – feel valued and willing to improve. Must improve work environment, this motivates or demotivates people.

Summary

1. **Manuscript 1:** The purpose of this Integrative review was to synthesize and critique the literature on continuing education (CE) approaches, content, and effectiveness with a particular focus on nurses and midwives in low-and-middle-income countries (LMICs) and on improving maternal healthcare. Bloom's Theory of Mastery-Learning and Taxonomy of Educational Objectives was used as a framework for analysis of CE approaches (1-3). The Kirkpatrick Model was used to evaluate training programs (4)**.**

Fourteen studies were identified by our review, grouped into three approaches: (1) short training courses; (2) longer-term educational interventions; and (3) eHealth. Teaching-learning content represented in the studies was categorized into emergency obstetric care (EmOC), with an emphasis on post-partum hemorrhage (PPH), and general maternal care. In terms of assessing the effectiveness of the interventions, there was significant heterogeneity within these studies. Not all of the studies reported statistical results; only a few reported the p values and none of the studies reported an effect size. Many of the studies utilized non-validated measurement instruments. Additionally, certain in-service training programs were delivered as one component of a larger maternal health intervention; therefore, it was difficult to specifically attribute a change in outcomes to training alone. Where training programs were evaluated, this was mainly to assess health provider competency before and/or after training; few studies evaluated the effect on change in practice and/or health outcomes.

We concluded that conventional trainings - both short and longer - using varied teaching methodologies can improve provider knowledge, skills, clinical

behavior or practice, and patient outcomes, however, there was limited evidence using robust study designs linking CE to long-term improved patient outcomes. Short-term emergency obstetric (EmOC) courses may be a feasible way to train a relatively large number of staff in a short time (5); however, in many settings, standard short-or medium-term training courses are difficult to carry out in hard-to-reach settings (6). None of the studies in this review included costing estimates or mentioned logistical challenges for their interventions.

We identified other creative interventions that are being piloted in eHealth and guideline adaptation that have shown positive results and may be more motivating for participants. Nilsson et al.'s [6] simple intervention study to improve PPH management skills compared an interactive hands-on PPH training versus a non-interactive video training for PPH management and found no difference in skill results between the two groups post-training. This suggests that there are other approaches to providing CE to health workers that may not come with the high cost and logistical requirements of conventional training. This also suggests that newer technologies may constitute one response to the "outreach gap" in sub-Saharan Africa's rural areas, as they may potentially be less costly and could facilitate access to clinical providers in remote locations (6).

2. **Manuscript 2:** The purpose of this Scoping review was to explore what is known from the existing research literature about technology-based newborn health learning initiatives for health workers in LMICs with an emphasis on nurses and midwives. Kirkpatrick's model for the evaluation of training programs (4) was used as the guiding framework to consider the various training initiatives. Twelve studies were

included in this review and fell into two main categories: (1) Simulation training in routine neonatal care and neonatal resuscitation (NR) via Helping Babies Breathe courses (n= 6) and other training methodologies (n = 3); and (2) eLearning initiatives (n = 3).

In this review, we identified a number of studies focusing on simulation training for facility-based health workers in India and Africa using evidence-based training programs. All nine simulation-training studies put emphasis on the use of low-cost and low-tech simulation technology using birthing simulator mannequins specifically designed for neonatal resuscitation demonstrations and evaluations. Results reported in this review from simulation training programs varied widely, both in terms of skill acquisition and retention, and in terms of provider behavior and patient outcomes. Some studies reported positive and negative results within the same study. The variable results suggest that while short simulation programs improve short-term knowledge and skills and may improve longer-term practice in the simulated setting, the training may be insufficient to enable HWs to integrate and translate those skills into clinical practice. Only a few of the included studies utilized more robust study designs and validated measurement instruments.

Additionally, we identified a limited number of studies utilizing eLearning initiatives, such as Internet based online learning with local hands-on skill enhancement and mobile phone apps, which points to the relative lack of peer-reviewed studies on eLearning and mLearning interventions for newborn health workers in LMIC's (7-8). The content of the initiatives focused primarily on essential newborn care including basic NR. Collectively these interventions targeted facility-based prevention and treatment of the major causes of neonatal deaths, particularly

perinatal deaths in the intra-partum period and during the first week of life, where intra-partum related "birth asphyxia" takes a heavy toll (9). Lund et al (10) carried out a cluster randomized controlled trial in Ethiopia using the Safe Delivery App (SDA) and measured significant changes and retention in birth attendants' knowledge and skill levels, demonstrating that the use of mobile phones is feasible for health care workers, irrespective of their educational level or prior training. Lund et al.'s study (10) also found a non-significant lower perinatal mortality rate in intervention clusters compared with control clusters subsequent to SDA use and results showed that providers perceive the use of mobile tools as an interesting opportunity for self-improvement with effects on health care workers' motivation, self-efficacy, and enthusiasm, in contrast to passive learning models (7, 10).

Our conclusions from this review were that learning approaches emphasizing simulation training and eHealth initiatives for facility-based maternal and newborn health workers in LMIC's hold promise for identifying potentially scalable approaches towards establishing better coverage of skilled birth attendants proficient in essential newborn care and neonatal resuscitation but that additional research documenting patient outcomes associated with technology-based learning interventions for newborn health workers is needed.

2. **Manuscript 3:** This manuscript describes the research carried out in the Democratic Republic of the Congo (DRC) by the PI from April - July 2017, which sought to determine the feasibility, acceptability, and potential impact of the Safe Delivery App (SDA)(25) on health workers' practices in basic emergency obstetric and newborn care (BEmONC) in the DRC. In this cluster-randomized and mixed

methods pilot trial in 2 health zones of central DRC, 8 EmONC facilities were randomized to an mLearning intervention or to standard practice (control). Knowledge in PPH and NR, and provider self-confidence in BEmONC provision, were assessed at baseline and at 3 months after the intervention among 62 maternal and newborn health care workers at the included facilities. We also conducted 18 interviews with app users and key stakeholders to assess feasibility and acceptability of mLearning and the use of the Safe Delivery App. Maternal mortality was compared pre-and-post intervention in intervention and control facilities using a smartphone-based Open Data Kit (ODK) data application, designed by the researchers for this study. The Theoretical Domains Framework (TDF)(57-59) guided this study.

Learning via the SDA was assessed, in interviews with pilot trial app users, to be feasible and acceptable for health workers in the DRC context. mLearning more broadly, was assessed by our sample of key stakeholders in the DRC, to be feasible and acceptable, and a potential solution to problems of access by health workers to up-to-date learning resources in hard-to reach settings. A pilot trial with the French language version of the SDA in central DRC led to a significant increase in health care workers' knowledge scores for PPH and NR management and in EmONC self-confidence scores in intervention areas as compared with control areas, irrespective of the gender, previous smartphone use, or professional cadre of the health worker. Our findings also support those of other studies that the use of electronic learning tools are perceived as an opportunity for improving health worker quality with effects on health care workers' motivation, self-efficacy and enthusiasm (11-13).

The Theoretical Domain Framework proposes domains of influences or constructs for health worker behavior change that mirrored these concepts, such as the

domains '*Belief about capabilities*', '*Intentions*' and '*Emotions*' as being critical determinants of behavior change (14). Qualitative interview results further elucidated barriers to mLearning and CE that are well known to key stakeholders in the DRC such as environmental and contextual barriers and lack of resources. The policy context including lack of accountability measures ('*beliefs about consequences*') and gaps in '*professional identity*' mutually reinforce the '*environmental context and resource*' gaps, contributing substantially to poor quality of care by health providers and high mortality indicators for mothers and newborns. Lessons were learned for a future adequately powered study on the effect of mLearning on health care provision quality towards reduced maternal and newborn mortality in the DR Congo.

Limitations of dissertation research

The small sample size of the study, which limited our findings by reducing the power of the study, was our major limitation. This was unavoidable, however, given a number of factors including: (1) the option taken to conduct a feasibility study rather than a fully powered trial; (2) limited available funding for research covering a greater geographical area; and (3) limitations on the approved travel time of the principal investigator (PI) by Medical University of South Carolina (MUSC). Limitations on travel approval were directly linked to the degrading security situation in the DRC throughout the study period. A related limitation was short study duration; a study of longer duration (6 – 12 months) would have allowed us to measure knowledge and self-confidence retention over a longer period of time and thereby strengthened our findings.

In terms of design limitations, 8 facilities were randomized in this study, rather than individuals, to avoid contamination of the intervention group to the control group (10). However, we noted some disparities between the intervention and control groups in the gender, professional cadre composition, and previous experience of the health workers, thus clearly a randomization of individuals might have provided more equal research groups. Additionally, blinding of intervention and control clusters was impossible owing to the nature of the intervention, which increased the risk for information bias.

Related to the measures used in the SDA pilot study, the design would have been strengthened by the measurement of hands-on provider skills pre-and-post intervention, using Objective Structured Competency Evaluation (OSCE), which was used to measure changes in psychomotor skills in the majority of pre-and-post studies in our literature review [such as in Lund et al. (10)] and is a key domain for both Bloom (2) and the TDF (14). However the requirements in terms of staffing and equipment needed to carry this assessment out properly were not possible given the limited funding and time as noted above.

The limitation of the non-availability of validated measurement instruments for SDA self-confidence and knowledge tests should be noted. Our data does, however, contribute to the body of knowledge of these measures, particularly for the PPH and NR knowledge tests, which were found to have significantly different values for three health worker cadres (MD's, nurses and midwives), which suggests internal validity of the knowledge tests.

We were unable to consistently track SDA use by intervention cluster facilities during the study, given that this capability was not completely developed by the

Maternity Foundation at the time of intervention. Access to such data would have enriched our results and our analysis of the association between SDA use and observed changes in knowledge and self-confidence measures.

There were limitations on the availability of IMA colleagues in the DRC prior to the deployment of the PI to the field, which made it impossible to complete and deploy the Open Data Kit (ODK) data collection instrument prior to PI arrival in country. As a result, we were unable to measure pre-and-post SDA intervention mortality data using the ODK. However, given our small sample size it would still have been unlikely that we would have been able to collect sufficient useful data for meaningful comparisons. Other limitations of the National Health Information System (HIS) and its use by health workers – such as the frequent non-reporting of certain key patient outcomes by health workers and the non-inclusion of certain key outcomes in the HIS indicators (such as maternal complications) would have rendered comparison difficult at this time. Notably, health workers reported regularly under-reporting neonatal deaths and maternal deaths in the HIS due to a variety of factors including poor record keeping, fear of punishment by health authorities and opportunities to not report revenue (thereby facilitating unofficial income for the health workers). Non-reporting of deaths would clearly result in artifically low reported mortality for both women and newborns.

The context in DRC with increasing civil strife and insecurity rendered the PI's efficient use of time difficult on certain occasions when activities needed to be cut short due to the security situation.

Finally, we were limited by having only one mobile phone per facility rather than per provider, as in Lund et al.'s trial of the SDA in Ethiopia (10), due to limited funding and ability to carry sufficient phones to the study site in the filed.

Lessons Learned

1. Carrying out a feasibility study prior to doing a fully powered study is important for a variety of reasons notably, in the case of this study, as related to understanding the limitations of the ODK data collection instrument in terms of triangulating the ODK generated data with HIS and hand-collected hand-completed facility registry data.
2. In a future fully-powered study, adding a measure to evaluate maternal provider partogram completion as an indication of behavior change (Kirkpatrick level 3) would be an option, given that it is a key action for tracking prolonged labor, one of the major causes of maternal mortality and morbidity (15). The research team did conceive of this measure while in the field, however in order to include it in the study it would have had to be included in the study protocol and IRB approval. Additionally, that measure would be best assessed with a pair of independent reviewers and clear appraisal criteria, which were not in place at the time of study.
3. In a future study, conducting a field visit prior to the study period would provide the opportunity to assess any potential limitations or barriers to the study, such as significant differences in potential cluster sites.
4. The PI achieved personal satisfaction in pursuing a research question and design that, although ambitious and complicated, was of true interest to the PI, the research team, and the community. This research will hopefully lead to future research and

programming and contribute concretely to making a difference in continuing education policy in the DRC and to improving maternal and neonatal outcomes.

Importance of theory, model, or framework to guide overall findings

Bloom's Taxonomy (2), Kirkpatrick's model (4) and the Theoretical Domains Framework were instrumental in supporting the conceptualization of the different pieces of research in this compendium and in analyzing data in the three manuscripts. Each framework/model contributed to understanding the research question from different angles and to nurturing a complex and organic relationship with the data.

The TDF was critical to carrying out the fieldwork, in terms of guiding the crafting of the qualitative interview guide, analyzing the results, and merging the qualitative and quantitative results. In terms of qualitative analysis, semi-structured interviews, held with eight SDA users and ten key stakeholders after the 3-month study period asked about the feasibility and acceptability, and barriers and facilitators, of using the SDA, mLearning, and CE in the DRC. All 14 TDF domains were considered in the data analysis and qualitative responses were mapped to these domains for both target groups, although certain domains are very closely delineated in terms of meaning. Responses for SDA users were coded deductively to 8 out of 14 domains ('knowledge', 'skills', 'belief about capabilities', 'reinforcement', 'intentions', and 'emotion', 'memory/attention/decision processes' and 'environmental context and resources'). Key stakeholder responses were mapped to these same 8 domains plus two additional domains ('social/professional role and identity', 'beliefs about consequences'), since the discussion took into account the broader issues and context of CE in the DRC. Quantitative and qualitative data were

interpreted and merged together, noting both the quantitative statistical results and qualitative quotes or themes that supported or refuted the quantitative results. The TDF allowed for this process to be carried out seamlessly, given that quantitative measures matched easily with the TDF domains of 'knowledge' and 'belief about capabilities' (or self-confidence).

Additionally, qualitative responses, analyzed using TDF domains, further clarified barriers to mLearning and CE that are well known to key stakeholders in the DRC such as environmental and contextual barriers and lack of resources. The policy context including lack of accountability measures ('beliefs about consequences') and gaps in 'professional identity' mutually reinforce the deficits of the resource-poor 'environmental context and resource' gaps, contributing substantially to poor quality of care by health providers and high mortality indicators for mothers and newborns in the DRC.

Research trajectory (candidate's next steps)

1. Our pilot trial laid the groundwork for a future, adequately powered, randomized-controlled-trial (RCT) to test the hypothesis that the SDA mLearning intervention is effective in reducing maternal and newborn mortality in the DRC. Planned future research will measure patient outcomes on a larger scale with a longer follow-up period and integrate a pre-and-post partogram completion research component for measuring provider behavior change. This research would necessitate the use of an ODK-like data collection instrument, given the concerns regarding misleading provider reporting in the HIS on key maternal and neonatal indicators, as indicated by qualitative interview results. The recently released new SDA version incorporates

additional features in the app to measure learning and to motivate the learner through video game-like features where learners have to gain a certain number of points to move to the next learning level and are certified once they achieve the top score. The new app is able to tailor questions for the individual user and has also refined capability to track individual usage, which would add useful data to study results. The PI would ideally work with the National DRC Ministry of Health and key in-country partners to develop and put in place the informatics capacity for SDA use data to feed into a Human Resource Information System (HRIS)(16) for tracking CE completion. That HRIS data would be part of an eventual required CE/continuing professional development (CPD) program for maternal and neonatal health workers in the DRC.

2. The PI would be interested in conducting a literature review and qualitative research study using the TDF to examine the widespread use of a dangerous practice for prolonged labor in the DRC ("Kristellerd technique") and subsequently designing an intervention to reduce the use of this practice in obstetric care for national roll-out. The "Kristellerd technique" is the application of fundal pressure during the active phase of the second stage of labor and is a controversial maneuver. It is further defined as the putting of manual pressure on the fundus of the uterus towards the birth canal. It is used to expedite vaginal birth of the baby either as routine practice or because of complications (fetal distress, failure to progress, maternal exhaustion) and/or medical conditions whereby prolonged pushing is contraindicated (17). Qualitative interviews suggested that this practice is widespread in the DRC.

Contribution of research to health, nursing, or interprofessional sciences

This research was innovative in a number of ways:

1. We pilot tested a new and recently translated (to French) evidence-based care mLearning app for the first time in a Central African country in an effort to enhance health worker competence in emergency obstetric care and improve maternal and newborn health outcomes.
2. The learning program may well prove useful throughout the Congo and also in other similar low-income Francophone African nations.
3. We utilized mixed methods to gain a holistic picture (including learner feedback) of the future of CE and CPD in the DRC to assure essential maternal, newborn, and child health (MNCH) competencies.
4. We partnered with civil society and the Ministry of Health (MOH) to jointly carry out this community-based research. Because this work occurred jointly with the stakeholders, the findings will contribute to the ongoing policy analysis that is occurring on the national level to evaluate current CE practices for health professionals.
5. There is no currently known published documentation considering CE approaches or the use of an mLearning program in the DRC, despite limited mHealth research carried out in other countries. This project will additionally make a contribution to the body of scientific literature from DRC, where maternal and child health outcomes are among the direst.
6. We developed and pilot tested an ODK app for maternal and newborn data collection in the DRC.

7. We are unaware of a similar use of the TDF as the theoretical basis for scientific research in Africa or in maternal health.

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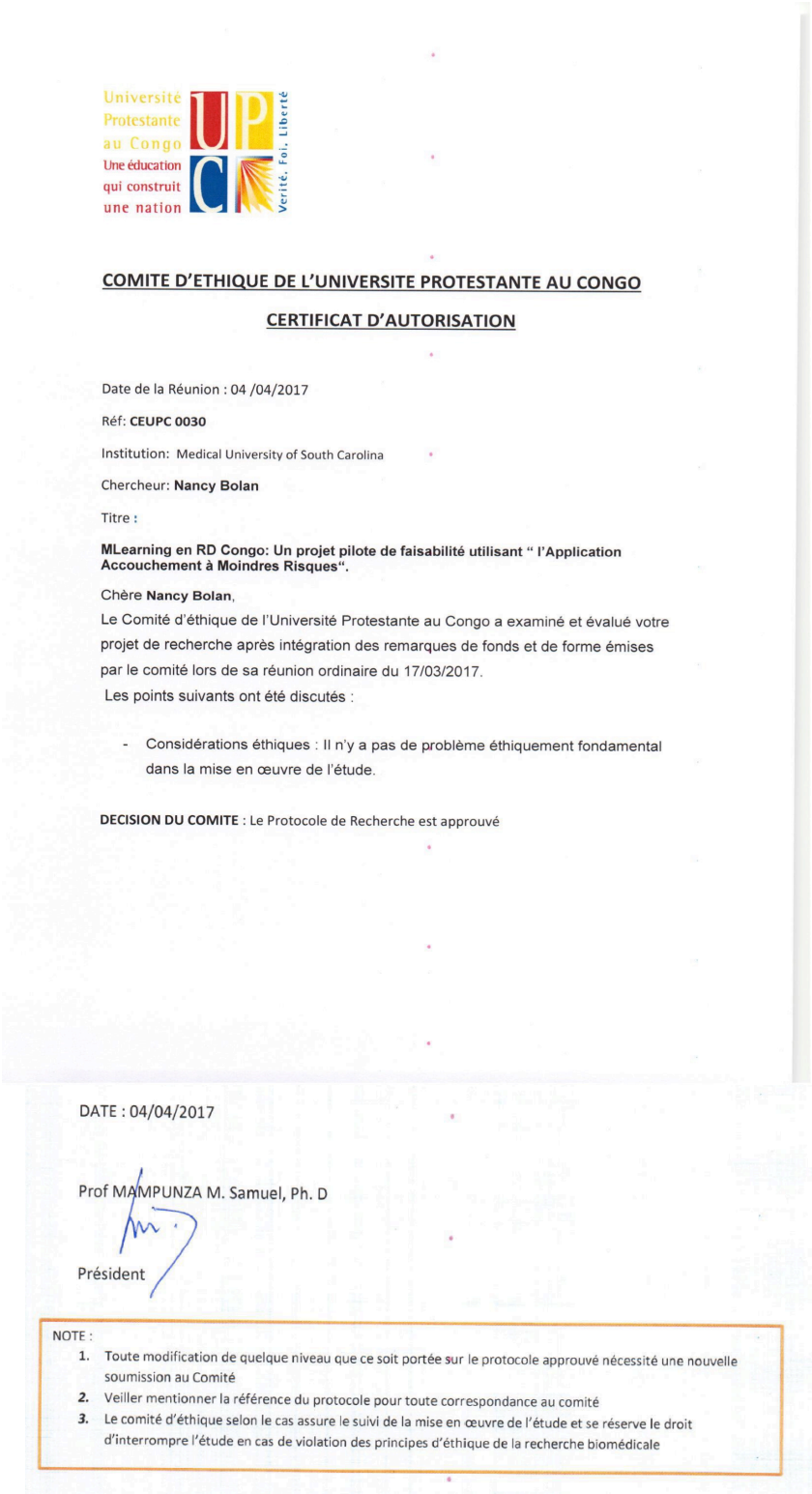
APPENDICES

APPENDIX 1. IRB APPROVAL DEMOCRATIC REPUBLIC OF THE CONGO



Université Protestante au Congo
Une éducation qui construit une nation
Vérité. Foi. Liberté

COMITE D'ETHIQUE DE L'UNIVERSITE PROTESTANTE AU CONGO

CERTIFICAT D'AUTORISATION

Date de la Réunion : 04 /04/2017

Réf: **CEUPC 0030**

Institution: Medical University of South Carolina

Chercheur: **Nancy Bolan**

Titre :

MLearning en RD Congo: Un projet pilote de faisabilité utilisant " l'Application Accouchement à Moindres Risques".

Chère **Nancy Bolan**,

Le Comité d'éthique de l'Université Protestante au Congo a examiné et évalué votre projet de recherche après intégration des remarques de fonds et de forme émises par le comité lors de sa réunion ordinaire du 17/03/2017.

Les points suivants ont été discutés :

- Considérations éthiques : Il n'y a pas de problème éthiquement fondamental dans la mise en œuvre de l'étude.

DECISION DU COMITE : Le Protocole de Recherche est approuvé

DATE : 04/04/2017

Prof MAMPUNZA M. Samuel, Ph. D

Président

NOTE :

1. Toute modification de quelque niveau que ce soit portée sur le protocole approuvé nécessité une nouvelle soumission au Comité
2. Veiller mentionner la référence du protocole pour toute correspondance au comité
3. Le comité d'éthique selon le cas assure le suivi de la mise en œuvre de l'étude et se réserve le droit d'interrompre l'étude en cas de violation des principes d'éthique de la recherche biomédicale

APPENDIX 2. MUSC IRB APPROVAL

Institutional Review Board for Human Research (IRB)
Office of Research Integrity (ORI)
Medical University of South Carolina

Harborview Office Tower
19 Hagood Ave., Suite 601, MSC857
Charleston, SC 29425-8570
Federal Wide Assurance # 1888

APPROVAL:
This is to certify that the research proposal **Pro00063763** entitled:
mLearning in the DR Congo:
A Feasibility and Pilot Project using the Safe Delivery App

submitted by: **Nancy Bolan**
Department: **Medical University of South Carolina**

for consideration has been reviewed by **IRB-I - Medical University of South Carolina** and approved. In accordance with 45 CFR 46.101(b)(2), the referenced study is exempt from Human Research Subject Regulations. No further action or Institutional Review Board (IRB) oversight is required, as long as the project remains the same. However, you must inform this office of any changes in procedures involving human subjects. Changes to the current research protocol could result in a reclassification of the study and further review by the IRB.

Because this project was determined to be exempt from further IRB oversight, consent document(s), if applicable, are not stamped with an expiration date.

Research related records should be retained for a minimum of three years after termination of the study.

Approval Date: **4/28/2017**

Type: **Exempt**

Grants Administrator, **IRB - Medical University of South Carolina**
Amy Haynes*

****Electronic Signature**: This document has been electronically signed by the IRB Chairman through the HSSC eIRB Submission System authorizing IRB approval for this study as described in this letter.*

APPENDIX 3. IRB APPROVED INFORMATION FOR PARTICIPANTS SHEET – FACILITY-BASED STAFF (ENGLISH)

Medical University of South Carolina
Information for Participants Sheet

TITLE OF RESEARCH:

mLearning in the DR Congo:
A Feasibility and Pilot Project using the Safe Delivery App

Subtitle: Facility-based participants in selected facilities

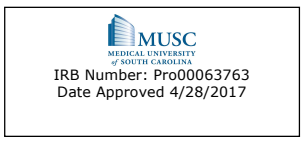
A. PURPOSE OF THE RESEARCH

You are being asked to volunteer for a research study. The purpose of this research study is to learn about approaches to continuing education for health care providers in the Congo and to test a new learning approach for maternal health care providers using a mobile phone based learning app about safe birthing techniques. You are being asked to participate in this study because you provide care to women in labor and newborns in IMA project facilities where emergency obstetric care is practiced. The study is being carried out by the researcher and IMA World Health, in collaboration with the Ministry of Health. The investigator in charge of this study is Nancy Bolan. The study is being done at 6 sites. Approximately 70 people will take part study-wide. Research studies are voluntary and include only people who choose to take part. As the researcher discusses this consent form with you, please ask him/her to explain any information that you do not clearly understand.

B. PROCEDURES

If you are interested to participate in this study, the following will happen:

1. You and your colleagues will be assigned to either the test or control facility. We will ask all participants in the facilities to fill in some questionnaires, as described below.
2. First we will assign you a numeric ID, and the ID, rather than your name, will identify you on any documents. Only the researcher will be aware of your name because she will have the list of IDs and this will not be shared.
3. We will ask you to fill in some basic information about yourself. We will then ask you to fill in a short questionnaire about how you feel about providing different aspects of emergency obstetric care and then questions about some aspects of emergency obstetric care. All of this information will be confidential for research purposes only.
4. If you are in the intervention group, we will then ask you to participate in a short training on the use of the app today with your colleagues and then to use the app when you wish during the next three months. The app will be on a smartphone that will be based at your



facility. If you are in the control group, you will be continue your duties as usual without using the app. You will be trained on the use of the app after three months.

5. We would then ask you again after 3 months about how you feel about providing emergency obstetric care and some questions about the provision of care. We may also wish to ask you questions about how you felt about the training on the app and about the use of the app.

6. You can withdraw from the study at any time. We are, however, hoping to learn from your experience with this new mLearning approach and look forward to meeting with you again in three months to discuss your experience.

C. DURATION

Participation in the study will require 2 visits over a 3 month period (including for the training today). Each visit will require about 2 – 3 hours.

D. RISKS AND DISCOMFORTS

There is a risk of a loss of confidentiality of your personal information as a result of participation in this study resulting in potential embarrassment regarding your answers on the survey or worries about your job. All possible measures will be taken to prevent this from happening.

E. BENEFITS

There is no direct benefit to you from participating. The potential benefit to you of participating in this research is that you will have the opportunity to express your opinions and perspectives, which could influence others in terms of the approaches used in continuing education and the potential use of new approaches. This research could lead to increased attention on the importance of continuing education for health workers and encourage favorable policy changes or programmatic decisions or could possibly result in future funding or innovative initiatives.

F. COSTS & PAYMENT TO PARTICIPANTS

There will be no cost to you as a result of participation in this study. You will not be paid for participating in this study.

H. EMPLOYEE PARTICIPATION

Your alternative is to not participate in this study. There would be no impact on your job related to not participating. Your participation or discontinuance will not constitute an element of your job performance or evaluation, nor will it be a part of your personnel record at this Institution. Your participation in this study is voluntary. You may refuse to take part in or stop taking part in this study at any time. Your decision not to take part in the study will not affect your current or future employment, medical care or any benefits to which you are entitled.

APPENDIX 4. IRB APPROVED INFORMATION FOR PARTICIPANTS SHEET – KEY INFORMANTS (ENGLISH)

Medical University of South Carolina
Information for Participants Sheet

TITLE OF RESEARCH:

mLearning in the DR Congo:
A Feasibility and Pilot Project using the Safe Delivery App

Subtitle: Key stakeholders

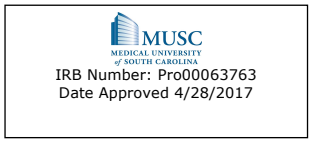
A. PURPOSE OF THE RESEARCH

You are being asked to volunteer for a research study. The purpose of this research study is to learn about approaches to continuing education for health care providers in the Congo and to test a new learning approach for maternal health care providers using a mobile phone based learning app about safe birthing techniques.
You are being asked to participate in this study because you play an important role in the DRC in terms of determining what approaches to continuing education will be used and how they will be implemented. The study is being carried out by the researcher and IMA World Health, in collaboration with the Ministry of Health. The investigator in charge of this study is Nancy Bolan. Approximately 70 people will take part study-wide in different parts of the study. Research studies are voluntary and include only people who choose to take part. As the researcher discusses this consent form with you, please ask him/her to explain any information that you do not clearly understand.

B. PROCEDURES

If you are interested in taking part in the study, the following will take place:

1. We will ask you to fill in some basic information about yourself.
2. We will brief you on the Safe Delivery App.
3. We will then interview you on the topic of continuing education approaches for health workers and mLearning (learning using mobile phones or electronic tablets). Your interview would be audio-recorded. We will transcribe the digital recordings. The transcripts will also be stored on a secure cloud account. Only the researcher and her advisors will have access to this information. The identity of the informant will not be revealed in any of the reporting of qualitative results, nor will the reporting refer to identifiers that could indirectly reveal the identity of the informant.
4. If at any time during the interview you wish to terminate the interview, you can do so.



C. DURATION

The interview will last approximately one (1) hour. This is the only activity that we will ask you to participate in; after the interview your participation in the research study will be complete.

D. RISKS AND DISCOMFORTS

There is a risk of a loss of confidentiality of your personal information as a result of participation in this study resulting in potential embarrassment regarding your answers on the survey or worries about your job. All possible measures will be taken to prevent this from happening.

E. BENEFITS

There is no direct benefit to you from participating. The potential benefit to you of participating in this research is that you will have the opportunity to express your opinions and perspectives, which could influence others in terms of the approaches used in continuing education and the potential use of new approaches. This research could lead to increased attention on the importance of continuing education for health workers and encourage favorable policy changes or programmatic decisions or could possibly result in future funding or innovative initiatives.

F. COSTS & PAYMENT TO PARTICIPANTS

There will be no cost to you as a result of participation in this study. You will not be paid for participating in this study.

H. EMPLOYEE PARTICIPATION

Your alternative is to not participate in this study. There would be no impact on your job related to not participating. Your participation or discontinuance will not constitute an element of your job performance or evaluation, nor will it be a part of your personnel record at this Institution. Your participation in this study is voluntary. You may refuse to take part in or stop taking part in this study at any time. You should tell the investigator in charge of this study if you decide to do this. Your decision not to take part in the study will not affect your current or future employment, medical care or any benefits to which you are entitled.

APPENDIX 5. IRB APPROVED INFORMATION FOR PARTICIPANTS SHEET – FACILITY-BASED STAFF (FRENCH)

CONSENTEMENT ECLAIRE

TITRE DE LA RECHERCHE:

mLearning en RDC:
Projet pilote de faisabilité utilisant
“ L’Application Accouchement à Moindre Risque“ (AAMR)

Sous-titre: Participants aux FOSA

A. OBJECTIF DE LA RECHERCHE

On vous invite à participer dans une étude de recherche. Le but de cette étude est d’obtenir une image holistique de l'avenir de la Formation Continue pour assurer les compétences essentielles en matière de santé maternelle, néonatale et infantile (SMNE) pour les prestataires de soins de santé en RDC. En plus, nous testerons une nouvelle approche d'apprentissage pour les personnels de santé travaillant dans la santé maternelle en RDC en utilisant une intervention « mLearning » [« l’Application Accouchement à Moindre Risque » (AAMR)]. AAMR est une application pour les smartphones (mLearning) qui peut aider à la formation et être utilisée comme aide-mémoire. AAMR tente de renforcer la capacité et la confiance des personnels qualifiés dans l’offre des soins obstétricaux et néonatals essentiels et d’urgence de base (SONU B), basé sur l’évidence scientifique mise-à-jour. L'étude est menée par le chercheur et le projet *Accès aux Soins de Santé Primaires* (ASSP en sigle, 2013-2018), en collaboration avec le Ministère de la Santé Publique. On vous demande de participer à cette étude parce que vous offrez des soins obstétricaux et néonatals essentiels et d’urgence de base (SONU B) dans une formation sanitaire (FOSA) désignée pour le renforcement de SONU par le projet ASSP. L'étude sera réalisée dans 6 sites. Environ 70 personnes participeront à l'étude dans différentes phases de l'étude. Les études de recherche sont volontaires et n’obligent pas que les personnes participent. Lorsque le chercheur discute avec vous de ce formulaire de consentement, veuillez lui demander de lui expliquer toute information que vous ne comprenez pas clairement.

B. PROCÉDURES

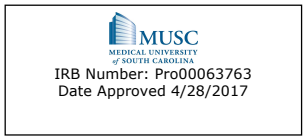
Si vous êtes intéressé de participer dans cette étude, ce qui suit se produira:

1. L'établissement dont vous travaillez sera désigné d’être dans le groupe d'essai ou de contrôle. Nous demanderons à tous les participants concernés de remplir certains sondages, voir ci-dessus :

2. Nous allons d'abord vous attribuer un numéro, qui vous identifiera sur les documents, plutôt que votre nom. Seule le chercheur sera au courant de votre nom parce qu'elle aura la liste des numéros. Cette liste ne sera pas partagée avec d'autres personnes.

3. Nous vous demanderons de remplir quelques informations de base sur vous-même (age, sexe, profession, etc.). Nous vous demanderons ensuite de répondre à une courte enquête sur la manière dont vous vous sentez à propos de différents aspects de la prestation des SONU, puis de répondre à des questions sur certains aspects de SONU. Toutes ces informations seront confidentielles, collectées uniquement à des fins de recherche.

4. Nous vous demanderons ensuite de participer à une courte formation d'environ deux heures sur l'utilisation de l'application AAMR avec vos collègues (si vous êtes dans le groupe d'intervention) et ensuite d'utiliser l'application lorsque vous le souhaitez au cours des trois prochains mois. L'application



APPENDIX 6. IRB APPROVED INFORMATION FOR PARTICIPANTS SHEET – KEY INFORMANTS (FRENCH))

CONSENTEMENT ECLAIRE

TITRE DE LA RECHERCHE:

mLearning en RDC:
Projet pilote de faisabilité utilisant
“ L’Application Accouchement à Moindre Risque“ (AAMR)

Sous-titre: Responsables clés a Kinshasa et Kananga

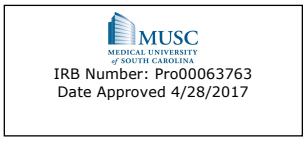
A. OBJECTIF DE LA RECHERCHE

On vous invite à participer dans une étude de recherche. Le but de cette étude est d’obtenir une image holistique de l'avenir de la Formation Continue pour assurer les compétences essentielles en matière de santé maternelle, néonatale et infantile (SMNE) pour les prestataires de soins de santé en RDC. En plus, nous testerons une nouvelle approche d'apprentissage pour les personnels de santé travaillant dans la santé maternelle en RDC en utilisant une intervention « mLearning » [« l’Application Accouchement à Moindre Risque » (AAMR)]. AAMR est une application pour les smartphones qui peut aider à la formation et être utilisée comme aide-mémoire; AAMR tente de renforcer la capacité et la confiance des personnels qualifiés dans l’offre des soins obstétricaux et néonatals essentiels et d’urgence de base (SONU B), basé sur l’évidence scientifique mise-à-jour. L'étude est menée par le chercheur et le projet *Accès aux Soins de Santé Primaires* (ASSP en sigle, 2013-2018), en collaboration avec le Ministère de la Santé Publique. On vous demande de participer à cette étude parce que vous jouez un rôle important en RDC pour ce qui est de déterminer quelles approches de la formation continue seront utilisées et comment elles seront mises en œuvre. Environ 70 personnes participeront à l'étude dans différentes phases de l'étude. Les études de recherche sont volontaires et n’obligent pas que les personnes participent. Lorsque le chercheur discute avec vous de ce formulaire de consentement, veuillez lui demander de lui expliquer toute information que vous ne comprenez pas clairement.

B. PROCÉDURES

Si vous êtes intéressé de participer dans cette étude, ce qui suit se produira:

1. Nous vous demanderons votre fonction.
2. Nous allons vous briefer sur l’AAMR et ensuite vous interviewer sur le thème des approches d'éducation continue pour les agents de santé et mLearning (apprentissage à l'aide de téléphones mobiles ou de tablettes électroniques). Votre interview sera enregistrée. Nous transcrirons les enregistrements numériques, en supprimant toute information d'identification. Les transcriptions seront stockées sur un système sécurisé. Seule le chercheur et ses conseillers auront accès à cette information. L'identité de l'informateur ne sera pas révélée dans aucun des rapports de résultats qualitatifs, et le rapport ne se référera pas à des identificateurs qui pourraient indirectement révéler votre identité.



APPENDIX 7. LETTER OF SUPPORT FROM IMA WORLD HEALTH

March 8, 2017

To Whom It May Concern,

I am writing to confirm IMA's support for Nancy Bolan's PhD dissertation research in the DR Congo over the next year. We conceived of the research jointly and have been working with Nancy throughout the entire planning process, thus the work will be carried out jointly between Nancy, IMA DRC, and the DRC Ministry of Health. We will use the structure and resources of the UK government-funded "Access to Primary Health Care" (ASSP) project to conduct this community-engaged research. We hope that the process and findings of this feasibility/pilot study will be of direct benefit to our project and to the country and that by testing an mLearning job aide and learning program for health workers, we can identify new and interesting ways to provide evidence-based care guidelines to underserved areas of the country and to impact the quality of emergency obstetric care currently being provided.

While working in Kinshasa, Nancy will be based out of our office and will use IMA vehicles and drivers. We will provide any necessary office or meeting space for her to work with our staff or partners in Kinshasa. While working in Kisangani, Nancy will be based out of our ASSP Kisangani partner's office and will use project vehicles and experienced drivers to visit ASSP project sites. Additionally IMA has a small office and staff in Kisangani. IMA staff on mission frequently use the hotel where Nancy will stay in Kisangani and it is located in a secure neighborhood. I can take this opportunity to also reinforce that Kinshasa and Kisangani generally have good security. Nancy will do her work during the day within the urban center of town in Kisangani and will not be dealing directly with patients but rather with health workers in the Ministry of Health or partner facilities and offices. Nancy has traveled to Kisangani recently and knows Kinshasa very well and thus will be mindful of any security related precautions.

We will collaborate with Nancy on the pre-intervention data collection, the training with the mLearning tool, and the post-intervention data collection. We will also work together to determine what support might be needed in the field in the period between her two trips. We will cover many of Nancy's in-country costs.

I am an external member on Nancy's PhD committee and will be her primary point of contact throughout both of her visits to the DRC. She can reach me via cell phone or SAT phone, both of which are available. I look forward to our collaboration and testing of this new educational approach.

Sincerely,

Larry Streshley

Dr. Larry Streshley
IMA DRC Country Director

500 Main Street • PO Box 429 • New Windsor, MD 21776 USA • p 410.635.8720 • f 410.635.8726 • www.imaworldhealth.org

APPENDIX 8. QUALITATIVE INTERVIEW GUIDE – APP USER (ENGLISH)

Interview Guide N Bolan
App acceptability

Goal: to assess app acceptability, to identify potential logistical and methodological issues of training on SDA, app use, and study procedures.

1. Have you used the Safe Delivery App during the last three months?

2. If no, elaborate why and what constraints were encountered?

3. If yes:
   Describe the last time you used the app. (where/when/who/why)
   - When, and for what?
   - How often?
   - Which features?
   - Emergency situations? (What has the app helped the health worker with?)

4. Were you able to use the following features of the app:
   (a) Videos
   (b) Action cards
   (c) Practical procedures
   (d) Drug List

5. Did you find any features particularly helpful or not helpful? Which features and why?

6. Did you see problems with the French?

7. Regarding the use of the Safe Delivery App – was the training you received adequate to use the app?

8. Was there additional information that would have been helpful for the use of the app?

9. Can you tell us how you feel about the phone? (Does it hold a charge; are you able to see the demonstrations?)

10. Thinking back to the training that we did for the phone use, do you feel that the training gave you the needed skills to be able to use the phone?

11. Was there additional information that would have been helpful to know for the use of the phone?

12. What were the constraints linked to having only one phone per FOSA?

13. Did you have any reactions to the self-confidence questions?

14. Did you have any reactions to the knowledge test EMOC?

15. Do you have anything else you wish to share with us about the phone or the Safe Delivery App? Suggestions/ comments/ questions?

APPENDIX 9. QUALITATIVE INTERVIEW GUIDE – KEY INFORMANTS (ENGLISH)

Interview Guide N Bolan
Policy Makers, Program managers, Professional org reps

I'm interested in learning more about your perspective on current and future approaches for Continuing Education geared to improving competence of health workers in maternal and newborn health care in DRC.

1. How does continuing education for nurses, midwives and other health workers occur currently?

2. What do you think are the most important barriers to CE in DRC? Probe: time, resources, content experts, interest

3. What do you think would help ensure continuing education for these workers can be accomplished better? Probe: simulation

4. What can be done to reach health care workers in hard-to-reach settings?

5. What are your thoughts on certain potential approaches tried in other countries for continuing education of health care workers. Do you think that might be worth trying here in DRC:
   (a) Mentoring
   (b) Local guideline development
   (c) Teamwork training
   (d) mLearning & AAMR
   (e) Self-directed learning

   Probe: feasibility (cost), acceptability and effectiveness (long-term)

6. What methods might motivate/change attitudes of health workers?

7. What other factors are important to consider in trying to improve the performance or quality of care of health workers in DRC?

8. How does the potential role of health professional regulations impact CE in DRC?

9. How is training effectiveness measured currently? How would you envision measuring this in the future in the most ideal way?

Would you like to add anything else related to this topic?

Appendix 10. QUALITATIVE INTERVIEW GUIDE – APP USER (FRENCH)

Interview Guide - French
App acceptability

Objectif: Evaluer l'acceptabilité de l'AAMR, identifier les problèmes logistiques et méthodologiques potentiels liés à la formation sur l'AAMR, à l'utilisation de l'AAMR et aux procédures d'étude.

1. Avez-vous utilisé l'application AAMR au cours des trois derniers mois?

2. Si non, expliquez pourquoi et quelles contraintes ont été rencontrées?

1. Si oui: Décrivez la dernière fois que vous l'avez utilisé. (Où / quand / qui / pourquoi)
   - Quand et pour quoi?
   - À quelle fréquence?
   - Quelles fonctionnalités?
   - Situations d'urgence? (À quoi l'application a-t-elle aidé l'agent de santé?)

2. Avez-vous pu utiliser les fonctionnalités suivantes de l'application:
   (a) Vidéos
   (b) Cartes d'action
   (c) Modalités pratiques
   (d) Liste des médicaments

5. Avez-vous trouvé des fonctionnalités particulièrement utiles ou pas utiles?

6. Avez-vous rencontré des problèmes avec le français/la traduction ?

7. En ce qui concerne l'utilisation de l'AAMR, est-ce que la formation que vous avez reçue était adéquate pour l'utilisation de l'application?

8. Y avait-t-il des informations supplémentaires qui auraient été utiles pour l'utilisation de l'AAMR?

11. Est-ce que vous avez apprécié le téléphone? (Ca s'épuise vite ? Ca va la taille de l'écran pour voir l'application?)

9. Pensez-vous que la formation que nous avons faite pour l'utilisation du téléphone vous a donné les compétences nécessaires pour être en mesure de l'utiliser?

10. Y a-t-il des renseignements supplémentaires qui auraient été utiles pour l'utilisation du téléphone?

12. Quelles était des contraintes liée à le fait d'avoir donné juste une téléphone/ FOSA ?

12. Pour les autres aspects de l'étude, avez-vous eu des réactions à des questions de confiance en soi?

13. Avez-vous d'autre chose à partager avec nous au sujet du téléphone ou de l'application ou l'étude? Suggestions / commentaires / questions?

APPENDIX 11. QUALITATIVE INTERVIEW GUIDE – KEY INFORMANTS (FRENCH)

Guide Qualitative N Bolan
Les Parties Prenantes Clés

Objectif: Savoir le point de vue du participant sur les approches actuelles et futures de la Formation Continue (FC) visant à améliorer les compétences des agents de santé dans les soins de santé maternelle et néonatale en RDC.

1. Comment se déroule actuellement la formation continue des médecins, infirmiers, des accoucheuses et d'autres professionnels de la santé?

2. Selon vous, quels sont les obstacles les plus importants à la FC ?
Sonde : le temps, les ressources, les experts de contenu, l'intérêt

3. Qu'est-ce qui, à votre avis, aiderait à assurer que la formation continue des travailleurs peut être mieux accompli?
Sonde : simulation

4. Quoi faire pour atteindre les travailleurs de la santé dans les endroits reculés?

5. Quelles sont vos réflexions sur certaines approches potentielles, éprouvées dans d'autres pays pour la formation continue. Pensez-vous que cela pourrait être intéressant d'essayer ici en RDC:
(A) Le coaching
(B) l'élaboration de directives locales
(C) la formation de travail d'équipe
(D) mLearning/AAMR
(E) L'apprentissage autodirigé

Sonde: faisabilité (cout), l'acceptabilité et l'efficacité (a long-terme)

6. Quelles méthodes pourraient motiver / changer les attitudes des agents de santé?

7. Quels autres facteurs sont importants à considérer pour essayer d'améliorer la performance ou la qualité des soins des agents de santé en RDC?

8. Comment l'efficacité de la formation est-elle mesurée actuellement? Comment envisageriez-vous de mesurer cela de la façon la plus idéale dans l'avenir?

1. Quoi sera l'impact potentiel des réglementations des professionnels de la santé sur la formation continue en RDC?

Souhaitez-vous ajouter quelque chose d'autre lié à ce sujet? Merci.

APPENDIX 12. DEMOGRAPHIC DATA COLLECTION INSTRUMENT (ENGLISH)

Facility-based Participant Demographic Data

1. Age

2. Sex/Gender
   a. male
   b. female

3. Profession/Educational level
   a. MD
   b. Nurse - polyvalent
   c. Nurse A0
   d. Nurse A1
   e. Nurse A2
   f. Nurse A3
   g. Midwife (A1) (Trained at ISTM)
   h. Birth Attendant (A2) (Trained at IEM/ITM)
   i. Birth Attendant (A23) (Trained at IEM/ITM)
   j. Matron/Traditional BA (Trained at the facility over time)

4. Years of experience in this profession

5. Deliveries performed in the past month (#)

6. Previous use of tablet/smartphone
   a. Tried using one
   b. Never tried using one

APPENDIX 13. DEMOGRAPHIC DATA COLLECTION INSTRUMENT (FRENCH)

Données démographiques Participants FOSA

1. Age
   a. <20
   b. 20 - 30
   c. 30 - 40
   d. 40 – 50
   e. >50

2. Sexe
   a. homme
   b. femme

3. Profession/Niveau d'études
   a. Médecin
   b. Infirmier A0
   c. Infirmier A1
   d. Infirmier A2
   e. Infirmier A3
   f. Sage-Femme (A1) (Formé à l'ISTM)
   g. Accoucheuse (A2) (Formé à l'IEM ou ITM)
   h. Accoucheuse (A3) (Formé à l'époque où les écoles existaient
   i. Matrones/Accoucheuses Traditionnelles (Forme au niveau de la structure au fil du temps et pratique)

4. Années d'expérience/Despuis combien d'annees exercez-vous cette profession ?
   a. 1-5
   b. 6-10
   c. > 10

5. Accouchements assistés en cours du dernier mois (#)
   a. 0
   b. 1-5
   c. 6-10
   d. >10

6. Utilisation antérieure du smartphone
   a. Jamais
   b. Expérience dans l'utilisation

APPENDIX 14. KNOWLEDGE TEST / KFQ'S (ENGLISH)

Key Feature Questions (KFQ)
You are about to take a Key Feature Questionnaire (KFQ) on the various topics covered in the Safe Delivery App. Key Feature Questions are used to test your practical application on knowledge and are based on clinical case scenarios.
Kindly read the following instructions carefully before you begin the assessment.

In total, there are 15 cases and 55 questions. For each case, there are multiple questions and answers. Questions are to be answered by choosing from the listed options. **For each question there may be several correct answers.**

The correct options are the "key features" and each key feature gives a positive score.
There may also be wrong answers either: a) Harmful, or b) Critically harmful. For those that are harmful, half of the total score will be deducted, regardless of the other answers given. For those considered critically harmful, the total score will be deducted, regardless of the other answers given.
Please select the answers you think are correct by clicking them. At the end of the KFQ, you will receive your total score. In order to monitor your progress you will be given the test again after some months.
Thank you for taking your time to answer the key feature questions.

Post Partum Haemorrhage

CASE 1:

You are delivering a primigravida at term with spontaneous onset of labour and normal progress of first and second stage. There is clear liquor. The baby is delivered and screams immediately.

Question 1:

What can be done to reduce the risk of post partum haemorrhage (PPH)?

a) There is no effective way to prevent PPH.
b) Active management of the third stage of labour more than halves the risk of PPH. 0.5
c) Performing episiotomy might reduce the risk of PPH moderately.
d) The effect of giving uterotonic drugs right after delivery to prevent excessive bleeding is scientifically documented. 0.5
e) Only when excessive bleeding occurs should something be done.

Question 2:

What will you do after the delivery of the baby to prevent PPH?

a) I would give an oxytocin injection within one minute of the delivery of the baby. 0.2
b) If oxytocin is not available I would give 3 tablets misoprostol orally. 0.2
c) I would not give any drugs before the placenta is delivered.
d) The placenta should be delivered by gentle controlled cord traction. 0.2
e) To deliver the placenta I would have to pull the cord with force.
f) To deliver the placenta I should squeeze the top of the uterus.
g) Uterus massage should be done after the delivery of the placenta. 0.2
h) Uterus massage only works if done clockwise.
i) The baby should start breastfeeding early. 0.2
j) Only after one hour should the baby be given to its mother.

CASE 2:

A 23-year old woman has just given birth to twins. Both babies are doing fine. The placenta has been delivered and examined, and no tissue seems to be missing. There are no visible tears to the perineum. Suddenly, the woman starts to bleed heavily.

Question 3:

What are the FIRST steps you would take now?

a) Measure the woman's blood pressure.
b) Call for help. 0.25
c) Empty the bladder. 0.25
d) Perform bimanual compression if the bleeding is not controlled quickly. 0.25
e) Palpate the pulse at the femoral blood vessels.
f) Give uterotonic drugs.
g) Find sterile gloves.
h) Perform continuous uterus massage. 0.25
i) Prepare intravenous accesses.
j) Measure the woman's haemoglobin. /2
k) Find normal gloves.

Question 4:
You have performed the initial steps to manage the bleeding and you are now performing a bimanual compression. An assistant is still present with you in the delivery room. What would you ask the assistant to do?

a) Position the head down if not done already. 0.25
b) Measure hemoglobin if not done already.
c) Encourage her to drink as much as she can.
d) Insert two IV lines. 0.25
e) Give 1 liter of IV fluids running one drip per second.
f) Give 2 liters of IV fluids running as fast as possible. 0.25
g) Give drugs to help the uterus to contract. 0.25
h) Get her up and walk. 0

Question 5:
Your assistant asks about the dosage and administration of uterotonic drugs. What are the correct drugs and their correct administration and dosages? Select the ones you find appropriate:

a) 1,600 mcg of Misoprostol orally.
b) 2 L of normal Saline fast. 0.25
c) 10 international units of Oxytocin IM if not already administered. 0.25
d) 800 ug of misoprostol per rectum. 0.25
e) Oxytocin drip: 20 international units in 1 L Normal Saline or Ringer's lactate 1 drop each 5 seconds.
f) Oxytocin drip: 20 international units in 1 L Normal Saline or Ringer's lactate: 10 drops per second.
g) 30 international units of Oxytocin IV push. 0
h) Oxytocin drip: 20 international units in 1 L Normal Saline or Ringer's lactate: 2 drops per second.0.25

CASE 3:
Fifteen minutes ago, an 18-year old woman gave birth to a boy after an uncomplicated delivery; the placenta was delivered five minutes later and appeared intact. Shortly after, you noticed an ongoing bleeding and administered relevant uterotonic drugs. You have just performed uterus massage, and the uterus is clearly well-contracted. However, the bleeding persists.

Question 6:
What are the possible causes of this bleeding?

a) A loss of uterine tone.
b) A tear in the cervix. 0.25
c) A urine tract infection.
d) Placental tissue remaining in the uterus. 0.25
e) A vaginal tear. 0.25
f) An infection in the uterus.
g) A perineal tear. 0.25

CASE 4:

A 27-year old woman was delivered 20 minutes ago. You have tried to deliver the placenta three times by controlled cord traction without success. The mother has started to breastfeed the baby, when you suddenly discover an uncontrolled, heavy bleeding from the vagina. The mother also starts to feel dizzy and cold, and sweat appears on her forehead.

Question 7:

What initial actions would you perform?

a) Call for help. 0.5
b) Measure the woman's blood pressure.
c) Give antibiotics.
d) Palpate the pulse at the femoral vessels.
e) Give uterotonic drugs.
f) Find gloves.
g) Perform uterus massage.
h) Prepare intravenous accesses.
i) Measure the woman's haemoglobin. /2
j) Immediately perform aorta compression. 0.5

Neonatal Resuscitation

CASE 9:

You are delivering a woman in your health centre. She is 21 years old and it is her first pregnancy. It is night and you are alone on duty. The delivery is an uncomplicated vaginal delivery and there is no thick meconium. There is little bleeding and you have administered intra muscular oxytocin to the woman. Immediately after the baby is born, you place the baby on the woman.

Question 33:

What steps would you take now? Select as many as are appropriate:

a) Suction the baby's mouth and nose.
b) Clamp and cut the umbilical cord.
c) Assess the baby's tone. 0.25
d) Look at the baby's color. 0.25
e) Start inflation breaths with a ventilation bag.
f) Assess the baby's heart rate.
g) Wrap the baby in a warm cloth.
h) Take the woman's blood pressure.
i) Check if the baby is crying and breathing well. 0.5
j) Rub the baby's back with a dry cloth.
k) Call for help.

Question 34:

During your assessment of the baby, you find that the baby is not breathing well and it is floppy with no tone and has blue lips. What is your next action?

a) Suction the baby's mouth and nose. /2
b) Clamp and cut the umbilical cord.
c) Assess the baby's tone.
d) Look at the baby's color.
e) Start inflation breaths with a ventilation bag.
f) Assess the baby's heart rate.
g) Wrap the baby in a warm cloth.

h) Take the woman's blood pressure.
i) Check if the baby is crying and breathing well.
j) Stimulate the baby by drying and rubbing the back with a dry cloth. 1
k) Call for help.

CASE 10:

A 38-year-old woman presents to the labor ward in the evening with a history of contractions for the whole day. On vaginal examination the cervix is fully dilated and there is no meconium staining of the liquor. On delivery, the baby is pale and limp and making a few gasping respirations. His hands and feet, as well as the tongue, are blue. The baby is not responding to stimulation by drying and rubbing the back.

Question 35:

What are the **four** most important actions to take now?

a. Find oxygen concentrator / bottle. /2
b. Call for help. 0.25
c. Intubate.
d. Perform cardiac massage (chest compressions). /2
e. Wrap the baby in a dry cloth.
f. Open the airway, or position the head in neutral position, or roll a towel and place it under the shoulders. 0.25
g. Suction thoroughly and deep. /2
h. Within one minute from birth give five inflation breaths with neonatal ambubag. 0.25
i. Continue with ventilation breaths, if breathing is still not sufficient. 0.25

Question 36:

You now start inflation breaths. What are important actions to provide successful inflation breaths?

a) Position the head in the neutral position. 0.25
b) Rub the baby's back with a dry towel.
c) Sustain the breath for 2-3 seconds. 0.25
d) Position the mask overhanging the chin and eyes.
e) Stop to assess the baby after 15 inflation breaths.
f) Make sure that chest moves with every breath. 0.25
g) Assess the heart rate.
h) Stop to assess the baby after five inflation breaths. 0.25
i) Sustain the breath for one second.

Question 37:

You have now successfully provided five inflation breaths, and the airway is open. The child is, however, still not crying or breathing, it is blue and the heart rate is below 100 pbm. What are your next actions?

a) Try to lift the baby's jaw forward.
b) Give five inflation breaths again.
c) Apply more force on the ventilation bag.
d) Reposition the head.
e) Start chest compressions.

f) Stop resuscitation. 0
g) Wait and see if the respiration is restored spontaneously.
h) Continue resuscitation with 15 ventilation breaths. 0.5
i) Apply more force on the mask.
j) Ask you assistant to try.
k) Counsel the mother on the loss of her baby.
l) Make sure that the chest moves upwards on every ventilation breath. 0.5

Question 38:

The chest is not moving during your attempts to provide ventilation breaths. What do you do?

a) Try to lift the baby's jaw forward. 0.25
b) Give five inflation breaths again.
c) Apply more force on the ventilation bag.
d) Reposition the head. 0.25
e) Start chest compressions.
f) Stop resuscitation. 0
g) Wait and see if the respiration is restored spontaneously.
h) Continue resuscitation with 15 ventilation breaths. 0.25
i) Apply more force on the mask.
j) Ask you assistant to try.
k) Counsel the mother on the loss of her baby.
l) Make sure that the chest moves upwards on every ventilation breath. 0.25

Question 39:

The baby is now crying with a good color and tone. What will you do now?

a) Put baby in incubator. 0
b) Place the baby with mother skin to skin. 0.5
c) Start early breastfeeding within one hour. 0.5

APPENDIX 15. KNOWLEDGE TEST/ KFQ'S (FRENCH)

Questionnaire

Vous êtes sur le point de répondre à un Questionnaire avec 14 questions sur différents sujets couverts par l'application mobile qui vous permettent de tester vos connaissances grâce à des cas pratiques et sont basées sur des cas cliniques. Veuillez lire les instructions qui suivent avant de démarrer le test.

Pour chaque cas, vous trouverez plusieurs questions à choix multiple. Répondez aux questions en choisissant parmi les réponses proposées. **Plusieurs réponses sont possibles pour chaque question.**

Il peut également y avoir des mauvaises réponses, de type : a) à conséquence grave ou b) à conséquence mortelle**.** Quand vous choisissez une réponse à conséquence grave, vous perdez la moitié des points accumulés, quelles que soient les autres réponses données. Merci de prendre le temps de répondre à ce questionnaire d´éléments clés.

1. Hémorragie post-partum

CAS N°1 :

Vous accompagnez l'accouchement d'une femme primigeste à terme, le travail débute

spontanément et les deux premiers stades progressent normalement. Présence de liquide clair,

l'enfant est né et pleure immédiatement.

Question 1 :

Que peut-on faire pour réduire le risque d'hémorragie post-partum (HPP) ?

a) Il n'existe aucun moyen efficace de prévenir une HPP.
b) Une prise en charge active de la troisième phase de travail réduit de moitié le risque de HPP.
c) Un recours à l'épisiotomie peut réduire modérément le risque de HPP.
d) Les effets des médicaments utérotoniques aussitôt après l'accouchement afin de prévenir les hémorragies sont documentés scientifiquement.
e) Il ne faut agir qu'en cas d'hémorragie.

Question 2 :

Que faites-vous après l'accouchement pour prévenir les HPP ?

a) J'administre une injection d'ocytocine dans la minute qui suit la naissance de l'enfant.
b) Si je n'ai pas d'ocytocine, j'administre 3 comprimés de misoprostol par voie orale à la patiente.
c) Je ne donne aucun médicament avant la délivrance du placenta.
d) La délivrance du placenta doit se faire par une traction douce et contrôlée sur le cordon.
e) Pour évacuer le placenta, je dois tirer fortement sur le cordon.
f) Pour évacuer le placenta, je dois pincer la partie supérieure de l'utérus.
g) Le massage utérin doit être effectué aussitôt après la délivrance du placenta.
h) Le massage utérin n'a d'effet que si la rotation va dans le même sens que les aiguilles d'une montre.

i) L'enfant doit être allaité rapidement.
j) Il faut attendre une heure avant de donner l'enfant à sa mère.

CAS N°2 :

Une femme âgée de 23 ans vient de donner naissance à des jumeaux. Les deux enfants se portent bien. Le placenta a été évacué et examiné, et aucun tissu ne semble manquer. Il n'y a aucune déchirure périnéale visible. Soudain, la femme commence à saigner abondamment.

Question 3 :

Quelles sont les PREMIÈRES choses à faire ?

a) Mesurer la tension artérielle de la femme.
b) Appeler à l'aide.
c) Vider la vessie.
d) Effectuer une compression bimanuelle si l'hémorragie n'est pas contrôlée rapidement.
e) Tâter le pouls au niveau des vaisseaux sanguins fémoraux.
f) Administrer des utérotoniques.
g) Aller chercher des gants stériles.
h) Effectuer un massage continu de l'utérus.
i) Préparer les accès intraveineux.
j) Mesurer le taux d'hémoglobine de la femme.
k) Aller chercher des gants normaux.

Question 4 :

Vous avez effectué les premières étapes pour prendre en charge l'hémorragie et vous effectuez à présent une compression bimanuelle. Un assistant est toujours présent avec vous dans la salle d'accouchement. Que demandez-vous à votre assistant ?

a) Positionner la tête en bas si ce n'est déjà fait.
b) Mesurer le taux d'hémoglobine si ce n'est déjà fait.
c) Encourager la femme à boire au maximum.
d) Poser les deux intraveineuses.
e) Administrer 1 litre de liquide IV à une goutte par seconde.
f) Administrer 2 litres de liquide IV le plus rapidement possible.
g) Administrer des médicaments pour permettre à l'utérus de se contracter.
h) Encourager la femme à se lever et à marcher.

Question 5 :

Votre assistant vous pose des questions sur la posologie et l'administration des médicaments utérotoniques. Quels sont les médicaments, doses et mode d'administration appropriés ? Sélectionnez ceux qui vous semblent corrects :

a) 1,600 mcg de misoprostol par voie orale.
b) 2L de sérum physiologique rapidement.
c) 10 unités internationales d'ocytocine en IM si le médicament n'a pas encore été administré.
d) 800 ug de misoprostol par voie rectale.
e) Perfusion d'ocytocine : 20 unités internationales dans 1L de sérum physiologique ou de Ringer lactate à 1 goutte toutes les 5 secondes.
f) Perfusion d'ocytocine : 20 unités internationales dans 1L de sérum physiologique ou

de Ringer lactate à 10 gouttes par seconde.

g) 30 unités internationales d'ocytocine par injection IV directe.
h) Perfusion d'ocytocine : 20 unités internationales dans 1L de sérum physiologique ou de Ringer lactate à 2 gouttes par seconde.

CAS N°3 :

Il y a quinze minutes, une femme de 18 ans a donné naissance à un garçon après un accouchement sans complication ; le placenta a été évacué cinq minutes plus tard et semblait intact. Peu après, vous remarquez un saignement continu et vous administrez les médicaments utérotoniques correspondants. Vous venez d'effectuer un massage utérin et l'utérus est clairement bien contracté. Cependant, le saignement persiste.

Question 6 :

Quelles sont les causes possibles de ce saignement ?

a) Une perte de tonus utérin.
b) Une déchirure du col utérin.
c) Une infection urinaire.
d) Un reste de tissu placentaire dans l'utérus.
e) Une déchirure vaginale.
f) Une infection de l'utérus.
g) Une déchirure périnéale.

CAS N°4 :

Une femme de 27 ans a accouché 20 minutes auparavant. Vous avez tenté trois fois d'évacuer le placenta par traction contrôlée du cordon, en vain. La mère a commencé à allaiter l'enfant lorsque vous découvrez soudain une hémorragie importante et persistante du vagin. La mère commence également à se sentir étourdie et à avoir froid, de la sueur apparaît sur son front.

Question 7 :

Quelles sont les premières choses à faire ?

a) Appeler à l'aide.
b) Mesurer la tension artérielle de la femme.
c) Administrer des antibiotiques.
d) Tâter le pouls au niveau des vaisseaux fémoraux.
e) Administrer des médicaments utérotoniques.
f) Aller chercher des gants.
g) Effectuer un massage utérin.
h) Préparer les accès intraveineux.
i) Mesurer le taux d'hémoglobine de la femme.
j) Effectuer immédiatement une compression de l'aorte.

2. Réanimation néonatale

CAS N°5 :

Vous accompagnez l'accouchement d'une femme dans votre centre de santé. Elle a 21 ans et il s'agit de sa première grossesse. C'est la nuit et vous êtes seule de garde. L'accouchement est un accouchement vaginal sans complications et il n'y a pas de mucus épais. Un léger saignement se produit et vous avez administré de l'ocytocine en intramusculaire à la femme. Immédiatement après la naissance de l'enfant, vous le placez sur la femme.

Question 33 :
Quelles sont les mesures à prendre ? Sélectionnez toutes les réponses qui vous semblent appropriées :

a) Vous pratiquez une aspiration de l'oropharynx.
b) Vous clampez et coupez le cordon ombilical.
c) Vous évaluez le tonus de l'enfant.
d) Vous examinez la couleur de l'enfant.
e) Vous démarrez les insufflations à l'aide d'un ballon insufflateur.
f) Vous mesurez le rythme cardiaque de l'enfant.
g) Vous enveloppez l'enfant dans un linge chaud.
h) Vous mesurez la tension artérielle de la femme.
i) Vous vérifiez que l'enfant pleure et respire correctement.
j) Vous frottez le dos de l'enfant à l'aide d'un linge sec.
k) Vous appelez à l'aide.

Question 34 :
Pendant votre examen de l'enfant, vous vous apercevez que l'enfant ne respire pas correctement, qu'il est flasque et sans tonus, les lèvres bleues. Que faut-il faire ?

a) Pratiquer une aspiration de l'oropharynx.
b) Clamper et couper le cordon ombilical.
c) Evaluer le tonus de l'enfant.
d) Examiner la couleur de l'enfant.
e) Démarrer les insufflations à l'aide d'un ballon insufflateur.
f) Mesurer le rythme cardiaque de l'enfant.
g) Envelopper l'enfant dans un linge chaud.
h) Mesurer la tension artérielle de la femme.
i) Vérifier que l'enfant pleure et respire correctement.
j) Stimuler l'enfant en le séchant et lui frottant le dos à l'aide d'un linge sec.
k) Appeler à l'aide.

CAS N°6 :
Une femme de 38 ans se présente en salle de travail le soir après avoir eu des contractions toute la journée. L'examen vaginal révèle un col de l'utérus complètement dilaté et une absence de mucus dans le liquide. À l'accouchement, l'enfant est pâle et flasque, sa respiration haletante. Ses mains, ses pieds et sa langue sont bleus. L'enfant ne réagit pas à la stimulation par séchage et friction du dos.

Question 35 :
Choisissez **quatre** actions cruciales à effectuer.

a. Aller chercher un concentrateur/une bouteille d'oxygène.
b. Appeler à l'aide.
c. Intuber.
d. Procéder à un massage cardiaque (compressions thoraciques).
e. Envelopper l'enfant dans un tissu sec.
f. Dégager les voies respiratoires, ou placer la tête en position neutre, ou poser une serviette enroulée sous les épaules.
g. Aspirer complètement et en profondeur.
h. Dans la minute qui suit la naissance, administrer cinq insufflations à l'aide du masque de réanimation néonatale
i. Continuer la ventilation assistée si la respiration n'est pas suffisante.

Question 36 :

A présent, vous démarrez les insufflations. Quelles sont les actions importantes qui vous permettent de réussir les insufflations ?

a) Placer la tête en position neutre.
b) Frotter le dos de l'enfant avec une serviette sèche.
c) Faire durer l'insufflation 2 à 3 secondes.
d) Faire déborder le masque sur le menton et les yeux.
e) Cesser d'évaluer l'enfant après 15 insufflations.
f) Vérifier que la poitrine se soulève à chaque insufflation.
g) Mesurer le rythme cardiaque.
h) Cesser d'évaluer l'enfant après cinq insufflations.
i) Faire durer l'insufflation une seconde.

Question 37 :

Vous avez réussi à exercer 5 insufflations, les voies respiratoires sont dégagées. Malgré cela, l'enfant ne pleure et ne respire toujours pas, il est bleu et le rythme cardiaque est inférieur à 100 bpm. Que faites-vous désormais ?

a) Vous essayez de relever la mâchoire de l'enfant.
b) Vous redonnez cinq insufflations.
c) Vous appuyez plus fort sur le ballon insufflateur.
d) Vous repositionnez la tête.
e) Vous commencez les compressions thoraciques.
f) Vous cessez la réanimation.
g) Vous attendez de voir si la respiration reprend spontanément.
h) Vous continuez la réanimation avec 15 insufflations.
i) Vous appuyez plus fort sur le masque.
j) Vous demandez à votre assistant d'essayer.
k) Vous délivrez des conseils à la mère sur la perte de son enfant.
l) Vous vérifiez que la poitrine se soulève à chaque insufflation.

Question 38 :

La poitrine ne se soulève pas quand vous essayez d'effectuer les insufflations. Que faites-vous ?

a) Vous essayez de relever la mâchoire de l'enfant.
b) Vous redonnez cinq insufflations.
c) Vous appuyez plus fort sur le ballon insufflateur.
d) Vous repositionnez la tête.
e) Vous commencez les compressions thoraciques.
f) Vous cessez la réanimation.
g) Vous attendez de voir si la respiration reprend spontanément.
h) Vous continuez la réanimation avec 15 insufflations.
i) Vous appuyez plus fort sur le masque.
j) Vous demandez à votre assistant d'essayer.
k) Vous délivrez des conseils à la mère sur la perte de son enfant.
l) Vous vérifiez que la poitrine se soulève à chaque insufflation.

Question 39 :

A présent, l'enfant pleure, présente une bonne coloration et un bon tonus. Que faites-vous ?

a. Vous placez l'enfant dans une couveuse.
b. Vous placez l'enfant en peau à peau sur la mère.
c. Vous démarrez l'allaitement précoce dans l'heure qui suit.

APPENDIX 16. SELF-CONFIDENCE QUESTIONNAIRE (ENGLISH)

Self-confidence scale

Below is a list of tasks related to the provision of Emergency Obstetric Care.

Please rate your level of confidence in your ability to perform the following on a scale from 0 to 10:

0	1	2	3	4
Cannot do at all		Moderately can do		Highly confident can do

	Confidence (0-4)
1. Managing manual vacuum (MVA) aspiration of the uterus?	_____
2. Managing dilatation and curettage of the uterus?	_____
3. Managing severe pre-eclampsia and eclampsia?	_____
4. Providing active management of third stage of labor?	_____
5. Managing prolonged labor?	_____
6. Managing performing vacuum extraction at birth?	_____
7. Managing strong bleeding?	_____
8. Managing retained placenta?	_____
9. Managing maternal sepsis?	_____
10. Performing neonatal resuscitation?	_____
11. Managing danger signs in the newborn?	_____
12. Managing severe infection in the newborn?	_____

APPENDIX 17. SELF-CONFIDENCE QUESTIONNAIRE (FRENCH)

Confiance en Soi

Voici une liste des tâches liées à la fourniture de soins obstétricaux et néonatals d'urgence (SONU).

Veuillez évaluer votre degré de confiance en votre capacité à effectuer les opérations suivantes sur une échelle de 0 à 4:

0	1	2	3	4
Je ne suis pas confiant	(e)	Je suis un peu confiant		Je suis très confiant

	Confiance (0-4)
1. La gestion de l'aspiration manuelle intra-utérine ?	_____
2. La gestion de la dilatation et du curetage de l'utérus?	_____
3. La gestion de la pré-éclampsie sévère et de l'éclampsie?	_____
4. La prise en charge active de la troisième phase du travail (GATPA)?	_____
5. La gestion d'un travail prolongé?	_____
6. La gestion de l'extraction par ventouse obstétricale?	_____
7. La gestion de forte hémorragie?	_____
8. La gestion de la rétention placentaire?	_____
9. La gestion de la septicémie maternelle?	_____
10. La gestion de la réanimation néonatale?	_____
11. L'identification et la gestion des signes de danger chez le nourrisson?	_____
12. La gestion d'infection sévère chez le nourrisson?	_____

APPENDIX 18. MATERNITY FOUNDATION DATA USE INFORMATION FOR PARTNERS

Maternity Foundation Safe Delivery App Data and M&E

1. Data collected via the Safe Delivery App

There are a variety of mechanisms in place on the Safe Delivery App that collect data which is sent to Maternity Foundation headquarters in Copenhagen, Denmark. To access any of this data, please contact Maternity Foundation and provide information on where geographically you are implementing the App.

- **GPS data** collected on frequency of App usage by user, including what features are being used. In order for this data to be recorded, users must agree to share GPS location.
- **User profile questions** collects background data on the skilled birth attendants.
- **The confidence level test** collects self-reported information on the self-confidence of users on managing the various basic emergency obstetric neonatal signal functions. The confidence level test is repeated after 3 months.
- **The Key Feature Questionnaire (KFQ)** on the App collects data on user knowledge of BEmONC signal functions at baseline and at other intervals determined by user and implementer.

Maternity Foundation is currently working on a new version of the Safe Delivery App, which will be able to offer our implementing partners:

- **Direct access through a dashboard** to the information listed above and to additional data such as:
    - More detailed data on usage of the app through Game Analytics features
    - Data on learning progress of the specific user through user profile questions and certifications for learned/passed topics
    - Data on the cognitive learning process through the adaptive learning platform - by adapting learning to the users' learning processes and progress we will be able to receive data on how our users learn.

2. How Maternity Foundation uses data

Maternity Foundation analyzes data and information for concrete and applicable findings, best practices, patterns and trends. For example we aggregate and analyze data for trends on App usage in terms of frequency, duration, supporting infrastructure and context, and then triangulate these with data on skills and knowledge of health care workers to determine which factors can enable and enhance the impact of the App.

Maternity Foundation uses this analyzed data to create relevant tools and resources, and to provide strategic partnership support to integrate findings and knowledge in a meaningful way into programmatic activities of partners.

Examples of tools and resources include but are not limited to: Spotlights (a mini case study of sorts)that highlight implementations in different contexts, settings and different use cases with a focus on best practices and lessons learned; impact assessments; scale-up Strategy Document and webinars with implementing partners (across organizations and locations) on key topic areas.

Finally, Maternity Foundation disseminates knowledge through tools and support through Maternity Foundation's website, participation at key conferences, and regular communication with partners. The goal is to help information flowing among the people who need it, when they need it.

3. Compliance with Data Protection Regulations and Guidelines

Maternity Foundation ensures that data collected through the Safe Delivery App will only be disseminated in an aggregated and individualised manner. No sensitive personal information will be shared. Furthermore Maternity Foundation takes precautions to ensure that data from the SDA is only used for the intended purposes (as described above) and not for commercial or unethical matters. The following structures are in place to make sure users understand data collection and usage: the introduction text in the about section of the App, an agreement when you first download, and documents provided by MF for implementing trainings.

4. Additional tools and resources for data collection

Maternity Foundation created an guide on interviews and focus groups on usage, perception and integration and level of acceptance of the SDA with health care workers, as well as an for interview for clients on if the App was used during delivery. For the randomised controlled trial in Ethiopia in 2013-2014 done by Maternity Foundation, University of Copenhagen, and University of Southern Denmark, the Objective Structured Assessment of Technical Skills (OSATS) was developed for the Safe Delivery App. The OSATS gives health workers scenarios that they are then asked to manage in form of a role-play to show what they would do in the actual clinical situation, using what they find available during the assessment.

These resources can be obtained upon request.

APPENDIX 19. MINUTES OF MEETING WITH MATERNITY FOUNDATION IN COPENHAGEN – NOV 2016

Minutes Meeting at Maternity Foundation – Copenhagen Nov 3, 2016

Present: Nancy Bolan (MUSC), Ida Boas (Maternity Foundation), Tara Talvacchia (Maternity Foundation)

We discussed a number of points, following up on the many email exchanges and the meetings between Tara, Larry, and myself and Tara and Mano, summarizing the main points regarding the following:

1. Safe delivery App:
    - Version two Module 1 is projected to come out in January. This will contain updated technical information as per updated WHO Technical Guidance & input. It will also contain a new CMS – wherein the Maternity Foundation will have more control (over changes/languages) and partners will have the ability to access the data through a dashboard.
    - Version 2 Module 2 is projected to come out in late spring (April – June). It will contain an adaptive learning piece with visual learning questions that tailors the experience to the learner and gamifies the learning process with incentives and levels. It will also render possible for different users (of a facility- based tablet for example) to have unique learner ID's (for their learning experience). Additionally, partners will have the ability to access the data through a dashboard.
    - For the dissertation, we will use Version 2 but plan to start before Mod 2 is released. Module 2 will not be a push update but will be installable via cable or Bluetooth from a PC (given poor internet in ASSP/DFID zones). For larger Phase 2 testing may be able to use V2, Module 2.
    - Discussed using facility-based tablet versus individual phone-based app and some of the constraints that would impose (ex. Usage data, self-con and knowledge test). Maternity Foundation is doing this in Kenya with tablet secured into an accessible location. In this case individual testing would be done on paper, hand-scored and entered into a database.
    - Discussed testing on all 8 cases versus choosing the priority cases to reduce time of testing.
    - Ida cant currently share reliability/validity info on KFQ (knowledge test) since it is not yet published.
    - Self-confidence scale has not been tested but being used now in Ethiopia & Guinea.
    - Discussed using KFQ/confidence instruments in DRC trial and using app to correct and give point totals.
    - Discussed signal function data collection under consideration for ODK. Will reference Columbia U doc (AMDD) and discuss with other partners for best measures but want to keep it as simple as possible (Nancy discussing with Jhpiego & WHO). Nancy proposing to triangulate data with register review, thus will have check on accuracy of data.

- Discussed potential reminder system – using flyers/posters or sms. Maternity Foundation used reminders in Ethiopia. Jhpiego used sms and phone-calls in similar study in Uganda. (However if using sms/calls this should be considered in setting "feasibility" use threshold frequency.)

2. MOU
   - Maternity Foundation has a draft/template that they have used with other partners and will share.

3. Training Materials
   - Nancy will assure translation in Geneva/validation in DRC. This will be shared with Maternity Foundation colleagues in Guinea and potentially gain their input.

4. Action Points/next steps:
   - Tara/Ida will check on release date for V 2 Mod 1 and report back on update/download modality of Version 2, Module 2.
   - Tara/Ida will update and send MOU template.
   - Tara/Ida will discuss question re use threshold for "feasibility" – while bearing in mind that the threshold could change depending on patient acuity, patient volume and provider learning needs.
   - Ida will share a demo data usage report in December so that we will have more clarity regarding currently collected usage data and format. She will also share SPSS data collection form for knowledge data collection.
   - Ida will check on content validity testing of self-confidence measure.
   - Nancy will share draft dissertation proposal for sharing within Maternity Foundation.
   - Nancy will organize app testing (GPS for data upload) in DRC – Kin and Kananga if possible.
   - Once discussed with DRC-based colleagues again, ODK draft data collection form will be shared by Nancy.
   - Nancy will discuss entire concept again with Larry/DRC team for their input.
   - Nancy will meet with WHO (Fran McConville) to see if any added input.
   - Nancy will discuss with DRC-based colleagues re: which signal functions to focus on and regarding ideas on reminder system.

Nov 3, 2016
Copenhagen

APPENDIX 20. REPORT FOR IMA

mLearning in the DR Congo:
A Feasibility and Pilot Project using the Safe Delivery App

The IMA-led ASSP project teamed up with former-IMA DRC Deputy Director, Nancy Bolan, to conduct research on the use of a new mLearning technology for the continuing education of health workers in the provision of Emergency Obstetric and Newborn Care (EMONC)(SONU/Soins Obstetricaux et Neonatale d'Urgence).

Published data show that health worker clinical performance is often inadequate in developing countries (Rowe, de Savigny, Lanata, & Victora, 2005). Sub-standard delivery and emergency obstetric care (EmOC) in health facilities has been widely documented as a major cause of maternal mortality in health facilities globally (Sorensen et al., 2011). A basic strategy for changing health worker behavior and strengthening clinical performance is promoting lifelong learning or continuing education (CE) (WHO, 2006), defined as a "systematic, ongoing, cyclical process of learning" for individuals. CE is a cornerstone of continued fitness to practice and is closely connected to the quality of care and patient safety (WHO, 2006, p.111). Given the challenges of organizing CE opportunities for healthcare workers in hard-to-reach developing country settings, the use of technology and mobile hand-held electronic devices (phones and tablets) holds promise for new mechanisms to reach these workers with up-to-date information (Nilsson, Sorensen, & Sorensen, 2014; WHO, 2013). The research goal is to explore an innovative educational approach for health workers working in maternal care, particularly for providers in hard-to-reach settings in the DRC and to help address excess maternal and newborn mortality. Because this work will occur jointly with the Ministry of Health, the findings will contribute to the ongoing policy analysis that is occurring on the national level to evaluate current CE practices for health professionals.

EMONC facilities in two ASSP health zones were selected in May 2017 to participate in a randomized controlled matched-cluster study to assess the feasibility of and pilot test the use of two new tools: the Safe Delivery App (Maternity Foundation, 2017) and SONU Open Data Kit (ODK, IMA, 2017). The mLearning intervention is being considered as an adjunct to traditional CE training for maternal care providers, in order to improve clinical quality through improved practice.

The Safe Delivery App is a training and job app that supports providers' capability and confidence in providing evidence-based basic emergency obstetric care**.** The content of the app is based on global state-of-the-art clinical guidelines and has been validated with an international group of global health experts. It contains four basic features: animated training video chapters and sub-chapters, action cards, drug list and practical procedure instructions. All features and functions are designed for low-literacy, low-income settings and work completely offline once downloaded; as such the App has been pre-downloaded to ASSP provided smartphones due to poor internet connectivity in the Kindu region. The 10 instruction films include the seven signal functions of Basic SONU and three related essential procedures (infection prevention, newborn management and active management of the third stage of labor). The videos are between 5 – 7 minutes and can be watched in sub-chapters. The availability of such a learning program may allow for enhanced training of maternal health providers as well as use of the app as an on-site job aid, thus reinforcing provider learning and contributing to the retention of essential maternal care competencies.

The SONU ODK is a data collection instrument designed by the ASSP team and the researcher to collect facility-based SONU related data at the point of care. All eight facilities in the study were trained to collect ODK data using smartphones. Data is collected on key SONU indicators for all deliveries and for maternal/newborn complications during the study period (maternal complications, maternal deaths, fresh neonatal deaths), as well as the execution of all SONU "signal functions" by the health care workers in treating those cases. "Signal functions" are clearly defined key medical interventions that are used to treat the direct obstetric complications that cause the vast majority of maternal deaths around the globe (WHO, 2009). The objective of this data collection is to collect improved and more up-to-data SONU data.

The research team randomly selected eight EMONC facilities located in Kindu or Alunguli Health Zones in Maniema. Of those eight facilities, four facilities were randomly selected for the Safe Delivery App intervention and four are serving as controls. The team carried out a two-week mission in the Kindu area from May 2 – 16. As part of their mission, health authorities from the DPS of Kindu and both Health Zones were initially briefed on the project. Trainings were then carried out in both Kindu and Alunguli Health Zones for all maternal and newborn health providers (MD's, nurses and midwives) working in the study facilities. Baseline data was also collected from the providers at this time on provider demographics, SONU knowledge on select topics, and self-confidence on SONU signal function execution. Key modules from the Safe Delivery App were reviewed in a group setting for intervention participants with critical discussion of the information presented and Q & A. Both Provincial and Zonal health authorities participated in the educational fora.

The study team then proceeded to do multiple site visits in all eight selected study facilities to reinforce hands on training on the use of both the Safe Delivery App (in intervention sites) and the ODK (in all sites). The team also took advantage of their site visits to assess EMONC equipment and drug availability and to review the maternity registers by hand for data collection and for assessment of completeness of recorded information.

On-site post-intervention data collection will take place 3 months subsequent to the training intervention, as will data analysis. Maternal outcome data and SONU signal function execution data collection will similarly take place 3 months subsequent to the training. SONU data will be triangulated between the ODK reporting, routine HIS data, and hand review of facility-based registers to assess the feasibility of SONU ODK implementation.

APPENDIX 21. REPORT FOR AITHERAS (SMARTPHONE DONATION)

mLearning in the DR Congo:
A Feasibility and Pilot Project using the Safe Delivery App

Nurse researcher, Nancy Bolan, gratefully acknowledges the generous donation of 10 Zopo phones from Aitheras earlier this year (2017). Please find below a brief report on the research that was conducted using the product donation:

Nancy is a PhD candidate in Nursing Science at Medical University of South Carolina, based in Charleston. Prior to doing her PhD studies, Nancy spent approximately seven years working in the Democratic Republic of the Congo (DRC). During her first stay in 1995, she worked in the Rwandan refugee camps after the Rwandan genocide in then Zaire (now DRC). She later went to Kinshasa (DRC's capital) as a program manager for the US Government's Agency for International Development from 2000 – 2003. Most recently she served as Deputy Director of a US non-profit based in Washington, DC (IMA World Health) from 2012 – 2015. Nancy's doctoral research builds on her prior experiences in the DRC.

The research focuses on the question of how to better provide continuing education for health workers in remote settings, on emergency obstetric and newborn care, in order to improve the quality of care given and contribute towards reducing the high maternal and newborn mortality. Given the increasing mobile phone usage throughout Africa, this way of disseminating information and learning (called mLearning) makes sense and can make a difference. This is our research hypothesis.

The Democratic Republic of Congo (DRC), the largest country in sub-Saharan Africa, has one of the highest maternal mortality rates in Africa (846 maternal deaths per 100,000 live births). A woman's lifetime risk of maternal death (the probability that a 15-year-old woman will eventually die from a maternal cause) is estimated to be 1 in 24 in the DRC, compared with 1 in 3,800 in the United States (WHO, 2015).

The research consisted of testing health workers on their knowledge and self-confidence related to emergency obstetric and newborn care in eight remote health facilities in the center of DRC. Health providers were then trained how to use a new learning App, that the research team had downloaded onto the phones. The health workers were also trained to use a new smartphone-based data collection tool for health data that was designed by the researcher. The phones were utilized during three months for both learning and data collection. The researcher then returned to retest the health workers for knowledge and self-confidence and to train a new set of health facility workers.

The Safe Delivery App is a training and job aide app developed in Denmark. It contains animated training videos on emergency obstetric and newborn care and written information based on global state-of-the-art guidelines. All features and functions are designed for low-literacy, low-income settings, and work completely offline once downloaded; as such the App was pre-downloaded to the smartphones due to poor internet connectivity in the research area.

Health workers were very happy with the study, the App, the data-collection tool and the phones. They were able to charge the phones on chargers that we provided adapted for solar panels, since there is normally no electricity in the study area. Additionally, the app developer was able to track app use via internal gps function and share this data with the researchers.

Health and political authorities were equally enthusiastic about the study and asked that the researchers find funding to repeat the study throughout the entire Province. National health authorities were also enthusiastic and we were able to leave phones with the top national medical authorities for maternal mortality and newborn mortality.

The researcher is currently analyzing the study data, however, preliminary findings showed a significant difference in the knowledge and self-confidence of the health workers as well as a positive change in behavior.

The researcher hopes to be able to identify funding and telephones (or tablets) to expand the research in 2018 to the Provincial level, as requested by the authorities. This would also expand the sample size so as to produce more important research data.

Thank you again to Aitheras and to Bob Sessions for arranging this generous donation. We wish you all the best for a good close to 2017 and a healthy and prosperous 2018.

Nancy Bolan, RN, FNP/CNM


Color C2
07:50

APPENDIX 22. ODK SCREENSHOTS (FRENCH)

IMA Data | Exécution des Fonctions SONU (Version 4)

ODK Review Form

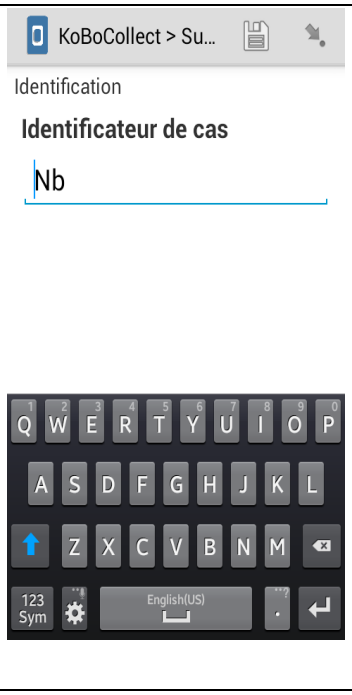
Surveillance SONU **Introduction**

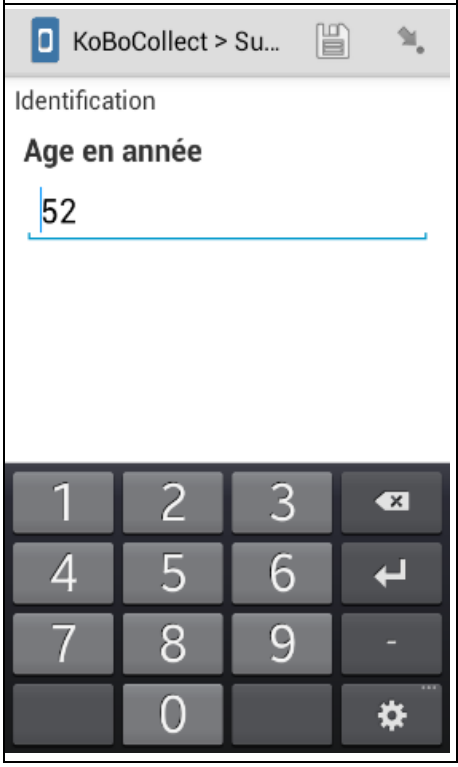
La première page.

Introduction

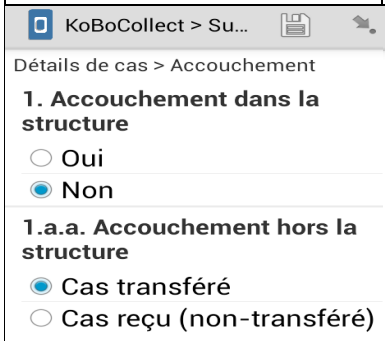
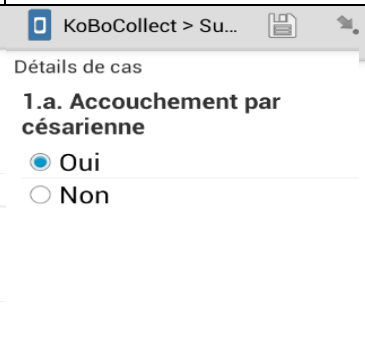
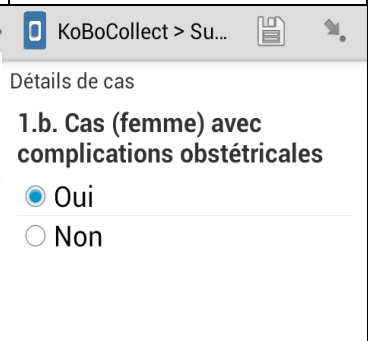
Identification

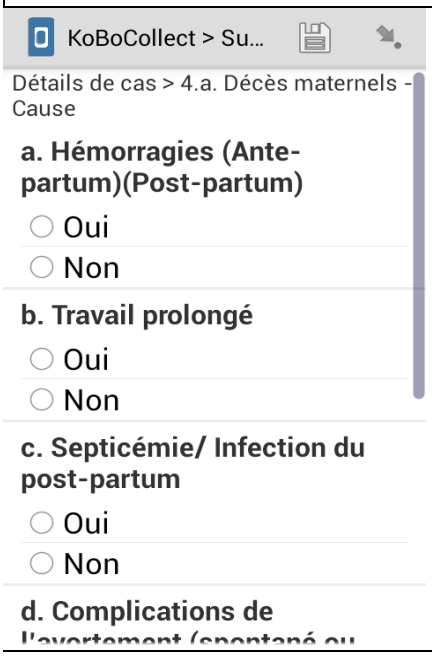
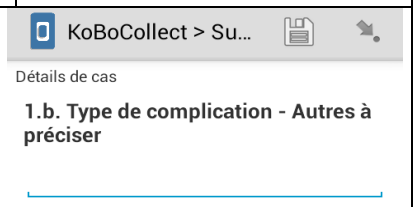
Les zones de santé et les aire de santé présentées ici ne sont que des exemples. Les zones doivent être fournies pour les spécifications du projet.

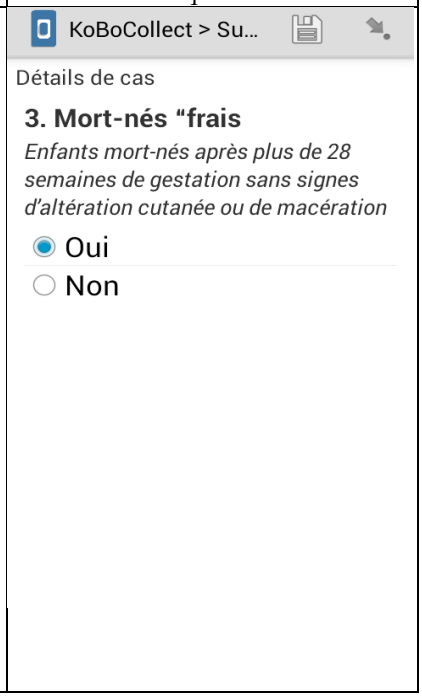
ZONE DE SANTE	AIRE DE SANTE	IDENTIFICATEUR DE CAS
		

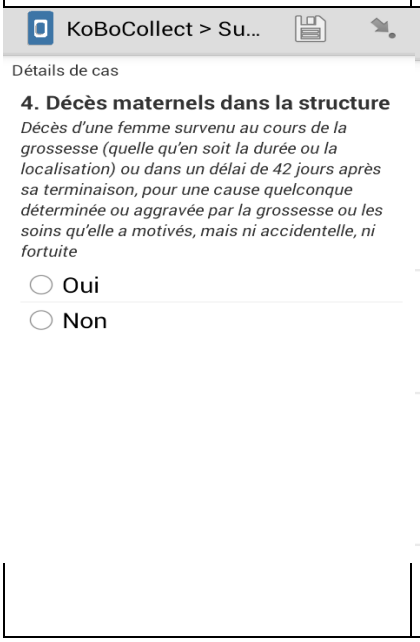
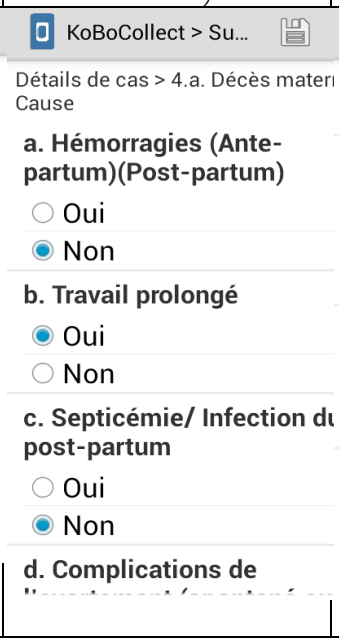
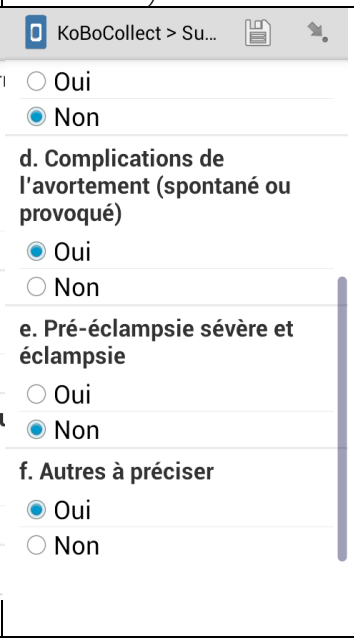
AGE EN ANNEE	DATE (CAS)
	

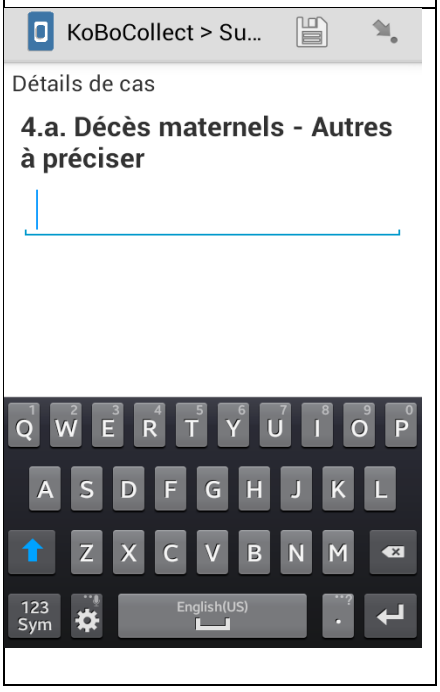
Détails de cas

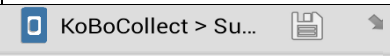
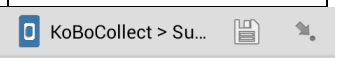
La première question si la question est 'Oui'		
1 & 1.a.a	1. a.	1. b.
		

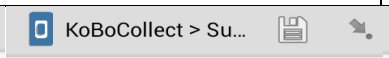
1. b. SI 'Oui' (HAUT DE L'ECRAN)	1. b. – SI 'Oui' (BAS DE L'ECRAN)	1. b. SI 'AUTRE A PRECISER'
		

2.	3. Intro Pratiques SONU
	

4.	4.a. SI 'Oui' (HAUT DE L'ECRAN)	4.a. SI 'Oui' (BAS DE L'ECRAN)
		

4.a. SI 'AUTRE A PRECISER'


5.a.	5.b.	6.a.
 Détails de cas ***EXECUTION DES PRATIQUES CLES DE SONU POUR LE CAS:*****5.a Administration d'antibiotiques par voie parentérale chez la mère (accouchée) (injection ou perfusion)** ○ Oui ○ Non	 Détails de cas **5.b Administration d'antibiotiques par voie parentérale chez le nouveau-né (injection ou perfusion)** ○ Oui ○ Non	 Détails de cas **6.a Administration parentérale des utérotoniques (oxytocine)** ○ Oui ○ Non

6.b.	7.	8.
 Détails de cas **6.b Administration d'autres utérotoniques (misoprostol et methergin)** ◉ Oui ○ Non	 Détails de cas **7. Administration du sulfate de magnésium par voie parentérale pour traiter une pré-éclampsie sévère ou une éclampsie** ◉ Oui ○ Non	 Détails de cas **8. Extraction manuelle du placenta** ◉ Oui ○ Non

9.a.

Détails de cas

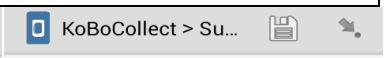
9.a. Evacuation utérine par aspiration manuelle (AMIU)

- (●) Oui
- ( ) Non

Détails de cas

9.b. Evacuation utérine par dilatation et curetage

- (●) Oui
- ( ) Non



Détails de cas

10. Accouchement par voie basse avec assistance instrumentale à l'aide d'une ventouse obstétricale ou d'un forceps.

- (●) Oui
- ( ) Non

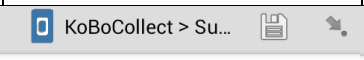
10

Détails de cas

11. Réanimation néonatale de base à l'aide d'un masque avec ballon de ventilation (ballon d'Ambu)

- (●) Oui
- ( ) Non

11



N.B Pour la validations des données collectés par l'ODK SONU, on peut les comparées avec les registres d'accouchement, du CPN, des soins maternels et aussi avec les partogrammes des accouchées.

Vous êtes à la fin de "Surveillance SONU".

Surveillance SONU: Nb

[x] Marquer le formulaire comme finalisé

Sauvegarder et Sortir

APPENDIX 23. INSTRUCTIONS SHEET FOR FINDING ODK DATA IN FACILITY REGISTERS (FRENCH)

Indicateurs pour le monitorage des fonctions SONU exécutées

		Ou trouver les données ?
1	Administration d'antibiotiques par voie parentérale chez la mère (accouchée)	**Partogramme**
	Administration d'antibiotiques par voie parentérale chez le nouveau-né	**Partogramme** **Fiche NN**
2	Administration d'utérotoniques ocytociques (ocytocine)	**Partogramme**
	Administration du Misoprostol comme utérotonique	
3	Administration du sulfate de magnésium par voie parentérale pour traiter une pré-éclampsie ou une éclampsie	**Partogramme** **Fiche Mat**
4	Extraction manuelle du placenta	**Partogramme**
5	Evacuation utérine par aspiration manuelle	**Reg Gyneco**
	Evacuation utérine par dilatation et curetage	**Reg Gyneco**
6	Accouchement par voie basse avec assistance instrumentale à l'aide d'une ventouse obstétricale ou d'un forceps.	**Partogramme**
7	Réanimation néonatale de base à l'aide d'un masque avec ballon de ventilation (ballon d'Ambu)	**Registre Mat**
8	Transfusion sanguine chez la mère (accouchée)	**Registre Mat**
	Transfusion sanguine chez le nouveau-né	**Fiche NN**
9	Césarienne	**Registre Mat**

APPENDIX 24. SCREENSHOT OF SAMPLING DATA

ZS	Nº	AS	Type	Appartenance	ACC	Méd. Gén.	Acc (A3)	Acc. (A2)	Acc./SF (A	Inf. Poly.	Total
ZS	Nº	AS									
	1	BASOKO	CS	Etat	528	0	1	0	1	15	17
	2	MIKELENGE	CS	Etat	498	0	0	0	0	13	13
	3	TOKOLOTE	CS	Etat	301	0	3	0	0	12	15
	4	KASUKU II	CS	Etat	914	0	0	0	0	17	17
ZS KINDU	5	HGR KINDU	HGR	Etat	974	6	0	0	0	11	17
	1	MIKONDE	CS	Mission religieuse - Ang	619	NA	1	0	0	6	7
	2	KAMA II	CS	Etat	279	0	1	0	1	3	7
ZS ALUNGULI	3	SOKOLO	CS	Etat	274	0	0	0	0	3	3
	4	MANGOBO	CS	Etat	191	0	0	0	1	6	7
	5	HGR ALUNGULI	HGR	Etat	216	8	2	0	0	29	39

APPENDIX 25. HOW TO DOWNLOAD SDA INFORMATION FROM MATERNITY FOUNDATION

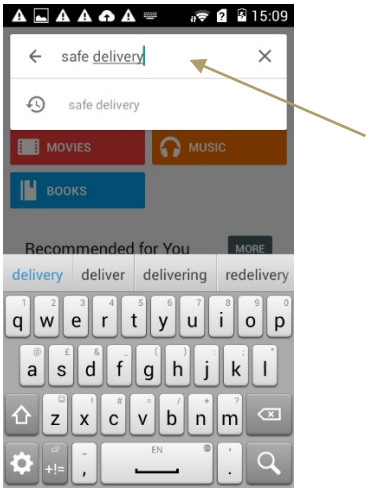
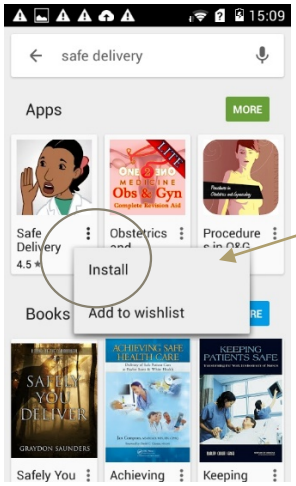
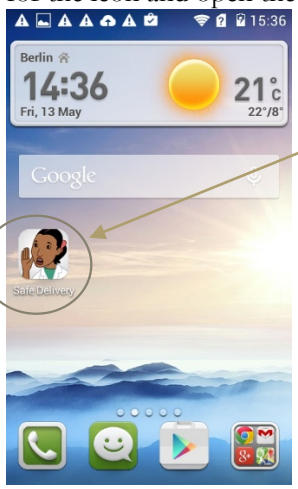
How to Download Overview

All you need to successfully download the Safe Delivery App

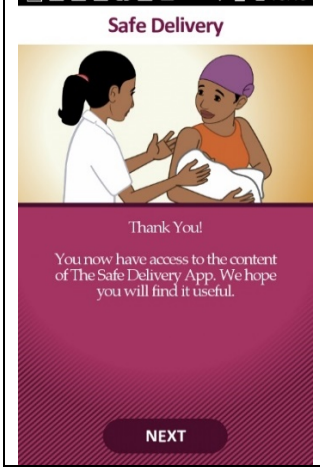
1. **Before you download ensure:**

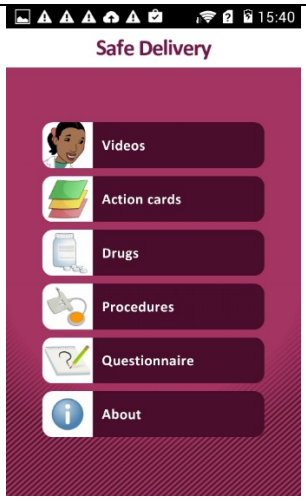
- **There is adequate space on the phone** to download the SDA, approx. 81M for Android and 105 M for iPhone
- **The phone or tablet is compatible with the SDA:** Android 4.0.3 and up; iPhone/ iPad/ iPod touch iOS 7.1 or later; no Windows option currently.
- **The phone is fully charged prior to the training** and/or that chargers and electricity are available at the training.

2. Google Play:

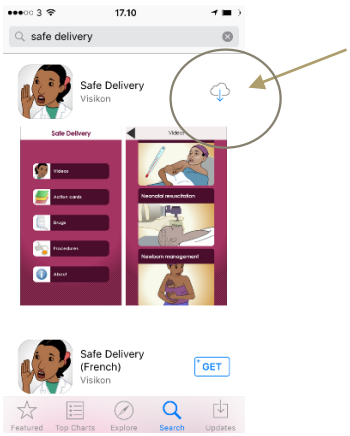
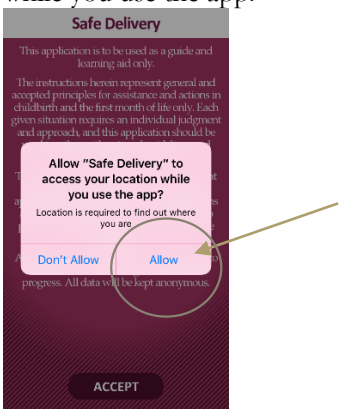
A. Open your Google Play App: 	B. Enter "Safe Delivery" in the search field 
C. Find the Safe Delivery App, and select for download: 	D. Once downloaded, you can find the app on your phone. Look for the icon and open the app: 
E. Click "Accept" to continue and then "Next":	**F.** Fill in both "User profile questions" and "Confidence Test" till you reach:

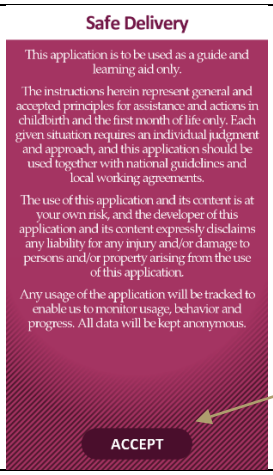
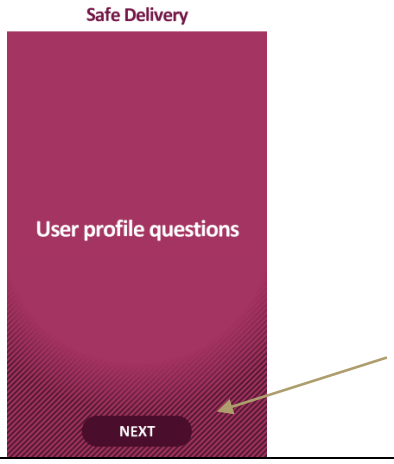

15:36
Safe Delivery
This application is to be used as a guide and learning aid only.
The instructions herein represent general and accepted principles for assistance and actions in childbirth and the first month of life only. Each given situation requires an individual judgment and approach, and this application should be used together with national guidelines and local working agreements.
The use of this application and its content is at your own risk, and the developer of this application and its content expressly disclaims any liability for any injury and/or damage to persons and/or property arising from the use of this application.
Any usage of the application will be tracked to enable us to monitor usage, behavior and progress. All data will be kept anonymous.
ACCEPT


15:40
Safe Delivery
Thank You!
You now have access to the content of The Safe Delivery App. We hope you will find it useful.
NEXT


15:40
Safe Delivery
Videos
Action cards
Drugs
Procedures
Questionnaire
About

3. App Store:

A. Open your App Store.	B. Enter "Safe Delivery" in the search field.
C. Find the Safe Delivery App, and select for download: 	D. Enter your personal Apple ID code (if asked for).
E. Once downloaded, you can find the app on your phone. Look for the icon and open the app.	F. Select "Allow" to allow "Safe Delivery" to access your location while you use the app: 
G. Select "OK" to allow "Safe Delivery" to send you notifications.	H. Click "Accept" to continue and then "Next" till you reach the "User profile questions":

<table>
<tr>
<td></td>
<td> 
</td>
</tr>
<tr>
<td>I. Fill in the questionnaire until you reach the content of the Safe Delivery App:
 
</td>
<td>J. Start using all the features of the Safe Delivery App:
 
</td>
</tr>
</table>

4. APK Overview

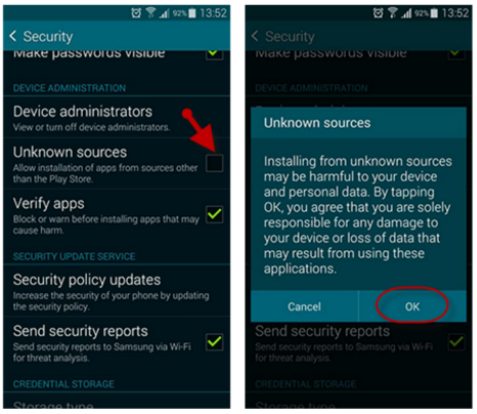
What is an APK file?
An Android Application Package (APK) is the package file format used by the Android operating system for distribution and installation of mobile apps and middleware. Maternity Foundation has an APK version of the Safe Delivery App that can be shared with you if necessary, upon request through Dropbox or WeShare. In settings with no or weak internet connectivity the app can be pre-installed to devices by downloading it as an APK file and transferred from a computer directly to the phone/tablet or via Bluetooth between two devices.

How do I install the APK file on my device?
You can install APK files on Android powered devices just like installing software on PC. When a user downloads and installs an Android application from either an official source (such as Google Play), or from some other (unofficial) site, they are installing an APK file on their device. A user can also install an APK file directly to a device (that is, not via download from the network) from a desktop computer, using a communication program, or from within a file manager app in a process known as side-loading.

By default, the ability to install from unofficial sites or directly from a desktop or file manager is disabled for security reasons on most Android devices. **Users can enable it by changing the setting "Unknown sources" in the Settings menu.**

You install the APK file, but downloading the file received via Dropbox or WeShare. Once downloaded, you install the app on the device. This is very straight forward and will appear on your device after download and when you open the file.

5. How to transfer the Safe Delivery App Using Bluetooth



1. Before you can actually install the APK file, you'll need to tell your device that it can install any apps outside of the Play Store. You can find this switch in your Settings –> Security –> Unknown Sources.
2. Download the Safe Delivery App APK file onto one device
3. Make sure that Bluetooth is switched ON, on all devices being used (sending and receiving devices).
4. The sending Android device will now scan any nearby Bluetooth devices. Wait for the name of the receiving device to appear on the list.
5. Next go to the file manager, when your APK files is stored (it is probably is "downloads" or "applications")
6. Do a long press or double click on the file, and options should pop-up/ appear
7. Select share
8. Select Bluetooth
9. Select the device you want to share it with, select okay
10. File should transfer to the next device

6. How to transfer the SDA using a USB cord, from computer to device:

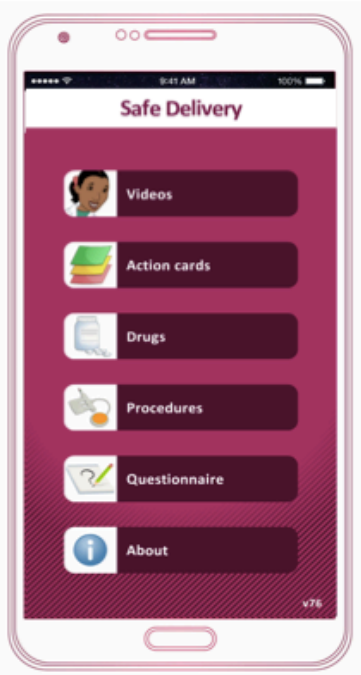
1. Before you can actually install the APK file, you'll need to tell your device that it can install any apps outside of the Play Store. You can find this switch in your Settings –> Security –> Unknown Sources.
2. Connect your smartphone to computer via **USB cable** and select "Media device" when prompted.
3. Then, open your phone's folder on your PC and **copy** the Safe Delivery App **APK** file you want to install.
4. Simply tap the **APK** file on your handset to facilitate installation.

7. How to Transfer Safe Delivery App from One Device to Another with File Manager App *(Courtesy of Abraham from HRI)*

About: This method uses a third party software to install APK on Android. The third party software- CM Transfer and Flash Share are examples there are many- provide a package manager for you to install apps on both phone memory and SD card. This method can be easier to use when compared with the manual method.

1. Install Safe Delivery App onto one Android phone.
2. Go to Google play store and download and install CM Transfer or Flash share application. This is for both phones -- the sender phone & recipient phone.
3. Open the downloaded CM Transfer or Flash share app in both phones, concurrently.
4. Select send file from the sender phone (where the SDA already installed).
5. Select the Apps icon at the bottom where you find Photos/Apps/Private/Files as options.
6. Select SDA that you wish to transfer.
7. Select receive file from the receiving phone. It will start searching & waiting for sender…
8. Click the send from the sending phone.
9. Install the received SDA and Open.
10. You will have successfully sent the App (in a very short time) and you are good to go!

APPENDIX 26. SDA SCREENSHOTS



Main Menu

The Safe Delivery App (SDA) can be used to **train and instruct skilled birth attendants** in BEmONC.

It can be used in **pre-service** and **in-service** trainings and as an in-practice **job aid.**

It contains 5 basic features:

1. Animated instruction videos
2. Action cards
3. Drug list
4. Practical procedure instructions
5. Questionnaire

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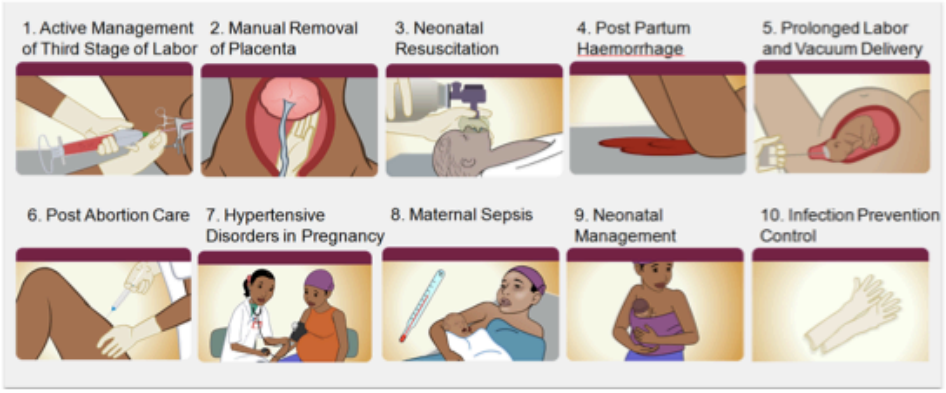
Videos

10 instruction films (image below) including the **seven signal functions** of BEmONC and an **additional three essential procedures** on infection prevention, newborn management and active third stage of labor. The videos are between 5 - 7 minutes and can be watched in sections.



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