Supporting Community Needs for Rural Water Management through Community-Based Co-Design

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ABSTRACT
We set out to support three rural communities in Uganda to manage their water supplies using a locally relevant and fit-for-use technological intervention developed with the Community-Based Co-design (CBCD) method. This participatory and inclusive approach allowed us to introduce Information and Communication Technologies (ICT) to communities that are untrained and inexperienced in technology design. We describe the intervention and identify research learnings for CBCD. Our design experience with the communities highlights the barriers and enablers of using the CBCD method with rural users. We conclude with reflections on the use of intermediaries and the issue of reciprocity in community-based ICT for development research.

CCS Concepts
• **Human-centered computing~Participatory design**

Keywords
Co-Design; Communities; Rural Water Management; ICT Intervention; Intermediaries; Reciprocity.

1. INTRODUCTION
The proliferation of affordable Information and Communication Technologies (ICTs) in developing regions, principally in the form of mobile phones, has created opportunities for information access to previously unreachable groups [8]. ICTs have provided a platform for more affordable information dissemination and communication mechanisms to improve service delivery in underserved and remote areas. To leverage the potential of ICTs, a number of ICT interventions have been implemented in rural areas with the aim of empowering communities through technology [7]. However, many of the implementations have remained pilot projects due to their inability to provide suitable content, failure to understand and address priority needs [3] or foster local buy-in from both the communities and supportive institutional structures [7, 11].

The implementation of technology-centric initiatives in developing regions has often been driven by donors or international organizations [1] with the financial resources to drive a developmental agenda. A disturbingly common characteristic of these interventions is that they are externally conceived, address an assumed need or are developed in an institution prior to deployment in the community [11]. The risk with such an approach is that the interactions are often short term, imposed, and therefore sustainability of the technology becomes uncertain when the implementer leaves the community. Sustainability is established and enhanced when interventions are embedded within institutional policies and structures and adopted to complement existing processes instead of replacing them [6].

To address the failures of ICT initiatives in local communities [1, 3, 7, 11], researchers advocate the use of more participative design approaches. This allows for closer engagement with the community to understand cultural nuances that could easily affect use and adoption of yet-to-be-developed technologies. Ramachandran *et al.* [29] echo the need to engage local stakeholders early on in the design of community-based technologies. Such engagement should not only focus on eliciting requirements but foster in-depth collaboration with prospective technology users by developing a co-design attitude. A long-term collaboration with the community is created by identifying the problem that needs to be addressed, agreeing on how to tackle the problem and together decide on how to measure success.

In using technology to help address community needs, it is most likely that we are engaging with inexperienced, untrained and vulnerable (or disadvantaged) groups. It requires the technology designer to get into design conversations with potential users so as to understand their needs, requirements and expectations [1]. At the same time, a community can come to understand where technology can possibly be helpful to them. Traditional participatory development methodologies however, assume that technology users can articulate their needs and are similarly educated [4].

Participatory Design (PD) as described above, has continuously evolved from an approach where industrial workers were given a level of influence on systems in their workplaces [15], to a platform where disempowered groups or users untrained in design are given a voice and treated as equal partners in the design process through co-design [25, 43]. PD through all its variations, remains focused on active design partnerships with participants [37] although the degree of participation may vary [20].

Co-creation and co-design are examples of approaches that have grown into established PD practices [34]. Sanders and Stappers [34] consider co-design as an instance of co-creation, which they refer to as the broader act of collective creativity, but limit co-design to the creativity of designers and people untrained in design working together in the design development process. Co-creation has broadly been applied to industrial designs for product development [27, 28, 34] while co-design has been applied in areas where participants have limited understanding of technology use and are more disadvantaged for example illiterate people with indigenous knowledge [42], homeless [36] and children [33]. Although such users may lack technical skills, they are

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knowledgeable about their own needs and community experiences that can positively shape and contribute to the design process. For our research, we work with participants from rural communities in Uganda: a group characterized by low literacy and poor access to basic services especially water, health and education.

Co-design is a step beyond PD where artefacts are created by building a shared vision, social learning and mutual understanding between the designer and the participants [32]. As a PD approach, co-design makes use of tools and techniques to facilitate system design such as scenarios, mock-ups, prototypes and future workshops to allow participants to experiment with design possibilities [20]. Some researchers use a co-design definition that focuses on co-creation or joint creativity [34, 43] but we approach co-design as the application of action research in a design setting [4] where we use technology probes to elicit requirements, collaborate with communities as we develop and evaluate an artefact.

Community-Based Co-design (CBCD) necessitates a long term commitment to the research process beyond initial design [4]. In this way researchers can gain a deeper understanding of the communities and appreciate the evolving use of technology over time [40]. This has consequences for both the researchers and participants in terms of time commitment and knowledge contribution. Although community members may take part in the research voluntarily without claiming payment [19], it is necessary and ethical to make provisions to compensate participants for their time and effort [35]. Brereton *et al.* [5] suggest that reciprocity in word, deed or spirit can build mutual trust, engagement and benefit.

We describe here how we applied CBCD, a participatory method, and the design process that led to the development of an ICT intervention to support rural water management in three rural communities. The community-based system helps rural water managers to track water users, payments and expenditures in a bid to improve transparency, accountability and trust. We critically examine the role of intermediaries and reciprocity in community-based interventions. This study builds on prior work done in the form of a situational analysis with these communities [39].

1.1 Community-Based Co-Design

Working with communities means dealing with groups of people as opposed to individuals and so the technologies meant for these groups need to be developed with a community in mind. The concepts of 'Ubuntu' [4, 41] are broadly shared in many parts of sub-Saharan Africa; in Kenya Canon Mbiti [22] enunciated the concept as: "I am, because we are; and since we are, therefore I am". The notion of 'communitisation' [21] further emphasizes the differences between the approaches used to develop community-based technologies from those used for individual or personalized technologies geared towards individual requirements.

With rural communities, much more time is spent on conversations that are not directly relevant to the design but essential for building trust and relationships. Differences exist in the participatory methods that are appropriate for communities in developing contexts compared to organizations or individuals [15, 21, 42] and appreciating these leads to better interactions and genuine participation of those previously not given a voice or considered powerless to engage in decision making [42]. Winschiers-Theophilus *et al.* [41] further argue that true participation is only achieved when we situate negotiations within the context in which we are working as opposed to adopting techniques that have worked elsewhere. Creating spaces that allow community participants to express themselves, sometimes deviating away from planned activities, provides a sense of release as the community leads the conversation or design process in unexpected ways [41].

In adopting a CBCD method, we acknowledge that different (possibly marginalised) groups exist within our study environments based on gender, age and ancestry, who need to be given a voice in the design process. Our choice of method is further guided by the need to remain sensitive to the values and culture of the communities we are trying to transform through the use of technology. To achieve this, we identify the key stakeholders in the communities and champions or gatekeepers (influential persons in the community) prior to the design conversations.

Whilst co-design enables active engagement with users, Marsden *et al.* [21] and Blake [2] argue that this design approach can only work if users have an understanding of what digital technology can do or if they have some ICT literacy. Therefore, the use of appropriate tools and techniques to encourage untrained users to participate in technology design can facilitate their learning about the technology [15, 42]. Such tools can also give insight to participants about the opportunities that the yet-to-be-developed technology can offer [4]. The role of the researcher or technologist is thus to facilitate the process by which the community participants learn about ICTs and eventually take on design roles [42].

Like most of the initiatives where co-design has been applied using a combination of PD methods and action research [7, 8, 15, 42], we use action research as a strategy to pursue action (or change) as we learn through the design and development of an intervention. Whereas PD techniques help users to voice their needs or requirements [3], action research guides the participatory process of working with communities. The mutual learning further allows for a common meaning of what ICTs can do to address the priority needs of the participating community.

1.2 Enhancing Community Engagement

ICTs have potential to contribute to community development [29] but creating locally relevant ICT applications for rural communities remains challenging. Resource limitations such as lack of reliable communication infrastructure, low literacy, political interference, gendered and biased culture of technology use as well as access and language difficulties are still barriers to effective ICT usage.

1.2.1 Intermediation

The success of the CBCD method is greatly dependent on the level of collaboration between the researcher (outsider) and the community itself in building and maintaining trust, understanding the community's agenda and build cohesion [19]. Communities may have value systems and subtle social structures not easily recognized by an outsider [41]. Furthermore, engaging members with the aim of empowering them (for example through the use of technology) easily threatens the power relations that exist within the community [3]. However, for successful engagement within these spaces, an understanding of the socio-economic, cultural and political nuances that shape user behaviour is paramount.

Developing technologies with rural users often requires immersion into the culture of the community by the researcher to build trust and negotiate expectations. This is facilitated by intermediaries (or human access points, champions or gatekeepers). These are people within the communities who are trusted by communities, are familiar with digital technology but also aware of the problems and context of the communities in which the technology is to be used [7, 21, 30]. Intermediaries provide linkages to communities, broker connections and facilitate relationships with community users. Additionally, they guide the implementation of com-

munity-based ICT interventions [13] (p 11) unhindered by language or cultural gaps [3] and are therefore seen as a means of encouraging the participation of the wider community with whom relationships in the community are maintained [9].

1.2.2 Choice of Intermediaries

Since community-based co-design is seen as fundamentally different from traditional workplace participatory design due to its focus on community development, having key figures to represent the different social groups within the communities contributes to acceptance of technological interventions [31]. These groups may be teachers, local business owners, local government entities, Non-Government Organizations (NGOs), village leaders or elders, women and youth. Involving such key representatives bridges the communication between the various categories of community members and the technology implementers [26].

Meissner and Blake [23] advocate using NGOs as intermediaries with more active roles than just community liaisons, but we argue that this is highly contextual, depending on whether the NGO in question is external or a grass root organisation. In our experience with external NGOs implementing projects in rural communities, long-term sustainability is not usually planned for. When funding for the specific project (usually from a donor organization) runs out, the NGOs wind up and exit the communities.

The decentralization of community services in Uganda has led to the establishment of governmental institutions (e.g., local governments) and institutional frameworks within the communities [38]. These facilitate and complement the democratic community structures and are therefore considered relatively more stable than international organizations in the communities. In the case of rural water management, the district water office is the local government institution mandated to provide water services and support rural communities to manage their water supplies. By training community leaders in water management practices, the district water officer builds capacity and empowers communities to manage their communal water supplies [12]. In this context, government institutions within the communities offer more stability (continuity) and are therefore more suitable intermediaries for service delivery projects. However, since they are instituted by political institutions, they are predisposed to political interference or unfavourable political decisions in terms of gaps in financial support and capacity. ICTs are seen as tools that can empower and support these institutions by providing actionable information to improve service delivery.

2. METHODOLOGY

This research is part of a wider study to explore co-design as an approach to improving engagement in technology design and development for community-based systems. We employed a cyclic process to allow the community participants to learn about ICTs and their flexibility whilst allowing the researchers to learn the context within which the intervention was to be used.

2.1 Research Stance and Context

The first author is Ugandan (lives and works in Uganda) and has worked on several rural ICT projects in Uganda. The second and third authors live and work in another developing country and are experienced in working with rural communities to introduce ICT interventions through co-design and to improve service delivery.

Many rural areas in Africa are challenged with poor access to safe water as a result of weak governance practices and disempowered institutions [10, 14, 17]. ICTs are therefore considered as viable tools capable of addressing the water access challenges that exist as a result of information gaps between the service providers and communities [10, 16, 39]. In Uganda, rural water facilities are maintained and managed by the communities through the Community-based Management Model (CBM) [38, 39]. Our study sought to empower these communities and their communal structures through the use of appropriate ICTs tools. This would provide access to information that the communities considered vital in order to enable them manage their water facilities.

2.2 Participants

Our stakeholder analysis on rural water management in Uganda identified the key stakeholders in this process as outlined in the national policy framework [12] (p 18). The preliminary study conducted as a situational analysis (1: July 2014) had twenty six participants that represented all stakeholder groups [39]. Since our research is based within the rural communities, our next cycles, that is; problem specification (2: October 2014), collaborative design (3: October 2014), implementation (4: January 2015), user experience evaluation (5: July 2015) and Re-design (6: August 2015) only involved user groups within the communities (39 participants).

The Community participants included the District Water Officer (DWO), the Assistant DWO, a Community Development Specialist (a representative of the Ministry of Water and Environment[1] at the community level), three water board treasurers, three Water User Committee (WUC) treasurers, twenty two Water Source Caretakers (eight of whom also work as pump mechanics responsible for fixing broken water sources) and eight communal water users. The participants' ages ranged from 25 and 65 with a mean age of 43; 35% were women.

2.2.1 Using an Intermediary

Our initial link to the communities was a Community Learning Facilitator, working with an international NGO that provided water services to the local communities. Since the NGO funded a number of projects within these communities, he was influential, knowledgeable and sensitive to their needs. He introduced us to the communities and the key people we were to work with. Two months after our preliminary study, the NGO ended its operations in the district due to failure to secure donor funding for the following year. Our intermediary left the community in order to find employment.

Our considerations for finding another intermediary were guided by the need to work with a more established institution (not necessarily an individual) within the community. The district water office had been involved in the preliminary study and played a key role in mobilizing communities in water management. Since we had established a relationship with the water officer from the initial visit, he agreed to be our intermediary for the rest of the study as he appreciated our approach and potential contribution. Working with a water officer who forms part of the government structure provided a certain continuity compared to the experience with NGO engagements.

2.3 Methods and Procedures

Engagement with participants was achieved through semi-structured interviews, workshops and focus group discussions organized by the water officer (intermediary). The research process was documented using notes, audio recordings and photographs. Community participants were orientated to the study by the water officer and we presented the objectives of the co-design sessions.

[1] www.mwe.go.ug

We provided workshop materials like markers, flip charts and notebooks. Participants were encouraged to be open and express themselves in whichever language (English or the local language) they felt comfortable since the water officer could ably translate.

To begin our study, we conducted a situational analysis (Cycle 1, July 2014) with three rural communities (Kasenda, Buheesi and Kicwamba) in Kabarole district in western Uganda. The objective was to understand the specific challenges of rural communities in managing their water supplies and to find out if an intervention would be useful. In assessing the challenges of water access, we focused specifically on the factors that affect the functioning of the communal water sources and how the communities make use of existing (non-technical) systems like notebooks and community structures to manage water services.

Following the preliminary study, the first workshop (Cycle 2) was conducted in October 2014, with the objective of understanding how each community currently managed water finances. Participants were grouped according to their respective communities and asked to analyse their community structures with regards to existing financial management practices, identify the problems with current practices as well as their causes. At the end of the workshop, each group gave a ten-minute presentation of their deliberations. The water officer mostly facilitated this workshop.

The second workshop (Cycle 3: collaborative design), held shortly after the first workshop, had two sessions. In the first session, we presented the participants with the reflections and outputs of the first workshop in the form of a stakeholder-interaction model (Figure 1) and a high-fidelity prototype. These guided the design conversations on the expected functionalities of the proposed ICT tool. Participants evaluated and re-modelled the conceptual model based on their experiences and local knowledge on how interactions can be supported or improved. As the participants engaged in these tasks, insights emerged on community relationships, perceived roles and expectations from the technology.

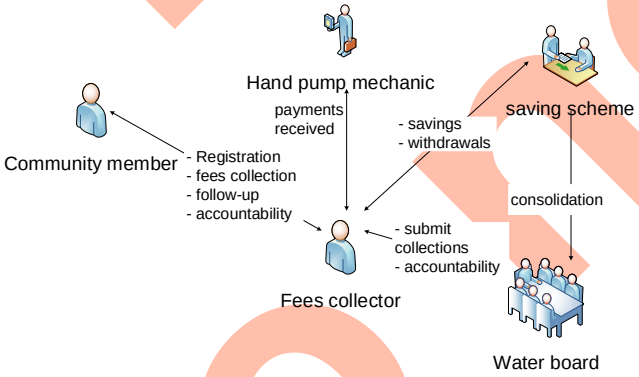

Figure 1: A model representing interactions between the different user groups

In the second session, participants with similar roles across the three communities (so all caretakers, all board treasurers, all water users, and all pump mechanics) were grouped together and each asked to deliberate on how the proposed system would support, change or enhance their activities. At the end of the workshop, each group presented their interaction models (Figures 5 & 6).

The resulting models from the design workshop were used to develop our initial prototype ICT application. For the third workshop (Cycle 4: January 2015), we demonstrated the initial prototype to the participants. We provided user documentation and conducted a training session to guide them on how to use the system to record information about water users and financial transactions.

After the prototype had been used for six months we conducted a formative evaluation (Cycle 5: July 2015) to get feedback and user experiences on its use. This was not done in a group setting but through semi-structured interviews with individual users.

The final cycle and fourth workshop (August 2015) used the evaluation feedback from users to re-design our prototype. We used this workshop to clarify contradictory feedback (e.g., issues of language and additional functionalities) so as to build consensus.

The workshops varied in length from two to three (full) days for six hours each day. At the end of each workshop we collected all documentation including the designs and group summaries.

3. RESULTS

The co-design ideas of the participants were expressed in the form of user stories, use cases, scenarios and interaction models. We use the pronoun 'we' in this section to refer to the collective design decisions made by both the researchers and participants

3.1 Situational Analysis (Cycle 1)

Rural communities manage their communal water sources by establishing water committees that run the operations and maintenance of the water source on behalf of the community. The committee nominates a care taker (anybody who lives closest to the water source) to maintain records of users and collect monthly or daily water user fees. Money is collected by moving around the community or at water collection points. Prior to our study, records of water users and finances were maintained in notebooks kept by caretakers. The committee treasurer then collected the money from the caretaker and passed it on to a water board member who together with the collections from other community treasurers, saved the money with a community financial institution (a cooperative society fund). The dependence on a caretaker being physically available to manually manage records made this arrangement vulnerable to loss of data and without clear forms of accountability and transparency, communities increasingly became apathetic towards communal water management.

The findings from this preliminary study indicated that at the core of the community based management of rural water supply and improved water access, is the ability to maintain water facilities by having a sustainable financial system in place. This means that communities must regularly pay, collect and manage water fees.

"…when community water funds are misused, communities lose morale. One such community collected money but a community member swindled the money they had collected and they have never collected money again. Their borehole is spoilt but you can't convince them to pay any money" [community water board member, July 2014].

The main reason for failure to pay fees by water users is mistrust by the community members. When funds are mismanaged or unaccounted for by the water managers, community members lose the motivation to pay. The communal water managers on the other hand struggle with maintaining the records of water users to keep track of monthly payments. Through the discussions with the communities and local government leadership, we identified ways to improve user-fees management. The emergent need was to develop an ICT tool to support efficient and transparent financial management procedures and activities of water facilities.

3.2 Problem Specification (Cycle 2)

Building on the preliminary study, this cycle (a workshop in October 2014) focused on participants reflecting on the roles they played within their communities, assessing their water manage-

ment practices and identifying gaps that the proposed intervention could support (Figure 2).

Figure 2: Participants from Kasenda community assessing their communal structures and practices

It emerged that across all three communities, the issues of transparency, accountability and water user management were problematic thus resulting in poor financial management practices. The participants however, exhibited a great sense of understanding of their individual responsibilities in regards to the water management practices like the caretaker who mentioned:

"…the caretaker is expected to keep a record of all the households using the water source. She/he collects monthly fees from each household to pay for maintenance activities of the water source. The fee is set by the Water User Committee (elected by the community and responsible for managing the source on behalf of the community)" [Caretaker, October 2014].

From the participants' presentations at the end of the workshop, we (lead researcher and participants) were collectively able to generate use cases and an initial specification model (Figure 1) for the interactions between the different stakeholder groups.

- *Use case 1 (water user): She/he pays a monthly fee (set by the water user committee) to the caretaker and gets a receipt or any form of acknowledgement of his/her payment. At the end of every month, a summary of expenditures and account balances is sent to the user as a text message.*
- *Use case 2 (Caretaker): She/he registers all the water users of the water source and collects monthly water fees. If a user defaults on fees, the caretaker sends a reminder or reports the user to the water user committee. The caretaker also records all transactions including collections and expenditures (for minor repairs) of collected fees. He/she is also able to query or inquire about the accounts status of the communal funds.*
- *Use case 3 (pump mechanic): He is responsible for repairs of the water source and logs all maintenance activities and the cost of each activity as expenditures of communal water fees.*
- *Use case 4 (committee or water board treasurer): She/he collects 70% of the monthly funds from the caretaker and puts it in a savings fund that accumulates and pays for major repairs.*
- *Use case 5 (Saving scheme/fund): Provides accounts statements for the different water source committees to be passed on to the different community members at a specific water source.*

Our ICT tool was therefore intended to facilitate the registration of users of communal water facilities, tracking of payments made by community members, tracking expenditures, follow-up of unpaid water fees and provide summarized information on monthly transactions or financial activities to the communities.

As researchers, we sought to have a solution that matched the local needs, local practices as much as possible and to account for factors that would shape local appropriation of the intervention.

3.3 Collaborative Design (Cycle 3)

This cycle (also conducted in October 2014) was geared towards providing a platform for participants to envisage the use of technology. It allowed them to use their knowledge and influence to shape the design of the intervention.

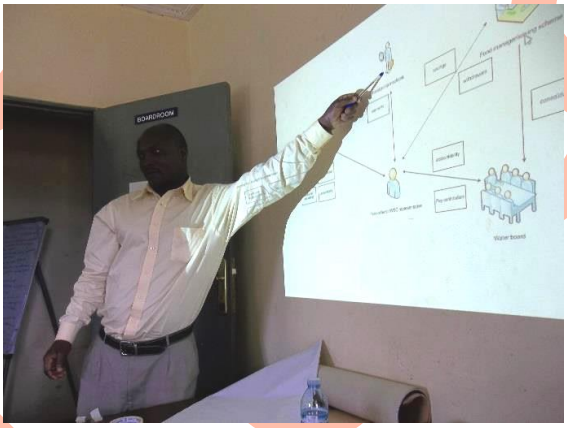

Figure 3: A participant critiquing the role of pump mechanics in the proposed workflow model during the design workshop

In presenting the interaction model (developed from the previous cycle) and allowing participants to critique it (Figure 3), we were collectively able to refine the requirements but also give the participants a better idea of what the intervention would allow or support them doing. During this session there was mutual consensus to remove the roles of pump mechanics and the saving cooperative from the system. This was because the cooperative only engaged with the water board and not the communities and the pump mechanics did not handle community finances but were only paid for their services such as repairing faulty pipes.

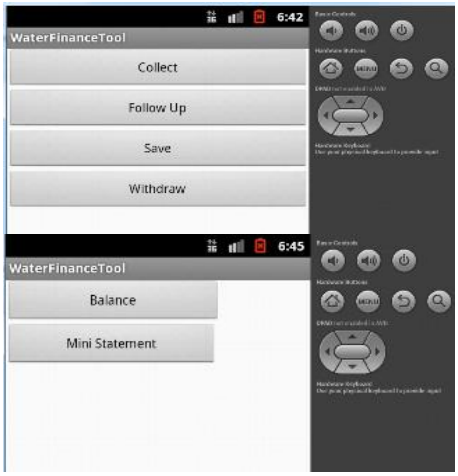

Figure 4: Sample screen shots of the high fidelity prototype evaluated during the design workshop. *(Top: allows the caretaker to log collections, track and follow-up on defaulters, submit (save) collections and log withdrawals; Bottom: provides any system user a view of finances of a particular community*.

A high fidelity prototype (Figure 4), a basic version of the system with limited functionality but which mimicked the intended system, was developed by the researchers. This helped participants to refine the design of the application further, e.g., by adding data fields for 'water source location' and 'total number of households defaulting on monthly payments'. Using a high fidelity prototype allows co-designers to associate the technology designs with actual software development [24] compared to paper sketches. This prototype is also useful in eliciting feedback to inform new designs within our context [29].

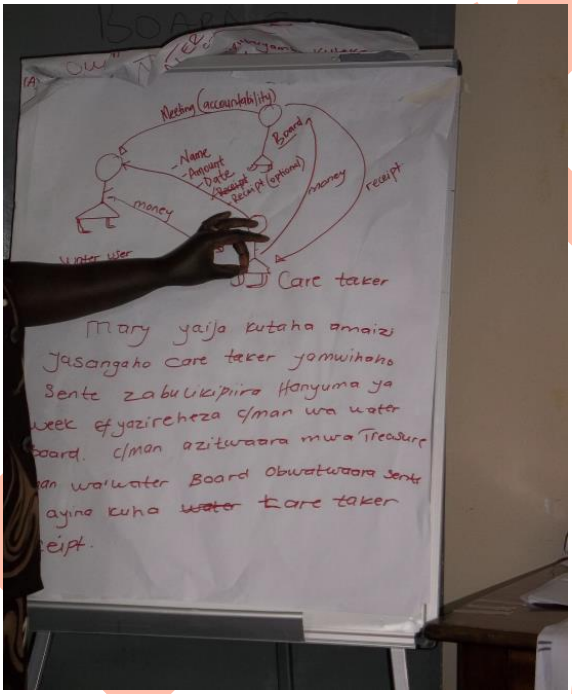

Figure 5: A community member (water user) presents her interaction model and scenario (in her local language) during the design workshop. *Mary goes to collect water and finds the caretaker to whom she gives her contribution and gets a receipt. The caretaker gives the money to the water board treasurer who then issues a receipt to acknowledge payment.*

Figure 6: A community treasurer presents a model depicting his desired interactions within the proposed intervention

By allowing participants to express themselves and represent their understanding of their environment and relationships (Figures 5 and 6), this co-design space became an enabling environment for inexperienced users to create or model their aspirations. These models showed intuitive relationships between community members and water managers, revealing participants' ideas and their needs and aspirations. This design workshop therefore enabled all of us to clarify how participants performed their tasks and whether the proposed design could actually support them.

3.4 Implementation (Cycle 4)

Using the outcomes (that is, models, scenarios and use cases) from the design workshops, we (researchers) developed an initial prototype of the application. Since sustainability is a key concern to our research, our choice of technology was going to be dependent on what communities could readily access, afford and use.

Because mobile phones were a familiar technology in the communities and all the participants had mobile phones, there was a consensus on running the ICT tool as a mobile-based application. However, all the participants only had basic phones that were unable to run the application, necessitating a discussion with the participants on the type of mobile platform to use for the system.

With the rapidly declining costs of Android phones, greater computing capabilities and improved interactions, we (researchers) facilitated the decision making process for the participants to use an Android platform with low-cost Android phones (USD 50). Since most of the participants had phones (basic), we did not want to burden them with an additional phone as this would mean extra costs for charging the phone batteries. We therefore chose to use dual-sim phones and that way, they were able to move their own sim cards (and phone contacts) into the new devices.

Uganda is a multilingual country with over forty indigenous languages and no single national language. English is therefore the *de facto* form of communication across the country but within Kabarole district (our study site), *Rutooro* is the common indigenous language. It is however common to find different communities in the same locality speaking intermediate/related dialects. Since 95% of the participants (who were to use the ICT tool) could express themselves in English, it was the preferred language to use for the application. The participants were also more concerned about the system workflows and therefore the decisions regarding icons for the interface where left to the researchers.

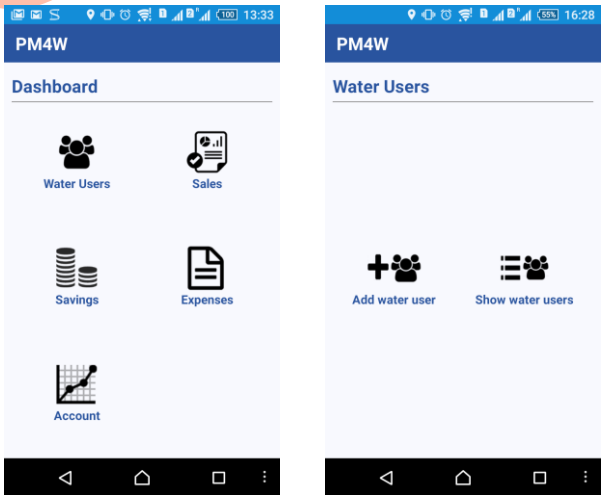

Figure 7: Sample interfaces of the PM4W application: (a) - the home screen for the caretaker to register and view water users (as shown in b), log daily and monthly collections (sales), log expenses, post savings and view account status

Our PM4W (Pay Me for Water) Android application (Figure 7) allows caretakers to register water users, provide information on

fees collected (sales) as well as expenditures. It allows community treasurers to record information on total savings submitted to the water boards. At the end of every month, a water board treasurer attached to a particular source generates an accounts statement and this is sent to every water user attached/registered to the water source as an SMS notification. This notification contains information of how much money was collected and the expenditures for the month. Defaulters are also sent notifications as reminders for payment and or reported to the water boards for further action.

The PM4W system supports the communal water management model by improving financial management practices. The assumption being that if communities are supported to manage efficiently and use the communal finances transparently, water users will be more willing to pay their water fees. Therefore, more funds will available for operations and maintenance activities and eventually lead to improved functionality of water sources and access to clean and safe water. We deployed this initial prototype within the study communities in January 2015.

3.5 User experiences and Feedback (Cycle 5)

Ten participants (six caretakers and four treasurers) were given mobile phones during the system deployment (January 2015). In July 2014, we (researchers) conducted an initial assessment in form of individual semi-structured interviews (Figure 8) to get user feedback on the use of the tool and establish whether and how the intervention was being appropriated in the communities.

Figure 8: The lead researcher assessing usability of PM4W with a community treasurer

We sought to understand the contextual factors that were potentially influencing the use of the technology, focusing on PM4W as a tool for mediation and support for human/community activities. We used four perspectives [18] to guide our assessment and make sense of the user feedback. These perspectives included; *Means and Ends* (extent to which technology supports or constrains users); *Environment* (extent of integration into existing structures and resources); *Learning* (extent of support of new ways of working); *Development* (extent of positive change caused). A more detailed description of these perspectives and the theory behind them is not the focus of this paper and will be published later.

3.5.1 Summary of Evaluation feedback

- *Means and Ends*: Four caretakers and two treasurers had used the system quite consistently, mainly to register water users (400 registered) and to a lesser extent, log transactions (including collections and expenditures). Active users attributed their use to the relevance of the functionalities especially the registration of users, which allowed them to know the number of users per water source and determine a monthly charge. Non-users attributed their minimal activity to slow learning since they were using smart phones for the first time. The use of English for the application turned out to be problematic especially for less literate users who could speak it but found difficulty writing it.
- *Environment*: Unstable communication networks in remote villages hampered the use of the system for many. Users infrequently had connectivity to log transactions. Furthermore, interruptions in water supply affected the use of the system in one of the communities. For this community that was experiencing pipe renovations for all communal taps, there was no PM4W usage for four months since no fees were being collected.
- *Learning*: None of the users had prior experience with touch screen devices. With the training during deployment, most of them found it easier to use and were encouraged to use the phones often. Two users relied on their children for more help while the rest were able to use the phones independently. With the interruptions in systems use (for example lack of connectivity and water), many users resorted to appropriating the phones to other activities. For example, a caretaker who also works as a pump mechanic decided to use the phone to take photographs of repairs he had undertaken. A treasurer who also serves as a minister in a local church learnt to use the recorder and would use it to record religious programs from the local radio station.
- *Development*: We set out to support the communal water managers to manage their financial activities and in so doing, build trust and accountability within the communities. However, due to the minimal use of the intervention as a result of the expressed challenges, our intended outcomes had not been achieved. Despite that, the engagement with the participants and technology design experience did enable users to articulate their needs, experiences and internalize new ways of using the mobile phones. A caretaker said: *"...since I can use this powerful mobile phone properly, now I think I can use a computer."*[July 2015].

3.6 Re-Design (Cycle 6)

The cyclical nature of our study requires us to create avenues for critical reflection and flexibility through revisiting design decisions and support requests for changes. User feedback necessitated a workshop to share the assessment with the wider section of participants who were neither caretakers nor treasures. The goal of the workshop was to build consensus on localizing the system, address the connectivity problem and any emergent requirements.

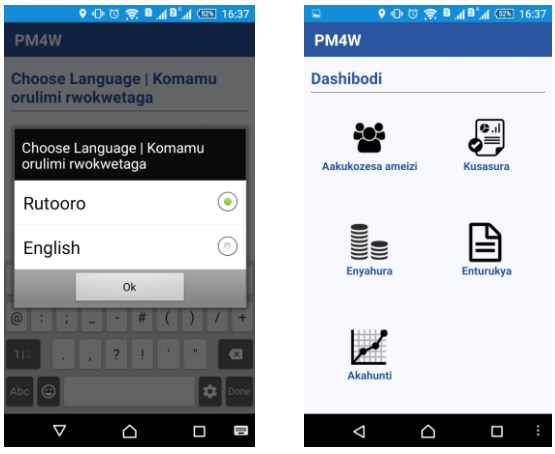

Figure 9: Version 2 of PM4W that allows users to select a language and a sample screen shot of the localised interface

This workshop was facilitated by the water officer (our intermediary). Although the use of English within the system had not been a problem in the previous workshops, it became necessary to support the users who were more comfortable using the local language. Again, consensus was achieved to localize the system into the major local language (Rutooro) while keeping the English version (Figure 9). Participants who were conversant with the Rutooro grammar did the translations.

To deal with poor connectivity within the villages, we discussed different ways of improving data transmission including changing to a different telecom provider or an offline database. The telecom provider who had better connectivity had higher charges than participants could eventually afford. We therefore implemented an offline database to which users would load information when out of network reach. Once a connection was established, the database would then automatically sync the offline data with the online database. This would then allow for uninterrupted system use.

An emergent requirement was the need to keep the amount that water users paid flexible. A fixed amount had been set but actually, different communities charged different fees for users depending on the model of community management of the water source. At this workshop, more potential users of the system were trained.

4. DISCUSSION

The overall aim of our study was to explore co-design as an inclusive design approach to developing a useful and more usable system for social development (in terms of contributing to improved access to water) in underserved communities. In this section, we reflect on our experience in doing co-design and hope that our method can inform similar initiatives.

4.1 Community-Based Co-Design

Successful development of ICT solutions in the field requires substantial effort in coordinating various stakeholder groups often with varying desired outcomes. It requires establishing deep connections within the communities to guide the process of continuous engagement. Engaging with multiple stakeholders at the community, district and national level was cumbersome but eventually rewarding when consensus was established regarding the priority needs (improving financial management) of the communities. By adopting the CBCD method, we committed to an evolving understanding of our users, their capabilities, their needs and relationships to create an appropriate and flexible solution.

Co-design can be a challenge when users have little understanding of digital technology. This calls for more creative ways to encourage participation and a space where users can articulate ideas and aspirations. In our study, we realized that some participants did not know how much they actually knew about their context and how their knowledge and experiences could help in shaping the final product. With time and appropriate techniques (e.g., high-fidelity prototypes and workshop structures), these participants became confident in sharing their knowledge in the discussions for an appropriate design. Some design issues and constraints were only realized when the technology was in place. Creating a space where changes in needs were accommodated and incorporated into design created resonance and led to the creation of a more relevant/useful technology. Such changes included; localisation of the application, offline data capture and updating data forms.

Technology is adaptable and users should be helped to see how it changes in response to their changing needs. We saw that participants remained motivated and more willing to participate when they saw their input or feedback being applied to improve/change the design of the system. Furthermore, the participants felt free to find new ways of using the system and the devices and were confident to communicate these ways of appropriation.

Our approach to sustainability is in empowering the local people in the communities to manage their water management activities using an affordable and accessible technology as a tool. Using the established government institutions such as the district water office and community structures such as the water boards and water committees has provided stability and continuity even when we have left the communities after the workshops.

4.2 On a Government official as intermediary

We started off with an intermediary from an NGO in the communities but his departure following the NGO's exit forced us to consider existing government institutions. As emphasized by Champanis and Rivett [6], using government structures supports sustainability of community ICT interventions and allows for the integration of the technology into communal practices.

Local community leaders (politically appointed) were involved in our study but often pushed for their own agenda that substantially differed from the needs of community members. Furthermore, they constantly trivialised the needs of communities and hindered participation of some. The district water officer was therefore a suitable intermediary. He was a government appointee, was influential and respected in the communities and able to control political interference and bridge the cultural and language gaps between the researchers and the communities. He was also enthusiastic about the use of ICT solutions to solve water problems.

Having the water officer as an intermediary has not only provided a stable link to the communities, but enabled us to integrate our intervention within existing government structures, thus reducing the need for monetary incentives to participants. Furthermore, he has been able to provide local support to the participants in helping them use and adapt to the system through regular meetings and training when the research team was absent.

The loss of an intermediary, as happened initially in our case, can easily affect the momentum or level of engagement with the community. Implementing a technology within a community in which one does not reside or originate requires a local support system to provide continuity. It is possible to maintain communication and engagement with communities beyond the intermediary, but this requires immersion in the community and established relationships that are not dependent on the intermediary.

4.2.1 Selecting an Intermediary

In choosing an intermediary for a community project, researchers need to think of sustainability issues of the project after they have departed. Although external NGOs and their team members may have vested interest in the outcome of a community project and have a lot of insight into community and users' characteristics, they eventually leave. We recommend selecting an intermediary from an institution that forms part of the community structure. In the eventuality of an individual leaving, the collaboration remains with the institution and so the partnership endures.

4.3 Issues of Reciprocity

There is a debate on acceptable ways of compensating study participants for their input. Actively engaging with community members in co-design workshops means that the people have to prioritize their time and participate in the research. In a resource constrained situation this has consequences for their livelihoods.

Considering the ethics of reciprocity, we collaborated with our participants and created a useful artefact as a direct consequence

of our research. This is considered a mutually beneficial relationship as we do not privilege theory over action [4]. However, we acknowledge that our participants, while motivated by the need to solve their problems, require compensation for participating in the research. We also acknowledge the fact that we as researchers might gain more from this research than other participants.

Our key concern was the sustainability of the mechanism we were to adopt so as not to create a dependency on monetary incentives. Since different cultures and customs have different appropriate ways of rewarding people, we consulted our intermediary prior to the field study to understand what methods would be appropriate. We therefore compensated the community members by giving them a transport refund of USD 10 per day and we provided meals during the workshops.

Furthermore, participants received phones that they were to use beyond the purpose of the study. Leaving the phones behind has given us another perspective on participant gains. For example, a treasurer was helped to learn to use the phone by her son and in return, the son was allowed to use the phone for his personal communication. These phones have become shared resources and are therefore considered a form of compensation for participation.

These forms of compensation may be considered exorbitant and possibly with potential to reaffirm existing social-economic inequalities ([35] p 176). Our choice of rewards was informed by our intermediary and was in recognition of our participants' commitment to the study. Scheyvens [35] suggests that providing feedback to research participants can be a form of reciprocity. Through our research approach, we were able to provide feedback to participants and also allowed them to share their feedback.

4.4 Future Work

We have built local capacity (with enthusiastic and active participants) within the communities to provide basic support and act as contact points in case of technical problems. The district water officer continues to provide additional support to the users. We are in discussion with an NGO that has shown interest in piloting PM4W in a neighbouring district. We intend to use our established relationships with the communities to extend PM4W to other communities as we improve it into a working system beyond the prototype. We intend to conduct another round of evaluations to get user feedback and conduct possible improvements.

5. CONCLUSION

We have presented a case study in which we applied co-design in a rural context in a developing country. We have attached a lot of importance to sustainability and are therefore not only interested in having a usable system but also in how it can be integrated into community water management practices and make a meaningful impact on the lives of community members and rural water services in the long run. In so doing, we remained sensitive to local values, available technological resources and constraints.

Community-Based Co-Design meant a commitment to a long term collaboration with communities beyond the initial design. This allowed us to develop a practical ICT intervention and study how technology users untrained in design can be engaged in design. We have explored the role and contribution of intermediaries in community-based research and how reciprocity can be achieved. Therefore, communities can be engaged successfully through knowledgeable and stable intermediaries that are able to provide clear perspectives on user capabilities and thus narrow the gap between community participants and external researchers. By so doing, we are better placed to capitalize on our interactions with communities and create technologies that are flexible and usable.

CBCD has afforded us a basis for continuous engagement with communities to understand their context, their needs and aspects in their environment that easily affect technology adoption and use. In so doing, trust and confidence have been built that previously 'powerless' participants have been empowered to make and contribute to design decisions.

Participatory practices are normal and deeply anchored in the rural lives of many African communities, which suggests that we can generalise our lessons more broadly (Section 0). Therefore, the emphasis of developers should be actively intervention-driven introduction of technology to build up communities' technological sophistication and thus enable their active participation in design. Concerns about excessive 'rewards' must not stand in the way of giving our design partners access to appropriate technology. It is a truism of mobile device development that 'advanced' devices rapidly diffuse and reach most communities. This is especially true of projects with a long anticipated life.

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7. REFERENCES

[1] Ashraf, M., Swatman, P. and Hanisch, J. 2008. An extended framework to investigate ICT impact on development at the micro (community) level. *European Conf. on Inf. Systems (ECIS)* (2008), 1–12.

[2] Blake, E. 2010. Software Engineering in Developing Communities. *CHASE Conf.* (2010), 1–4.

[3] Blake, E. and Tucker, W. 2006. Socially Aware Software Engineering for the Developing World. *Proc. IST-Africa Conf.* (2006), 1–8.

[4] Blake, E.H., Tucker, W.D. and Glaser, M. 2014. Towards communication and information access for Deaf people. *South African Computer J*. Special issue on ICT and development (2014), 10–19.

[5] Brereton, M., Roe, P., Schroeter, R. and Lee Hong, A. 2014. Beyond Ethnography: Engagement and Reciprocity as Foundations for Design Research Out Here. *Proc. CHI '14 Conf.* (2014), 1183–1186.

[6] Champanis, M. and Rivett, U. 2012. Reporting Water Quality – A Case Study of a Mobile Phone Application for Collecting Data in Developing Countries. *Proc. ICTD Conf.* (Atlanta, 2012), 105–114.

[7] Chetty, M., Tucker, W. and Blake, E. 2004. Developing locally relevant software applications for rural areas: A South African example. *Proc. SAICSIT Conf.* (2004), 239 – 243.

[8] Dell, N., Vaidyanathan, V., Medhi, I., Cutrell, E. and Thies, W. 2012. "Yours is better!": Participant response bias in HCI. *Proc. CHI '12 Conf.* (2012), 1321–1330.

[9] DePaula, R. 2004. Lost in Translation : A Critical Analysis of Actors , Artifacts , Agendas , and Arenas in Participatory Design. *Proc. Participatory Design Conf.* (2004), 162–172.

[10] Dickinson,N & Bostoen, K. 2013. *ICT for monitoring rural water services :From data to action*. Technical Report, Retrieved August 4, 2014 from www.ircwash.org/resources/using-ict-monitoring-rural-water-services-data-action

[11] Dodson, L., Sterling, S. and Bennett, J. 2012. Considering failure: eight years of ITID research. *Proc. ICTD Conf.*

(2012), 19–34.
[12] DWD 2011. *National Framework for Operation and Maintenance of Rural Water Supplies in Uganda*. Retrieved April 12, 2014 from www.mwe.go.ug/index.php?option=com_docman&task=cat_view&gid=13&Itemid=223
[13] Gigler, B. 2011. *"Informational Capabilities" - The Missing Link for the Impact of ICT on development*. Technical Report, Retrieved September 15, 2014 from dx.doi.org/10.2139/ssrn.2191594
[14] Glotzbach, R., Barakzai, S., Adisu, J. and Tiwaru, C. 2013. Functionality : The challenge to sustain rural water supply services. *SNV Practice Brief*, no. 5, pp. 1–8. Retrieved August 12, 2014 from www.snvworld.org/en/regions/africa/publications/functionality-the-challenge-to-sustain-rural-water-supply-services
[15] Hussain, S., Sanders, E.B.N. and Steinert, M. 2012. Participatory design with marginalized people in developing countries: Challenges and opportunities experienced in a field study in Cambodia. *Int. J. Design*. 6, 2 (2012), 91–109.
[16] Hutchings, M., Dev, A., Palaniappan, M., Srinivasan, V., Ramanathan, N. and Taylor, J. 2012. *mWASH: Mobile Phone Applications for the Water, Sanitation, and Hygiene Sector*. Retrieved March 12, 2014 from www.indiasanitationportal.org/sites/default/files/Full_Report_MWASH.pdf
[17] Jiménez, a. and Pérez-Foguet, a. 2010. Challenges for Water Governance in Rural Water Supply: Lessons Learned from Tanzania. *Int. J. Water Resources Development*. 26, 2 (Jun. 2010), 235–248.
[18] Kaptelinin, V., Nardi, B. and Macaulay, C. 1999. The Activity Checklist : A Tool for representing the "space" of context. *Interactions*. July-August (1999), 27–39.
[19] Kapuire, G.K., Winschiers-Theophilus, H. and Blake, E. 2015. An insider perspective on community gains: A subjective account of a Namibian rural communities′ perception of a long-term participatory design project. *Int. J. Human-Computer Studies*. 74, (2015), 124–143.
[20] Kensing, F. and Blomberg, J. 1998. Participatory Design: Issues and Concerns. *Computer Supported Cooperative Work*. 7, 3 (1998), 167–185.
[21] Marsden, G., Maunder, A. and Parker, M. 2008. People are people, but technology is not technology. *Philosophical transactions. Series A, Mathematical, physical, and engineering sciences*. 366, 1881 (2008), 3795–3804.
[22] Mbiti, J.S. 1990. *African Religions and Philosophy*. Heinemann.
[23] Meissner, F. and Blake, E. 2011. Understanding culturally distant end-users through intermediary-derived personas. *Proc. SAICSIT Conf.* (2011), 314–317.
[24] Molapo, M. and Marsden, G. 2013. Content Prototyping – An Approach for Engaging Non- Technical Users in Participatory Design. *INTERACT 2013*. (2013), 788–795.
[25] Muller, M.J. and Druin, A. 2003. Participatory design: The third space in HCI. *Human-Computer Interaction Handbook*. A. Jacko, J. A. ; Sears, ed. Lawrence Erlbaum Associates. 1051–1068.
[26] Peters, A.N., Blake, E., Awori, K., Chivuno-kuria, S., Kumar, A. and Bidwell, N.J. 2014. Collaborating with Communities in Africa : A Hitchhikers Guide. *Proc. CHI Conf.* (2014), 1969–1974.
[27] Prahalad, C.K. and Ramaswamy, V. 2004. Co-creation experiences: The next practice in value creation. *J. Interactive Marketing*. 18, 3 (2004), 5–14.
[28] Prahalad, C.K. and Ramaswamy, V. 2002. The Co-Creation Connection. *Strategy and Business*. 27, 27 (2002), 50–61.
[29] Ramachandran, D., Ramachandran, D., Kam, M., Kam, M., Chiu, J., Chiu, J., Canny, J., Canny, J., Frankel, J. and Frankel, J. 2007. Social dynamics of early stage co-design in developing regions. *Proc. CHI Conf.* (2007), 1087-1096
[30] Rey-moreno, C., Ufitamahoro, M.J., Venter, I. and Tucker, W. 2014. Co-designing a Billing System for Voice Services in Rural South Africa : Lessons Learned. *Proc. ACM DEV Conf.* (2014), 83–91.
[31] Sabiescu, A.G., David, S., Zyl, I. Van and Cantoni, L. 2014. Emerging Spaces in Community-based Participatory Design : Reflections from Two Case Studies. *Proc. Participatory Design Conf.* (2014), 1–10.
[32] Salomao, D., Sabiescu, A.. and Cantoni, L. 2013. Co-design with Communities. A Reflection on the Literature. *7th International Development Informatics Association Conf., Bangkok, Thailand* (2013), 152–166.
[33] Sanders, E.B.-N. 2000. Generative tools for CoDesigning. *Collaborative Design*. Scrivener Ball and Woodcock, ed. Springer-Verlag.
[34] Sanders, E.B.-N. and Stappers, P.J. 2008. Co-creation and the new landscapes of design. *Int. J. Cocreation in Design and the Arts*. 4, 1 (Mar. 2008), 5–18.
[35] Scheyvens, R. 2014. *Development Fieldwork*. Sage Publications.
[36] Southern, J., Ellis, R., Ferrario, M.A., McNally, R., Dillon, R., Simm, W. and Whittle, J. 2014. Imaginative labour and relationships of care: Co-designing prototypes with vulnerable communities. *Technological Forecasting and Social Change*. 84, (2014), 131–142.
[37] Spinuzzi, C. 2005. The Methodology of Participatory Design. *Technical Communication*. 52, 2 (2005), 163–174.
[38] Ssozi, D. and Danert, K. 2012. *National Monitoring of Rural Water Supplies*. Technical Report, Retrieved October 28, 2014 from www.rural-water-supply.net/_ressources/documents/default/1-383-3-1354809704.pdf
[39] Ssozi-Mugarura, F., Blake, E. and Rivett, U. 2015. Designing for Sustainability : Involving Communities in Developing ICT Interventions to Support Water Resource Management. *Proc. IST-Africa Conf.* (2015), 1–8.
[40] Taylor, N., Wright, P., Olivier, P. and Cheverst, K. 2013. Leaving the wild: lessons from community technology handovers. *Proc. CHI'13 Conf.* (2013), 1549–1558.
[41] Winschiers-Theophilus, H., Bidwell, N.J. and Blake, E. 2012. Altering participation through interactions and reflections in design. *CoDesign: Int. J. CoCreation in Design*. 8, 2-3 (2012), 163–182.
[42] Winschiers-Theophilus, H., Chivuno-Kuria, S., Kapuire, G.K., Bidwell, N.J. and Blake, E. 2010. Being Participated - A Community Approach. *Proc. Participatory Design Conf.* (2010), 1–10.
[43] Yoo, D., Huldtgren, A., Woelfer, J.P., Hendry, D.G. and Friedman, B. 2013. A Value Sensitive Action-Reflection Model: Evolving a Co-Design Space with Stakeholder and Designer Prompts. *Proc. CHI'13 Conf.* (2013), 419–428.