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Mutual Learning during Post-implementation

A study of designing a maternal and child health application in rural Tanzania

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Abstract. Cooperation between users and designers requires mutual learning about the information system to be developed, and research has provided guidelines and techniques for how to achieve it. However, for designers working in contexts where they experience a wide knowledge gap between themselves and prospective users, attaining mutual learning (ML) in these settings can be challenging. This study demonstrates an action research project carried out at a rural clinic in Tanzania to develop and implement an electronic medical record system. In that setting, techniques such as hands-on training, prompted reflections and extensive support after implementation helped the nurses (system users) to learn how to use the system. Similarly, these techniques helped the designers to learn about the clinical work. Large parts of the ML therefore took place during and after the system implementation when there was a real system to mutually learn from.

Key words: participatory design techniques, mutual learning, post-implementation learning, electronic medical record system and maternal and child health.

1 Introduction

The cooperation between users and designers in computer systems development has been highly advocated within the Participatory Design (PD) community. This cooperation requires some insight into each other's activities and a mutual view of what the result will be. Arriving at this joint understanding was termed ML (Bjerknes & Brat-

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teteig, 1987). Studies agree that ML has been fruitful in building a bridge between users and designers (Blomberg et al., 1993; Bødker & Grønbæk, 1991; Bødker et al., 2004; Greenbaum & Kyng, 1991; Hansen, 2012; Joshi & Bratteteig, 2016; Kensing, 1998; Lyng & Pedersen, 2011; Trigg et al., 1991).

ML as one of the main principles of PD can be achieved through the application of different techniques. These include prototyping (Brandt et al., 2012; Bødker & Grønbæk, 1991; Mörtberg et al., 2010), ethnographic techniques (Blomberg et al., 1993; Blomberg et al., 2003; Blomberg & Karasti, 2012; Mörtberg et al., 2010), prompted reflections (Kensing, 1998), collaborative analysis of work (Karasti, 1997; Karasti, 2001), storytelling, future workshops, design games, thinking-aloud and mapping (Bratteteig, 1997; Bødker et al., 2004; Greenbaum & Kyng, 1991; Mörtberg et al., 2010). In addition to these, there are multiple variations of the techniques that have been demonstrated by combining, extending and adapting them in different ways.

Despite the demonstrated achievements of ML in system development, the effectiveness and application of these techniques need to be further explored in different contexts. For example, what technique(s) will work in a specific context as well as how and when to apply these techniques during the system development period to allow ML to thrive among users and designers? For example, in contexts where wide knowledge gaps exist between the learning parties, would the same techniques support the achievement of ML as when the gap is smaller? Further research is needed to bring more understanding of ML in system development.

This paper contributes to the PD community by answering the research question; what techniques can enforce ML when wide knowledge gaps exist between designers and users? I demonstrate the use/choice of techniques that enhanced ML to take place in a context where wide knowledge gaps existed between users and designers. The users were nurses in a rural clinic in Tanzania who had never worked with computers, while the designers were academic computer scientists without experience in clinical work. Large parts of learning were experienced during the post-implementation period where the system met reality. During the post-implementation period, designers understood more about what was or was not applicable in that context, and users understood how technology supported or did not support their daily activities.

The organization of the rest of the paper is as follows: Literature review is presented in section 2. In section 3, I present the research setting and method. The results and discussion are presented in section 4 and concluding remarks are presented in section 5.

2 Literature review

PD offers principles, and guiding techniques for examining the phenomenon that emerges when technological systems interact with social systems in IS development. With its roots in the Scandinavian countries PD emphasizes the involvement of users in system design, promotion of workplace democracy, ML and empowerment. These principles however have been challenged when applied in different contexts such as the developing countries context. For example, the participation of users with no IT skills (Braa et al., 2004; Byrne & Sahay, 2007; Kimaro & Titlestad, 2008; Nhampossa et al., 2004; Winschiers et al., 2010). Another example is the question of who should participate when there is a shortage of human resources, diverse power relations, strong hierarchies, and political systems (Byrne & Sahay, 2007; Elovaara et al., 2006; Puri et al., 2004). Winschiers et al., 2010 demonstrates another interesting phenomenon where participation was defined differently in different cultures. In this study the ML principle was the main focus to understand how it could be reached when wide knowledge gaps existed between the users and the designers.

In this section I present the PD's description of how ML can be achieved in system development. With a specific focus on ML during the post-implementation period, I also present literature review on post-implementation learning.

2.1 Mutual learning

ML is an approach whereby involved parties cooperatively learn from each other. This learning can be fostered when the participants acknowledge each other as experts in their work and eventually learn from each other. ML consists of two perspectives; (1) how users can gain knowledge about the designed system (this may include learning IT skills to use computers as a prerequisite), and (2) how designers can gain users' domain knowledge. In this section, I describe some of the PD techniques used to support creation of a mutual vision of a new system in these two perspectives.

Techniques addressing users' learning about the designed system

A long tradition of designing and experimenting with prototypes has prevailed in the PD community to support gaining this knowledge. Prototypes have been used not only to help users gain knowledge about the system designed but also to help designers evaluate the system design (Brandt et al., 2012; Bødker & Grønbæk, 1991; Carmel et al., 1993; Mörtberg et al., 2010). When users collaborate with designers in designing

the prototypes, a work-like environment is established whereby they can start a mutual dialogue and negotiate about the future system. To create a meaningful dialogue, Bødker et al. (2004) encourages designers to design and test prototypes with users by using "their own data to perform their own tasks in their own environment" (p. 182).

Despite the effectiveness on using prototypes to support users in gaining knowledge about the system, the application of this technique has been challenged when working with users who have no basic IT knowledge of how to operate a computer. Studies conducted in such settings show an urgent need for giving users the IT skills before they can participate in prototype development (Kimaro & Titlestad, 2008; Nhampossa et al., 2004; Winschiers et al., 2010).

Kimaro and Titlestad (2008) present a case that demonstrates the application of a pedagogical approach of learning-by-doing where they argue that this approach helped them to reduce the learning curve. In that case the designers developed a system prototype without the users, introduced it to the users and then worked with the users in further customisation of the system. Training on basic computer skills was conducted in parallel with the system customisation. Their results indicate that users gained knowledge about the system design and IT skills to use computers simultaneously. However, there was a high demand on system support and re-training during and after the system implementation. This indicates that, even though the learning curve on gaining IT skills to use the computers was shortened, the overall learning curve for the users to understand the designed system was prolonged.

Techniques addressing designers learning about users' work

There are multiple techniques proposed in the PD community to support this learning. This paper focuses on ethnographic techniques such as interviews, observations, focus groups and document analysis. These techniques have been widely used to probe users' work in a particular work setting. The techniques are useful for designers to learn about users' first-hand experience by questioning them about their work and by observing them while they perform their work (Blomberg et al., 1993; Blomberg et al., 2003; Blomberg & Karasti, 2012; Bødker et al., 2004; Mörtberg et al., 2010). According to Mörtberg et al. (2010, p. 113), the techniques can help designers "create rich pictures of the practices, people and artefacts" used.

When conducting observations, Bødker et al. (2004) elaborate that the observer can take a participant (participate in observed work) or a passive (fly on the wall) role. Using interviews and observation techniques however can be challenging in a work setting that is not familiar to the designer (Bjerknes & Bratteteig, 1987). It can be difficult to

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conduct appropriate observations and ask proper questions about work that one does not understand. To understand users' work in such conditions, studies (Kensing et al., 1998b; Stewart & Williams, 2005) recommend that designers combine ethnographic techniques with other techniques in defining system requirements. For instance, Kensing et al. (1998b) propose the use of prompted reflections and Karasti (1997, 2001) proposes collaborative analysis of users' work.

Prompted Reflections technique aims to build a mutual understanding of a work domain between the designers and users. According to Bødker et al. (2004), the technique can be useful when designers are unfamiliar with users' "materials, tools, work processes, and products involved in the work" (p. 284). The technique is also useful when an understanding of users' work has not been achieved through interviews, document analysis and observations.

The technique was developed as part of the MUST method for PD (Kensing et al., 1998a). As described by Kensing (1998), prompted reflections technique consists of four activities (preparation, workshops, analysis, and discussion of results). Preparations involve selecting a topic of the work area that was difficult to understand and selecting participants capable of making free-hand drawings to describe that area. In workshops, participants explain their drawings to each other. The main goal is "to take advantage of the participants' reflections prompted by their drawings" (p. 11). Designers analyse the data collected during workshops to "prompt their reflections about the work domain and potential interventions" (p. 12). Discussion of results involves discussing the analysis report with the workshop participants. This will allow participants to challenge the designers' interpretations and to gain new insights. Despite the formality of the sequence of activities for using the prompted reflections technique, Kensing (1998) encourages researchers to adapt and use the technique in their own styles.

Furthermore, Kensing (1998) demonstrated a successful application of the prompted reflections technique in designing IT support for an R&D lab for engineers. He explains that the engineers' work setting was difficult to grasp and little about it was understood through interviews and observations. Also, the engineers provided different explanations on how they performed their work. The application of the prompted reflections technique established a meaningful dialogue among the engineers. In this dialogue, the engineers started discussions about how they conducted their work, and everyone became aware of what the others were doing. The dialogue was also beneficial to the designers in understanding the engineers' work. The successful use of the prompted reflections technique happened during the early stages of the system development.

The work of Karasti (1997, 2001) also demonstrates another profound technique for supporting ML by involving designers and users in collaborative analysis of users'

work during system design. In this technique, users are video-recorded while performing their daily work. The videos are then analysed by users and designers in collaborative workshops. According to Karasti (2001), such analysis gave the practitioners a chance to draw on "their lived experiences … and their professional expertise" (p. 225), demonstrate a reflective account of their work and describe relevant aspects of their work practices. As a result, an understanding about users' work and design options were co-constructed by designers and practitioners.

PD literature has reported many techniques for supporting ML in system development. Most studies have demonstrated the application of techniques for supporting how designers can gain users' domain knowledge as compared to how users gain knowledge about the designed system. Also, these techniques have been heavily explored during the early stages of system development as compared to later stages like the post-implementation period. Literature about post-implementation learning shows that system users come alive during the post-implementation period when they are using the system in their work environment (Marcolin et al., 2012; Wagner & Newell, 2007; Yetim et al., 2012). For example, Marcolin et al. (2012) demonstrate that the post-implementation period is the ideal time for users to raise different interpretations, tinkering, misuse, and workarounds. It is obvious that ML can still thrive during the post-implementation period. To increase our knowledge about ML, it is important to understand the techniques that will enhance learning during this period.

2.2 Post-implementation learning

Previous studies during the post-implementation period have focused on system re-design and user innovation (Barcellini et al., 2008; Marcolin et al., 2012; Yetim et al., 2012) as well as involving users as designers in system customisation during use (Yetim et al., 2012). Furthermore, studies such as Wagner & Newell (2007) and Tsertsidis et al. (2019) emphasise the importance of the post-implementation period as compared to the pre-implementation period for improving system acceptance. Promotion of learning activities for both users and designers during post-implementation is a common thread in these studies. According to Santhanam et al. (2007, p. 171) when "a new system is assimilated as a routine element of users' work… IT professionals and users engage in considerable learning activities".

According to Marcolin et al. (2012), users play a crucial role in keeping the system alive during the post-implementation period unlike during other stages of the system development. This is because when the users use the system, this is the ideal time for

them to maintain the "system consistency", keep the system "operational and "useful" (p. 60) as they align the system with their work. These attributes can create opportunities for both users and designer to cooperatively learn from each other.

Furthermore, Yetim et al. (2012) view the post-implementation period as a crucial stage in re-designing the system. In their research, they created a communication tool as a common ground for users and designers to communicate and share their knowledge. Through this tool, "potential misunderstandings between users and designers" could be raised and addressed. Though this tool was beneficial to the designers with respect to feedback on the system design, they did not demonstrate how the users benefited from the tool.

Wagner and Newell (2007, p. 519) describe that when the users have used the system, "and begin to learn about its advantages and limitations from their situated practice, they are much more likely to want and be able to have their voices heard". In this manner, the users are more likely to negotiate their demands by comparing the system design and what it can/cannot offer in their daily practices. Studies such as Kensing and Munk-Madsen (1993) and Santhanam et al. (2007) propose analytical lenses that can be used to understand what users and designers can learn during system development.

Kensing and Munk-Madsen (1993) propose the application of a user-developer communication model to study how users and designers gain knowledge during system development. The model describes how users and developers gain abstract and concrete knowledge during system analysis and design. It distinguishes between knowledge of technology and of users' work. However, it does not include the way the domain is represented in the information system. Also, it does not consider post-implementation learning.

During this period, users and designers gain competence in three areas as demonstrated by Kaasbøll et al. (2010): IT competence to use the system (know-how), representation of the users' work domain in the system design (know-what), and tasks and work practices (know-why). Distinctions will therefore be used for characterising pre- and post-implementation ML.

This study focuses on promoting learning among users and designers during the post-implementation period. I demonstrate the importance of supporting ML activities in the post-implementation period as a way of allowing users to learn about the system and designers to gain concrete domain knowledge.

3 Research setting and method

This section is divided into three subsections. In the first subsection I present the setting of the research and in the second I present the research method employed to observe ML taking place during prompted reflections and other techniques used during system development. In the third sub-section I present the study limitations posed by the research setting and application of the employed research method.

3.1 Research setting

This study was conducted in a Reproductive and Child Health (RCH) clinic in a rural health center in Tanzania. The research was done under the project "Improving access and quality in maternal health care in sub-Saharan Africa." The project as documented by Roland et al. (2017) was part of on-going action research in the Health Information System Programme (HISP) global network and it was established in one of the HISP's pilot areas. I therefore gained access to the health center as a member of the HISP Tanzania team. In this accord, I conducted this study in collaboration with programmers and researchers from the HISP team whom I refer to as 'we' (designers/researchers) in this paper. Though the undertakings of the fieldwork were done by the team, I am presenting the findings as a single author in this paper.

The study involved customisation and implementation of the District Health Information Software Version 2 (DHIS2) module called DHIS Tracker at the clinic to support provision of maternal and child health services. This customisation continued while the system was in use. Working in this setting, I assumed different roles such as a researcher, facilitator (organising and conducting workshop and training), designer (working with a programmer from the HISP team and nurses in designing the maternal and child health application) and implementer (providing in-service support and supervision). Working in these roles posed challenges and limitations that I elaborate in detail in section 3.4. In the following sub-sections, I provide a detailed description of the setting of maternal and child health in Tanzania followed by the elaboration of the DHIS2.

Maternal and child health services

Maternal and child health service in Tanzania includes antenatal care (ANC), delivery, postnatal care (PNC), child health management and prevention of mother to child transmission (PMTCT) of HIV. Provision of these services goes hand in hand with paper-based data collection and reporting. Handling of a client incorporates exchange

of verbal and written information that was formal (using standardised data collection tools) and informal (using improvised data collection tools). These entities include RCH clinic, other clinics (care and treatment center and outpatient department), laboratory, and entities outside the health center (mother and the community members). The laboratory and clinics can belong to one or different health centers.

The provision of maternal and child health services incorporated data recording where formal and informal data collection tools were used. Also, adherence to procedures and organisation of roles among nurses was highly important to in-service delivery. These procedures and roles ranged from formally defined by the Ministry of Health and Social Welfare (MoHSW) to locally tailored procedures

Data collection tools used at the clinic included registers which stayed there and cards which were in the mothers' possession. The registers and the cards recorded similar but not the same information. The registers recorded administrative data that was useful for further reporting and administrative activities. The cards recorded personal details for the sake of providing continuous care and follow-up when a woman/child returned or attended a different health center or clinic.

The nurses produced quarterly and yearly reports that were sent to the district level. Most of the information reported was acquired from the registers and some of the information from the cards. Since the cards were not stored at the health center, the information from the cards that was needed for reporting was recorded in nurses' improvised registers. These registers were informal, and the nurses revealed them after they learned to trust the designers.

DHIS2

DHIS2 is a generic software which can be customised to fit local requirements. The customisation involves designing data structures and interfaces to support the local setting. This is done by setting parameters in the existing software and by adding new code. The addition of new code is limited to some functionality whereby local innovations can be added but the structure of the software cannot be modified. Throughout this paper the process of DHIS2 customisation is mentioned as a design process because it involved designing of data structures and user interfaces.

The software was initially designed to support data management and analysis at the district levels. At this level only aggregate data are dealt with. An urgent need to improve accuracy and completeness of the data necessitated the support of collection and reporting of individual data at the health facility levels. To enable this, a module called DHIS tracker was developed. Within the HISP network, DHIS tracker had been

customized to support several use cases such as tracking of women through pregnancy, delivery and postnatal care, anonymous inpatient admissions and deaths, collection of vital events such as neonatal and maternal death and supporting provision of family planning education (HISP).

In this study DHIS tracker was customised to support provision of maternal and child health services and store records for easy access and sharing. Based on the longitudinal nature of providing maternal and child health services, the application was designed to operate in stages over a period through which pregnant women and children were followed-up. The customised application was named maternal and child health application.
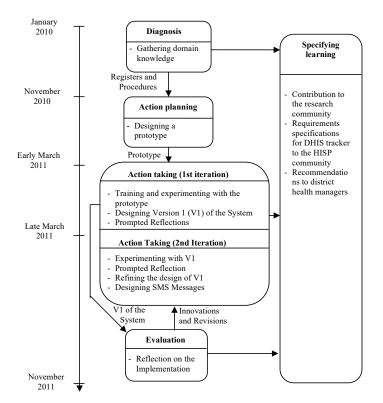
3.2   Research method

Action research was the chosen method employed in this study because the study was part of the HISP action research project. One aim of this study was to design a maternal and child health application that would improve the quality of maternal health data (action), and the other goal was to provide new knowledge on patient information systems in rural settings in developing countries and the process of developing, implementing and governing such systems (research).

The study followed five phases of action research as described by Susman and Evered (1978): diagnosing, action planning, action taking, evaluation, and specifying learning. The movement from one phase to the next was not strict, since the knowledge gained in one phase determined whether to move to the next phase or to go back to a previous phase. Furthermore, the specifying learning phase was not only at the end of the iterations; there was rather a constant movement between the action taking, evaluation and specifying learning phases.

In this section I present the phases of the action research and describe the data collection and analysis techniques in each phase. Figure 1 demonstrates activities conducted in this study with a timeline. In total I spent fifteen months in the field.

While the data collection took place 10 years ago, most health centres in low-income countries still work with paper records. While the smart-phone, used by many health workers, has provided basic digital competence, it is a long step from being familiar with a phone to mastering a computer with keyboard, Kanjo et al. (2019). Hence, the health workers still have to develop their computer literacy.

Figure 1. Phases of the action research and the timeline

During the six months diagnosis phase, I observed what data they recorded and procedures used around these activities. The knowledge gained from the diagnosis phase was used in the planning phase to customise the DHIS Tracker to a prototype. The prototype was designed during four months in collaboration with programmers from the HISP Tanzanian team.

In the action taking phase hands-on training, system experimentation and prompted reflections activities were conducted. After the training, V1 of the maternal and child health application was designed based on insights gained from the trainees. Further revision of V1 continued while experimenting with the system and conducting prompted reflections. In this manner the evaluation and action taking phases overlapped through five months of work.

Learning was specified during evaluation of the intervention and also throughout this study as presented in Figure 1. Lessons learned were disseminated to the research community (including this paper) and to practice.

Data collection

Table 1 summarises the data collection techniques applied in each phase of the research.

Period		Action research cycle	Data collection technique
System Design and implementation Period	January 2010	Diagnosis	Focus groups (5 groups) Interviews (1st iteration—20 respondents) Observations Document reviews
	November 2010	Action planning	Documented in plans
	Early March 2011	Action taking (1st Iteration)	Document reviews Observations
Post-implementation period	Late March 2011	Action taking (2nd Iteration)	Observations
	November 2011	Evaluation	Observations Interviews (2nd iteration—7 respondents)

Table 1. Data collection techniques used in each action research phase

Diagnosis phase: In this phase, data were collected using focus groups, interviews, observation and document reviews as indicated in Table 1.

Focus groups: These were formed during a workshop session that was conducted in January 2010. The workshop participants were nurses and doctors from five health facilities including the health center in question, district health managers in-charge of RCH services and community health services, HMIS focal persons, and the regional medical officer-in-charge as presented in Table 2. The participants were selected by the district health management, following our written request for key people involved in provision and management of maternal and child health care.

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Place		Nurse	Doctor in-charge	District health managers	HMIS focal person	Medical officer in-charge
Health facility	Health center 1	2 (Nurse A and B)	1			
	Health center 2	1				
	Health center 3	1	1			
	Health center 4	1				
	District hospital	2				
District	District 1			2	2	
	District 2			2	1	
Region						1

Table 2. Workshop participants

In this workshop, five focus groups were formed; each with 3 to 4 participants. In each group there was a mix of a nurse, doctor and district health manager/HMIS focal person. Discussion topics included service provision, data collection and reporting, handling referral cases and provision of support, supervision and feedback from health managers to health facility workers.

Interviews: After the workshop, twenty interviews were conducted between January and March with the participants shown in Table 3. Two of the nurses, doctor and HMIS focal persons had also taken part in the focus group discussions. All the informants are presented in Table 3.

Place	Nurse	Doctor in-charge	HMIS focal person	Community health workers
Health center 1	4 (Nurse A, B, C and D)	1		
District 1			2	
Community				13

Table 3. Interview participants in the diagnosis phase

The aim of the the interviews was to understand the interplay between formal (defined by the MoHSW) and informal (locally defined) routines in providing maternal and child health services. The objective of interviewing community health workers was to understand how they collected, recorded and reported maternal and child health data.
Observations: In conducting observations, I assumed the roles of both a passive and a participant observer (Bødker et al. 2004). As a passive observer, I observed how the nurses recorded data in registers, how they interviewed women during antenatal, postnatal and child clinic sessions and how they handled referral cases. The aim was to understand the interplay between the registers used for recording data and the procedures followed to accomplish their activities.

As a participant observer, I conducted observations in the workshop described earlier. My roles in the workshop were to prepare, invite participants and conduct the sessions. These activities were done in collaboration with the HISP Tanzanian team, and I was the leading actor.

These observations were both planned and opportunistic and they were conducted between January and March 2010. Planned observations took 2 hours each day for 3 days in a week. Opportunistic observations were conducted when an interview session was cancelled or delayed. In total I observed for about 96 hours. Results were recorded in journals daily. Electronic recording was not used to avoid being too intrusive and because it would be cumbersome while also being a participant observer at times.
Document reviews: Documents reviewed include data collection registers, clinic cards and report forms. The reviewing process started in January 2010 and only formal registers were acquired at this stage. At that time the MoHSW was updating its registers, and the old ones were still used at the clinic.. The prototype design was based on the old registers, but it was later revised to reflect the new registers that were coming in 2012. Clinic cards reviewed include RCH and child health cards. Monthly and quarterly re-

ports generated at the clinic and other reports created by the nurses for local utilization of their data were also reviewed.

Action taking phase (1st iteration): As depicted in Table 1, in this phase data were collected through observations and document reviews techniques.

Observations: As a passive observer, I observed the nurses when they were working with the maternal and child health application. As a participant observer, I conducted observations during the hands-on training sessions. In these training sessions my roles were to prepare the training, invite participants and conduct the sessions, and the HISP Tanzanian team also took part.

The training was hands-on-, aimed to teach health workers how to use computers and the system prototype. The observation aimed at evaluating the prototype in order to design a stable version of the system. Training on how to use computers focused on giving them an understanding about computer components and how to use them. After the health workers had mastered basic computer skills, we introduced them to the prototype where they continued to exercise their IT skills.

Prospective system users were nurses, but other health workers were also included in the training because of the projects' standard procedure of engaging all stakeholders to encourage system ownership and awareness. However, only the nurses were included in the later stages of this study, since they carried out all the maternal and child health services.

Document reviews: Documents reviewed in this phase were improvised registers and new revised registers that the MoHSW at that time started to pilot. Findings obtained from the improvised registers and the new revised registers were incorporated in refining the system requirements.

Action taking (2nd iteration) and evaluation phases: In these phases, data were collected using interview and observations techniques.

Interviews: Four nurses, one doctor and two HMIS focal persons were interviewed after the implementation of the system. The respondents were the same as in the diagnosis phase except the 13 community health workers interviewed earlier. The objective of these interviews was to investigate what the health personnel had learned from the system implementation.

Observation: From late March to November 2011, I continued to observe the use of the application at the clinic. As a participant observer, I conducted these observations while I was supporting and supervising the nurses when they were using the system at the clinic. I observed their reactions to the system design and listened when they proposed new and changed requirements.

Data analysis

In this study, I analysed the data collected by using data reduction, data displays and verifications method. This method as described by Matthew et al. (1994) helped me to organise and present my data, and to draw meaningful conclusions on the ML.

In this analysis, I first created categories of data by summarising field notes recorded during focus group discussions, interview sessions, observations, and document reviews. One category highlighted the knowledge gaps and language differences between the designers and the nurses. Another category identified was individual and collaborative learning activities that appeared between the designers and the nurses through the application of different techniques.

To further analyse these categories to identify trends of data, I employed the Kaasbøll et al. (2010)'s categorisation of learning activities during system development. Using this categorisation, I was able to explicate ML activities whereby I identified how the nurses gained IT competence on using the system (know-how); how the designers gained knowledge on tasks and work practices (know-why); and how both the nurse and the designers created an understanding of how to represent the nurses' work domain in the system design (know-what). When being a passive observer, I mostly studied the users. As an active one, also taking up the designer role, I partly observed my co-designers and partly observed the products we created.

After identifying the learning activities, I was able to see different trends of data. The main trends identified were the learning activities that emerged in each system development period, and the relationship between techniques used and their corresponding learning outcomes. From these data trends, I was able to create data displays and to generalise my findings; see Section 4.

3.3   Study limitations

The research design created limitations towards requirement specification for the maternal and child health application designed, since the decision for adapting DHIS Tracker was already established before understanding the local requirements. Consequently, the design was guided by what the DHIS tracker could offer.

The choice of the action research approach also posed limitations in conducting this study. While I was the leading actor in conducting the intervention, I also had other commitments as a PhD student that forced me to detach myself from the fieldwork from time to time. As a result, I had a limited amount of time to complete all the activities. Thus, there are probably aspects of the process and the outcomes which slipped my attention.

4 Results and discussion

This section presents the results obtained in this study. In the first sub-section I demonstrate the system development activities during the design, implementation and post-implementation of the maternal and child health application. In the second sub-section, I present the learning activities by demonstrating what was learned by the nurses and the designers in each stage of the system development.

4.1 System development activities

This section presents the system development activities, constituting the actions in the action research conducted. I describe the system development activities that were conducted during the system design and implementation period and during the post-implementation period. Table 4 presents a summary of the system development activities:

Period		Action research cycle	Development activity
System design and implementation period	January 2010	Diagnosis	Gathering domain knowledge
	November 2010	Action planning	Designing a prototype
	Early March 2011	Action taking (1st Iteration)	• Training and experimenting with prototype • Designing Version 1 (V1) of the system
Post-implementation period	From Late March 2011	Action taking (2nd iteration)	• Refinement of V1 and experimenting with V1 • Working with SMS
	November 2011	Evaluation	

Table 4. System development activities

Gathering domain knowledge and designing the prototype

After gathering the domain knowledge through focus groups, interviews, observation and document reviews, customisation of the DHIS tracker started in November 2010.

At this stage, the designers had very little understanding about the work domain. We first designed a system prototype with the goal of upgrading it to a fully functional system after gaining users' insights. The requirements that were used to customise the generic software were based on the MoHSW standardised procedures in providing maternal and child health services. These requirements were gathered through the ethnographic techniques of focus group discussions, interviews, observations and document reviews as described earlier.

The designed prototype was expected to allow the nurses to register and make complete service delivery and follow-up on all clinic visits for ANC, delivery, PNC and child health management. At this stage, designing the interface for data entry was challenging because of the different layouts that existed on the cards and registers. Figures 2, 3 and 4 present these different layouts.

Figure 2 shows the first page on the cards that was used for recording information during client registration. The information was grouped based on categories such as personal information, pregnancy history, danger signs etc. On the second page of the cards as presented in Figure 3, information on each visit were recorded in one column; see the direction of the arrow. On the registers (Figure 4), both personal information and information on visits were recorded in one row for each visit. Information on both the card and the register were filled-out simulteneosly for each client. These different layouts posed a challenge on which one to adapt on designing the data entry form. The designers decided to design the interface to mimic the layout of the cards on page 2 (Figure 3). This layout was chosen because of its clarity in presenting continuation of care from all the visits where the nurse could observe what was done or omitted in

Figure 2. Cards on Page 1 (registration)

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MAHUDHURIO	HUDHURIO LA KWANZA (Ndani ya saa 24)	HUDHURIO LA PILI (Ndani ya siku 7)	HUDHURIO LA TATU (Ndani ya siku 28)	HUDHURIO LA NNE (Ndani ya siku 42)
Tarehe				
Uzito (Kilo)				
Upungufu wa wekundu wa damu (Hb au weupe wa viganja)				
Joto la mwili (°C)				
Lishe ya Mtoto: Maziwa ya mama pekee (EBF), Maziwa mbadala (RF)				
Hawezi kunyonya				
Angalia kuchezacheza kwa mtoto. Je, ni kidogo kuliko kawaida?				
Macho - Yanatoa uchafu.				
Mdomo - Una utando mweupe.				
Masikio -Yana uchafu				

Figure 3. Cards on Page 2 (recording visits). The arrow shows direction for recording data on a visit
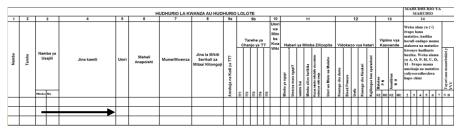

Figure 4: Registers (registration and visits). The arrow shows direction for recording data on a visit

previous visits. Figure 5 presents a screenshot of the designed data entry form on the computer.

The designed data entry forms incorporated all the data elements on the cards and on the registers. Though the prototype seemed to be sufficient for data entry, no clear requirements were understood by the designers on aggregating the data to produce reports as well as using the data. Further design to aggregate data to produce monthly, quarterly and annual reports, and to support sending SMS messages to clients was planned for later stages of the system development after gaining concrete insights from the users.

Training and experimenting with the prototype

In early March after designing the prototype, the designers taught health workers how to use computers and how to operate the prototype as described earlier. It was necessary to give them basic IT skills before they were able to work with the prototype. Working with the system prototype, the focus of the training was on how to register clients, enter data about their check-ups, medication and vaccinations given in different visits, and

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Figure 5. Data entry form

interpretations of different colour displays, icons and pop-up messages. In this training, hands-on exercises to enter data in the prototype using real data were used.

During hands-on training and experimenting with the prototype, it was evident that the prototype was too abstract for the health workers to contribute to its design because it did not represent their actual work. We embraced this set-back as an opportunity to learn how the nurses actually performed their daily activities. To enhance this learning, the prompted reflections technique was introduced. This technique was chosen for two main reasons. The first was to give the nurses an opportunity to reflect on their work based on how it was represented or misrepresented in the system desin. The second reason was to provide a common point of reference to be used throughout the design process based on the mutual understanding developed between the designers and the nurses.

The application of prompted reflections in this study did not follow the formal sequence of activities (preparation, workshops, analysis and discussion of results) as that described by Kensing (1998). In this study, we followed three of the four activities: preparation, workshops and analysis. We went back and forth between preparation and workshop activities. Analysis was done at the end of the training session.

Preparation and workshop activities: During this activity, the nurses were given time to experiment with the DHIS tracker. When they encountered misrepresentations of their practices in the system, they were asked to make free-hand drawings to elaborate accurate representations of their work. The nurses were also asked to make free-hand drawings to describe practices that were difficult to grasp for the designers.

Workshops: In the workshop activity, the free-hand drawings made by the nurses were discussed. These discussions were focused on brainstorming on the nurses' daily tasks and procedure inorder to understand theirwork and how to represent it in the system.
Analysis: This activity was guided by reflections that emerged in discussions during the workshops. The nurses raised concerns, questions and ideas as they reflected on their work based on how it was represented or misrepresented in the system. These reflections gave the designers an opportunity to gain firsthand experience on how the nurses carried out their work. The analysis also developed a mutual understanding between the designers and the nurses on designing the system. The major reflections made during training were on the presentation of check-ups to be made, and medication to be dispensed in the system. I will demonstrate these reflections in the following paragraphs.

While the nurses were experimenting with the system, they realized that the system had restricted check-ups and medication to specific visits while in real practice this was not the case. Nurse A described that

> For example, we are supposed to do HIV and syphilis tests on all first visits, however due to the availability of our lab technician and lab equipment, we may not be able to do so. When a check-up was not made in the current visit, it will be made in the next visit if possible. Similarly, we are supposed to provide iron, folic and malaria medication to the women on different stages of their pregnancy and this depends on the availability of the medication. These things should not be restricted on a specific visit.

Similarly, Nurse D noted something useful on provision of vaccinations. She said,

> We have our own timetable for dispensing vaccinations, and we arrange the timetable based on the activities in the clinic and the availability of nurses to provide the services. Following the timetable, we inform mothers when to bring their babies. This may be one week or so past or before the required time in some cases. However, we try to stick to the standard of four weeks intervals between the main vaccines for children.

The nurses' timetable was determining which dates particular vaccination will be provided regardless of the fixed time intervals between vaccinations scheduled in the protocol. However, the vaccination intervals were fixed in the system, and this could not support the current practice. Furthermore, due to the context that not all babies were born at the health center (Ngoma & Igira 2012), these babies were brought to the clinic

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at different ages from newborn to over one year old. In any case they were supposed to be given necessary vaccinations. Nurse A explained that

> All the babies receive the necessary (BCG, OP0-3, PNT1-3 and measles) vacci-
> nations within the period of nine months. However, there are cases where a baby
> is brought to the health center for the first time when they are one year or more.
> In such cases we give them all the vaccinations on the same day.

At this point there was a misunderstanding between the designers and the nurses on how they dispensed vaccinations. We asked one Nurse A to elaborate the intervals in a timeline. This is what she drew for explaining:

Figure 6 gave us (designers) more understanding of the practice. Compared to the design where vaccinations, check-ups and medication were set at intervals in specific visits, the system prototype could not support these practices. The prompted reflection technique unveiled these practices which were otherwise unknown or misunderstood by the designers. As a result, the the designers decided to stop working with the prototype and start to customize the DHIS tracker and came up with V1 of the system.
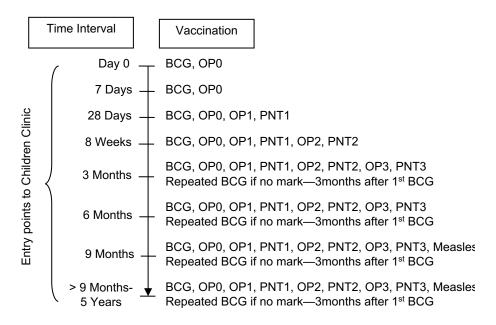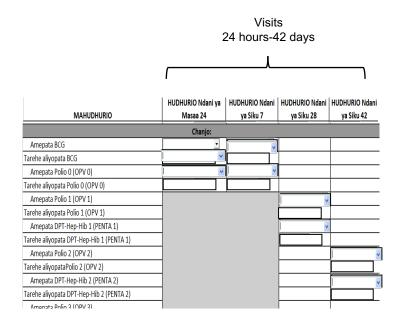
Time Interval	Vaccination
Day 0	BCG, OP0
7 Days	BCG, OP0
28 Days	BCG, OP0, OP1, PNT1
8 Weeks	BCG, OP0, OP1, PNT1, OP2, PNT2
3 Months	BCG, OP0, OP1, PNT1, OP2, PNT2, OP3, PNT3 Repeated BCG if no mark—3months after 1st BCG
6 Months	BCG, OP0, OP1, PNT1, OP2, PNT2, OP3, PNT3 Repeated BCG if no mark—3months after 1st BCG
9 Months	BCG, OP0, OP1, PNT1, OP2, PNT2, OP3, PNT3, Measles Repeated BCG if no mark—3months after 1st BCG
> 9 Months- 5 Years	BCG, OP0, OP1, PNT1, OP2, PNT2, OP3, PNT3, Measles Repeated BCG if no mark—3months after 1st BCG

(Entry points to Children Clinic)

Figure 6. Description on Vaccination Timeline (Redrawn by the author based on Nurse A's drawing)

Designing V1 of the System: After the training and prompted reflection activities, we (designers and nurses) came up with a common vision on what should or should not be included in the system. Based on the feedback from the prototype, the designers changed the design by relaxing the restrictions so that any vaccination, check-up or medication could be recorded at any visit. To provide further description, Figures 7 and 8 present some screenshots of the prototype vs new design (V1) respectively.

As presented in Figure 7, note that in the prototype, data entry boxes are present for each vaccination on a specific visit. This means that specific vaccinations were only allowed to be recorded in specific visits. In the new design (Figure 8), data entry boxes are present in all vaccinations in each visit to allow any vaccination to be recorded in any visit. The layout of the data entry form also indicates what was recorded/not recorded in the previous visits to allow the nurses to make a follow-up on what to do next based on what was done.

Refinement of V1: V1 of the maternal and child health application was introduced to the clinic in late March 2011. In this implementation, the application was used in parallel with the paper-based system, in that the nurses started to enter data into the

Figure 7: Data Entry Form on the Prototype

Figure 8: Data Entry Form on V1

system. However due to the busy schedules of the nurses and the nature of the pilot (the health center administration did not allow the system to be used at the point of service delivery), the nurses entered data after working hours.

During this implementation, we continued to support and supervise the nurses at the clinic on different intervals. The first week after the training, we worked for two hours every day for five days. The following weeks we supported the nurses once a week, and throughout these interactions, in collaboration with the nurses, we refined the system to fit their practices.

Using prompted reflections at this stage, the nurses continued to further reflect on how the system design fit with their everyday practices. The following sub-sections present reflections made by focusing on two main areas: system and domain definition of the stages, and the possibility of using a computer for data entry at the point of service delivery.

System vs domain definition From late March 2011, when the nurses were entering data into the system, we discovered that most of the data entered on ANC service was on the first pregnancy stage, <16 weeks. When I asked the nurses to explain why there were many entries on the first stage as compared to other stages, Nurse C mentioned that

More women attend their first visits than any other visit, that's why they are many.

But this explanation was not very satisfactory. When we continued to observe how they chose a stage to enter data, we realised that all the women who attended their first visit at the clinic were recorded in this stage. Stage is a medical concept denoting a time interval during the pregnancy, for example before week 16. This indicated that the nurses did not understand the meaning of 'stage' as defined by the designers versus a 'visit' which they were referring to as a stage. The system meant to enter data on a stage of pregnancy regardless of a visit. When we explained what the system meant regarding stages and visits, they were surprised, Nurse B said,

> We never thought about that, we normally record ANC on visits not on stages. When a woman attends the ANC for the first time when she is 40 weeks pregnant, we will record that as a first visit and not as a fourth stage, even though it means so. However, in children and PNC we record on the stages and not on the visits.

At this point, there was a need to create a common understanding of the terms, 'visit' and 'stage'. The nurses were asked to describe how they related to the visits and stages in a free-hand drawing and explain how they used the terms in their daily practice. Nurse B came up with a drawing like Figure 9.

From Figure 9, Nurse B continued to explain and drew Figure 10:

> …this is how we record from the first entry point that can be at any stage.

> However, under special cases there can be more than four visits and the intervals between visits will be four weeks or less depending on the situation.

Figure 9. Description on stages

Figure 10. Description on visits

These explanations were eye-openers to designers. The nurses' understanding was completely different from the system design. So, we changed the system to allow for this practice where data was recorded on visits and not stages in ANC. Figures 11 and 12 present an example of screenshots on what was designed in V1 vs. the refined design. As indicated in Figure 11, previously the nurses were supposed to select a particular stage of pregnancy, however they only selected the first stage (ANC First Stage—Up to 16 Weeks) for all client records for the first visit. Figure 12 depicts a new design where the nurses were selecting visits (example ANC First Visit) as they were doing in their daily practices. The word Stage (circled in Figure 12) continued to appear on the form because it was part of the data structure that could not be modified through customisation; only the content within the combo box could be changed.

Data entry at the point of service delivery: Due to the nature of the project, as we were conducting a pilot study, we did not get permission for the nurses to use the computer at the point of service delivery. The nurses were recording the data on their normal registers and mothers' cards. They eventually entered the data in DHIS tracker after working hours, and sometimes one or two weeks later. However, the nurses were concerned about obtaining the data from the cards since the cards were given back to the mothers before entering the data into the computer. Nurse D noted that:

Figure 11. Previous design (V1)

We do not record most of the information about the check-ups in our registers, they stay in the mother's ANC card. We only record in our registers (referring to improvised registers) what we use for reporting. How are we going to get this information so we can enter it into the computer?

There was no simple way for the nurses to capture these data so we asked them to enter into the computer whatever information was available. To our surprise the next time

Figure 12. New design (refined design)

we visited, they had filled-in all the information from mothers' cards. When asked how that was possible, Nurse C said,

We have created a register that records all the information that is missing from our daily register (showing me the improvised register). We have realised that we need to record this information for further following-up of the mother by seeing what check-ups were made last time and what were not made instead of relying on our own practices where we could forget sometimes. So now we are using this register to enter data into the computer.

This new register was an innovation made from what they were doing previously. From that register they added other columns that were necessary for data to be entered in the computer. The presence of the computer application was perceived as a way of simplifying their work and making it more efficient. The application first created a motivation for entering data which the nurses found useful for retrieving previous information andfollowing-up on their clients.

Working with SMS messages: At this stage, the SMS messages to be sent to the health center's clients were not incorporated in the design. The purpose of these messages

was to send reminders about the next clinic visit and to provide information on health education to registered women and key person(s) around women and children. For assurance of creating appropriate messages, the nurses' input was necessary because they knew how and when they communicated with their clients. The nurses were asked to create a list of messages they normally exchanged with their clients. These messages were to remind women and key persons around them about their next appointment and to give them health education. Also, the messages were supposed to be short (not more than 160 characters) and precise. The nurses came up with a list of 43 SMS messages. For example:

> Nenda kituo cha huduma mara moja iwapo utaona dalili zifuatazo: Maumivu makali ya tumbo, Kuchoka, Kupumua kwa shida, Kuona maruweruwe

This translates:

> Go to a health center immediately if you experience any of the following symptoms: Severe tummy ache, Tired and restless, Difficulty breathing, dizziness.

The SMS messages designed by the nurses were incorporated in the system. The nurses were then trained how to add new SMS, modify them and set dates depending on the specific needs of their clients.

When the nurses were using the system at the clinic, they continued to come up with prompted reflections. These reflections were made while we were together experimenting with the system and while the nurses were working on their own in our absence. What they discovered in our absence was elaborated when we visited them. With these reflections, we continued to refine the system design.

4.2   Learning activities

In this section I describe the knowledge gained throughout the system development in three categories: knowledge on how to use the system (know-how), knowledge on tasks and work practices (know-why) and knowledge on representation of users' work in the system design (know-what). These categories will help me to extrapolate how ML activities emerged in this study. In this section I will also highlight the techniques applied in each stage of the system development with their corresponding learning outcomes.

Timing	Technique		What was learned		
			Know-how	Know-why	Know-what
System design and implementation period					
Before designing the prototype (before November 2010)	Focus groups Interviews Observations Document reviews	Designers		Provision of services based on the MoHSW standard procedures and tools	
During training (early March 2011)	Hands-on training and System experimentation	Nurses	Recording medication, vaccination and check-ups; Modifying visit dates		Flow of activities in the system; Interpreting colours, icons, pop-up messages
	System experimentation	Designers			Representation of medication, vaccinations and check-ups in the system
	Prompted reflections	Nurses			Flexibility on recording medication, vaccinations and check-ups
		Designers		Provision of services based on nurses' timetable vs. MoHSW standards	
	Observations	Designers		Application of local practices	
Post-implementation period					
When the nurses started to use V1 of the system (from late March 2011)	System experimentation	Nurses	More knowledge on recording medication, vaccination and check-ups; Registering clients on appropriate visit		
		Designers			More knowledge on representation of medication, vaccinations and check-ups in the system
	Prompted reflections	Nurses			System definition of visits vs. stages
		Designers		Domain definition of visits vs. stages	
	Interviews Observations	Designers		Utilisation of improvised registers; Challenges of using a computer at the point of service delivery; Informal exchange of information between nurses and mothers and community members	
Working with SMS (from November 2011)	System experimentation	Nurses	Create SMS to be sent to clients		
		Designers			Appropriate messages to be sent to clients

Table 5. When and what was learned by nurses and designers through the application of different technique

Referring to Table 5, I will analyse the data from top to bottom and from left to right. From top to bottom, I will discuss the comparison of what was learned during the system design and implementation period, and during the post-implementation period. This analysis will demonstrate the learning activities between the nurses and the designers that emerged during the system development. From left to right, I will discuss the relationship between techniques applied and their corresponding learning outcomes. This analysis will allow me to evaluate the effectiveness of the techniques used in attaining ML in the context where wide knowledge gaps existed between the nurses and the designers.

Learning during system design and implementation vs post-implementation

In this section, I will elaborate what was learned by the nurses and the designers during the system design and implementation as compared to the post/implementation period. These two kinds of representations will help me to explicate ML activities during each period. Following the summary from Table 5, I further unpack the results from top to bottom to demonstrate the learning activities.

As indicated in Table 6, substantial knowledge was gained by nurses and designers during the system design and implementation period as well as the post-implementation period. When the nurses continued to use the system at the clinic during the post-implementation period, on one hand, they gained concrete IT knowledge on how to use the system and on the other hand, they started to realise how their work was represented or misrepresented in the system. Using the system in a real-life environment allowed the nurses to reflect on their daily practices, and as a result, they pointed out bad design, missed and new requirements, and a need for more training. This feedback from the nurses allowed the designers to reflect on the system design and to revise the design accordingly. In a way, the designers gained concrete domain knowledge during the post-implementation stage. Mutual exchanges of knowledge (ML) thrived in this study during the post-implementation period.

Contrary to tradition whereby most learning activities emerge during the early stages of the system development (Bjerknes and Bratteteig, 1987; Bødker and Grønbæk, 1991; Kensing, 1998: Mörtberg et al., 2010), results show that during the post-implementation period there were equally as many learning opportunities in this study. This was a result of three main factors. First the nurses had gained basic IT knowledge at that stage. Second, there was a real working system to learn from. Third, the nurses had established a trust relationship with the designers in such a way that they started to actively contribute to the system design. It is the combination of these factors that created a platform whereby the nurses and the designers could both participate in developing a common vision of the future system.

Period	What was learned	
	Nurses	Designers
System design and implementation	• Recording medication, vaccination and checkups • Modifying visit dates • Flow of activities in the system • Interpreting colours, icons, pop-up messages • Flexibility on recording medication, vaccinations and check-ups	• Provision of services based on the MoHSW standard procedures and tools • Representation of medication, vaccinations and check-ups in the system • Provision of services based on nurses' timetable vs. MoHSW standards • Application of local practices
Post-implementation	• More knowledge on recording medication, vaccination and check-ups • Registering clients on appropriate visit • System definition of visits vs. stages • Working with SMS to be sent to clients	• More knowledge on representation of medication, vaccinations and check-ups in the system • Utilisation of improvised registers • Challenges of using a computer at the point of service delivery • Informal exchange of information between nurses and mothers and community members • Domain definition of visits vs. stages • Appropriate messages to be sent to clients

Table 6. Learning during system design and implementation as compared to the post-implementation period

Furthermore, results from this study demonstrate the effectiveness of different techniques applied to achieve ML. In the following section, I further unpack the results by demonstrating the learning outcomes achieved through the application of the different techniques.

Techniques used and learning outcomes: The summary in Table 5 indicates the application of a combination of different techniques that supported the nurses and the de-

signers in gaining knowledge. To simplify my description, Table 7 further summarises the learning outcomes in relation to the technique applied.

Technique	Learning outcome		
	Know-how	Know-why	Know-what
Focus groups Interviews Observations Document reviews		✔ Designers	
Hands-on training and system experimentation	✔ Nurses		✔ Nurses and designers
Prompted reflections		✔ Designers	✔ Nurses and designers

Table 7. Techniques used and learning outcomes

Know-how (Nurses learn about the designed system): Nurses in this study gained this knowledge through the learning-by-doing approach whereby they learned how to use computers while they were involved in customisation of the system. In this process, hands-on training and system experimentation techniques were used to support nurses in gaining IT competence on how to use computers and the system at the same time. Since the nurses lacked basic computer knowledge, it was necessary to help them develop skills for using computers to enhance their participation in the system design.

In the early stages of the system design, the developed prototype was very abstract and inadequate for supporting the nurses understanding the system and the designers ein valuating the system design. This is contrary to the PD tradition whereby prototyping is emphasised as a technique for supporting users in understanding the system and designers in evaluating the system design (Bødker & Grønbæk, 1991, Kimaro & Titlestad, 2008; Mörtberg et al., 2010; Nhampossa et al., 2004; Winschiers et al., 2010). This study has shown that know-what on the nurses' work practices that were intertwined with provision of the services could not be obtained in the early stages of

the system development. The wide knowledge gaps caused the prototype to deliver poor ML outcomes.

Know-why (Designers learn about users' work): The knowledge on tasks and work practices as demonstrated in Table 7 was gained by the designers through the application of ethnographic (focus groups, interviews, observations and document reviews) and prompted reflections techniques. Findings indicate that this knowledge was abstract in early stages of the system development, and it became concrete during the implementation and post-implementation period.

As described in other studies (Bjerknes and Bratteteig, 1987, Bødker et al., 2004), the ethnographic techniques were not sufficient to provide knowledge about users' actual work in this study. The designers did not gain knowledge on how work was done but narratives on standards of performing work. These narratives lacked the demonstrations of the improvisations used in performing work that reflected on the nurses' firsthand experience. This may be a result of designers' inadequate knowledge about the clinical work and time limitations that hindered the nurses from having enough time to build trust and be able to share their knowledge and experiences with the designers. These circumstances may have hindered proper application of ethnographic techniques and thus the results obtained.

Concrete knowledge about the nurses' work was gained through the application of prompted reflections technique. The technique allowed the nurses to engage more in demonstrating their work and at the same time improve the designers' domain knowledge. Findings indicate that prompted reflections emerged after the nurses gained IT know-how and knowledge on how their work was represented in the system design (know-what). This learning happened during the implementation and post implementation period.

Know-what. Nurses and designers learn cooperatively to represent the nurses' work in the system design): As demonstrated in Table 7, results of this study indicate that the application of hands-on training, system experimentation and prompted reflections techniques supported the nurses in understanding how their work was represented in the system design. At the same time, this allowed the designers to reflect on the system design concerning bad design, missed and new requirements, and a need for more training.

Prompted reflections and system experimentation techniques were used simultaneously during training and after the system implementation. The techniques enhanced ML between the nurses and the designers whereby together they gained more understanding of how the work should be represented in the system design. The techniques also enabled the designers to gain more knowledge about the tasks and work practices

of the nurses by complementing what was learned through the ethnographic techniques used as described earlier. It is evident that the designers understood how to represent the nurses' work in the system design after the nurses gained IT skills and knowledge about how their work was represented in the system.

This shows that ML took place during the design and implementation and post-implementation periods. The actual use of the system during and after implementation prompted the nurses' reflections on how their work was misrepresented or not represented in the system. And free-hand drawings and discussions conducted prompted the designers' reflections on how to represent the nurses' work in the system. A mutual understanding gained by the nurses and designers became the basis for designing V1 of the system and further refining the system design.

The application of system experimentation and prompted reflections techniques have highly contributed to bridging the knowledge gaps between the designers and the nurses, and thus promoting ML. The success of the techniques however manifested after the nurses gained IT skills on using the system and thus knowledge on how their work was represented in the system design. Also, the success was manifested after the nurses had established trust with the designers.

5   Conclusion

This study has elaborated how PD techniques were applied in designing a maternal and child health application. The techniques created learning activities whereby the nurses gained IT knowledge, the designers learned about the nurses' work, and together the nurses and designers developed a mutual understanding on how the domain should be represented in the system designed. Arriving at this understanding was highly challenged by the wide knowledge gaps that existed between the designers and the nurses. As a result, a significant amount of ML was necessary.

The wide knowledge gaps as demonstrated in this study posed a challenge to designers in that the nurses' practices were not properly understood during the early stages of system development. What was done by the nurses, especially informal procedures and improvised work, surfaced during and after the system implementation. Similarly, the nurses gained system know-how during and after the system implementation. This was after they had gained basic computer skills and understood how their work was represented in the system design.

Results indicate that the knowledge gaps were bridged through interviews, document reviews, observations, focus groups, hands-on training, system experimentation and prompted reflections. Users and designers learned more when the users started to

use the system in their work environment and after they established a trust relationship with the designers.

To answer the research question posed: what techniques can enforce ML when wide knowledge gaps exist between designers and users? This study has shown that in such a setting, the application of a specific or a combination of techniques can either lead to or not support creation of specific knowledge. This is because when knowledge gaps exist between designers and users, it may not be possible to create situations where good ML can evolve, especially during the early stages of the system development. The application of PD techniques such as prototyping and ethnographic may not be sufficient for the designers to understand the domain and for the users to understand the system design.

This study has shown that we can develop our knowledge of ML through AR. This research approach has enabled me to demonstrate that, in context where wide knowledge exists, the post-implementation period was the most prominent stage where ML flourished. At that stage, the nurses had gained basic IT knowledge through the application of hands-on training and system experimentation techniques. As the nurses continued to work with the real system, they started to analyse their work by reflecting on how it was represented or misrepresented in the system design. As the nurses established trust with the designers, the application of prompted reflection technique created learning activities that assisted the nurses and the designers to harmonize their knowledge. The application of prompted reflections and system experimentation techniques helped the designers to gain concrete domain knowledge by complementing what was missed or misinterpreted through the application of ethnographic techniques. The nurses on the other hand gained knowledge of the designed system through prompted reflections, hands-on training and system experimentation. However, it was necessary for the nurses to gain IT knowledge and trust before the application of the prompted reflections technique was successful.

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