Exploring the methodology of participatory design to create appropriate sanitation technologies in rural Malawi

Ben Cole, John Pinfold, Goen Ho and Martin Anda

ABSTRACT

The methodologies of demand-led sanitation programmes (including community-led total sanitation [CLTS] and sanitation marketing) encourage participation of users in the design of appropriate sanitation facilities. There has been limited examination of the application of established methodologies in participatory design in the sanitation sector. This paper describes and reflects upon three case studies that applied established participatory design methodologies to create sanitation technologies in rural Malawi. Participants of the design sessions represented two groups: (i) researcher–designers (government staff); and (ii) users (local builders and householders). The methodology created a space to develop a common language between the two groups and allowed an exploration of tensions about the use of sanitation hardware subsidies. The design sessions created a number of innovations including corbelling structures, trapezium shaped bricks and reinforcement of wooden frame structures with sandbags. The paper critically reflects on the processes of participatory design in relation to power, ownership and continued participation.

Key words | design, participation, rural, sanitation

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INTRODUCTION

Top-down sanitation programmes that promote a specific technology based on the presumptions of 'outside experts' have been criticised for endorsing unsustainable, expensive and inappropriate technologies (Cairncross 2004; Jenkins & Sugden 2006). In response to these failings, a new era of demand-led sanitation programmes encourage greater participation of users to create, identify and select appropriate sanitation technologies (Cairncross 2004; Kar & Chambers 2008). Although comprehensive compilations of sanitation systems and technologies exist (e.g. Tilley *et al.* 2008), few studies critically examine the methodologies used to engage local users and suppliers in the design of appropriate sanitation technologies. This paper engages with that space by presenting and reflecting upon a participatory design methodology applied in rural Malawi.

Two common demand-led sanitation programmes are sanitation marketing and community-led total sanitation (CLTS) (Mara *et al.* 2010). Sanitation marketing programmes in Lesotho, Cambodia and Kenya applied human-centred design approaches (Blackett 1994; Baker *et al.* 2011). Human-centred design attempts to create sanitation products and services that match the needs, practices and preferences of users and suppliers of sanitation technologies. In Vietnam, Cambodia and Kenya sanitation marketing programmes have engaged international researchers–designers to conduct qualitative market research with users and suppliers (Sijbesma *et al.* 2010; Baker *et al.* 2011). The market research informed the researchers-designers to create iterative prototypes that were subjected to extensive user testing.

The CLTS methodology does not recommend inputs from external researchers–designers but suggests that local facilitators should 'help in establishing linkages with local markets' (Kar & Chambers 2008). The role of local facilitators also includes: encouraging local innovation and production; identifying locally available products and materials; and training locals to manufacture sanitation technologies (Kar & Chambers 2008). Recently, a founder

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of the CLTS approach emphasised that the selection of technology is crucial to overcome second- and third-generation problems such as groundwater contamination and environmental pollution (Kar 2012).

Participatory design practices

This research applied a participatory design methodology described in Spinuzzi (2005) and IDEO (2009) to engage users and researchers-designers in the creation of appropriate sanitation technologies. Participatory design evolved through the US labour movement and Scandinavian codetermination laws during the 1970s. The approach was used to democratically engage workers in the design and integration of new technologies within their work processes (Nieusma 2004; Spinuzzi 2005). Participatory design is now an established methodology used across a wide breadth of development programmes (Nieusma 2004; Winschiers-Theophilus *et al.* 2012). Steen (2011) argues that participatory design is a specific approach of human-centred design that 'attempts to give future users of a system a role in its design, implementation and evaluation'. Participatory design provides a space for users to express traditional, tacit and often invisible knowledge and skills used in their daily lives (Spinuzzi 2005).

Participatory design's methodological and philosophical position aligns to participatory action research (PAR) (Winschiers-Theophilus *et al.* 2012). Both approaches attempt to create a democratic space between researchers-designers and users and link research objectives with actionable goals (David 2002; Bozalek 2011). Criticisms of PAR methodology include the application of Western-democratic practices in non-Western cultures (Campbell 2002) and the failure to include participation from marginalised groups (Bozalek 2011; Winschiers-Theophilus *et al.* 2012). These criticisms have encouraged commentators of participatory design to advocate that researchers have a duty to critically reflect on their research processes and outcomes (Steen 2011).

Existing sanitation technologies in rural Malawi

Evaluations of CLTS programmes and formative market research identified an urgent need for design improvements in existing sanitation technologies in rural Malawi (Phiri 2010; Cole *et al.* 2012). Research conducted in three rural districts found more than half of all sanitation facilities collapsed within 12 months of construction, resulting in users returning to open defecation or sharing a facility (Cole *et al.* 2012). Cole *et al.* (2012) also reported that sanitation suppliers were unengaged in the sector because of low demand for existing sanitation technologies.

The overall objective of this paper is to record, examine and critically reflect on the use of Spinuzzi's (2005) and IDEO's (2009) participatory design methodology to identify appropriate sanitation technologies. To achieve this objective the following specific aims are addressed:

- To describe the methodology used during the participatory design sessions.
- To evaluate the outcomes of the participatory design methodology between the three case studies.
- To explore the challenges of power, ownership and ongoing engagement in the application of participatory design methodology.

METHODS

Country context

Up to 49% of households in rural Malawi have an inadequate or absent sanitation facility (WHO & UNICEF 2010). The Malawian government has identified CLTS and sanitation marketing as the two leading mechanisms to achieve its objective of total sanitation coverage by 2015 (MoAIWD 2011). Since 2009, CLTS programmes have been applied extensively across rural communities (Maulit & Kang 2011). In contrast, few rural sanitation marketing programmes have been implemented (DeGabriele 2009).

Programme context

In 2011, UNICEF Malawi initiated a rural sanitation marketing programme with three district government partners. In partnership with staff members of the District Environmental Health Office (DEHO), the first author conducted formative market research (Cole *et al.* 2012).

The research informed the development of an integrated marketing strategy that addressed the four Ps of 'Price', 'Product', 'Promotion' and 'Place'. In 2012, the participatory design sessions were applied to address the 'Product' and 'Price' components of the integrated marketing strategy.

The development of the 'Product' and Price' components was based on a ground-up philosophy such that the primary source of information was derived from the collective knowledge and skills of local builders and villagers. It was intended that in each district, the designs would be collated and provided to the DEHO. The DEHO would identify designs that would be provided to the National-level Open Defecation Free (ODF) Taskforce. The ODF Taskforce is a co-ordinating body for organisations operating in the sanitation sector and includes representatives from the Ministry of Health, Ministry of Irrigation and Water Development, UNICEF and leading non-government organisations.

Participatory design approach

The participatory design sessions were derived from the methodologies presented in Spinuzzi (2005) and IDEO (2009).

The three-day design sessions consisted of four stages:

Stage 1: Initial exploration of work

Teams of five builders/masons, two village health workers/householders and one staff member of the DEHO were formed. Each team was asked to draw and label the existing sanitation technologies in their villages. The teams were then instructed to identify the advantages and disadvantages of each technology. Each team then presented their findings to the group (Photo 1).

Stage 2: Discovery processes

The discovery process asked each team to identify numerous potential design options. The design options were framed by a design challenge. A design challenge presents a challenge in human terms, in a broad manner that offers opportunities for discovery in areas of unexpected value but is 'narrow enough to make the topic manageable' (IDEO 2009). The design challenge used during the sessions was:

> 'Can we create a toilet that matches what the majority of villagers want, need and can afford using local materials?'

Teams visualised their designs through drawing and text (Photo 2). After two hours of brainstorming, each team was asked to identify three designs that they would like to prototype. The teams identified the materials required to create the prototypes and these were submitted to the DEHO staff for collection from local suppliers.

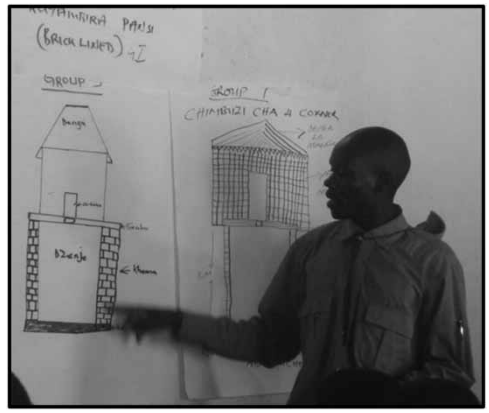

Photo 1 | User describes the components of existing brick-lined pit latrines.

Stage 3: Prototyping

Day 2 was dedicated to the process of creating small and medium-sized prototypes. Local building materials were

Photo 2 | Design team visualise their designs.

provided to allow each team to explore and create their design directions (Photo 3). Users were encouraged to share and discuss their ideas with people from outside their nominated team.

Stage 4: Feedback

The first half of day 3 allowed the design teams to estimate the material and labour costs of their prototypes.

During the final afternoon on day 3, teams presented their designs to 12–15 local villagers including both men and women. The villagers were invited to review the prototypes and provide feedback (Photo 4). The feedback sessions were intended to allow the design teams to hear critiques from potential users.

Study sites

Three study sites were chosen to represent areas located along the lakeshore of Malawi with both clay and sandy soil profiles. The sites were located in Salima, Mangochi and Nkhata Bay districts. The design sessions were conducted at the group village level. In Malawi, a group village commonly consists of three to four villages.

Group villages were purposefully selected using the following criteria: (i) consisting of more than three villages or greater than 300 households; (ii) not more than 90 minutes drive from a central market; (iii) representative of a typical soil type within the district; (iv) a suitable location to conduct building and construction of prototypes; and (v) a group village leader or senior health worker with a proven record in supporting innovative social programmes.

Photo 3 | Design team creates a small-scale prototype of corbelled pit lining.

Photo 4 | Villagers inspect a prototype in Salima district.

Participant selection

The participatory design engaged with two groups, 'researcher-designers' and 'users'. *Researcher–designers* included environmental health officers (EHO) and their support staff. The EHO and their support staff were engaged in formative market research prior to the design sessions (Cole *et al.* 2012). *Users* included builders, masons and householders. Users were purposefully selected from the group villages. Five builders/masons were invited to attend from each village (total of 20 representatives). The selection criteria were: (i) proven reputation as a builder, carpenter or mason; (ii) constructed a latrine in the last 12 months; and (iii) a permanent resident of their village. Two representatives of households were invited from each village (up to eight representatives). Householder representatives were individuals that had acted as natural leaders during previous CLTS events, village health workers or people with a proven interest in sanitation.

Data collection and analysis

The study applied a qualitative multiple-case study methodology (Baxter & Jack 2008). The first author conducted overt participant-observation at one design session held in each of the three study sites. Qualitative data was collected using triangulated sources that included the first author's descriptive and reflective field notes, participants' drawings and text, and recorded interviews with participants. The interviews were conducted during the design sessions with builders/masons, householders and government staff. The

unstructured interviews were conducted through an interpreter speaking in Chichewa. The interpreter had five years experience and a university diploma in teaching. The local interpreter was trained for two days prior to conducting the design sessions. The training developed a rapport between the first author and interpreter and was used to clarify the methodology, interview process and terminology (Pitchforth & Teijlingen 2005; Squires 2009). The lead author and interpreter identified potential biases and addressed these through the process of 'bracketing' described by Ahern (1999). The interviews were recorded and replayed to inform the first author's descriptive field notes. Key statements from the transcripts were transcribed.

Additional data was collated through photographs of prototypes and a report prepared by a structural engineer. The field notes, transcripts, photographs and reports were analysed using qualitative content analysis to identify and prioritise key themes and outcomes across the three case studies (Sandelowski 2010). The themes reported in this paper were selected for inclusion based on the interpretation of the first author.

Limitations

The design sessions were conducted in three of the 28 districts of Malawi. In each district, three traditional authorities were identified of which three group villages participated in the design sessions. Up to 35 participants attended each workshop, with a total of 104 participants attending the three sessions. The findings from the three case studies must be interpreted in the context of their geographical scope. The designs identified are specific to their place of origin. It is likely that design sessions held in different geographical locations and with different participants would result in design ideas reflecting the different needs, resources and challenges of different locations and social contexts.

Participant observation brings both advantages and challenges to the rigour of a study. Advantages include the ability of the researcher 'to be open, discovery oriented and inductive and less reliant on preconceptions' (Boyd 2009). Criticisms of participant observation include the risk of selective memory, encoding and attention, which bias the focus and recording of information by the participant observer. These criticisms were addressed in this study by recording notes during and immediately after each design session, through reflective bracketing (Ahern 1999) and through re-listening to interviews to elaborate the first author's field notes.

The selection of participants is a central determinant of the outcomes of PAR (David 2002). This study identified participants through identifying selection criteria with district-level government staff. Local health workers and village leaders applied the criteria to select the participants. It is possible that participants were selected based on their position within the community or through personal connections with village health workers or village leaders. This may have biased the selection against the inclusion of users from marginalised and lower income groups.

RESULTS AND DISCUSSION

Confirming language and knowledge between users and researcher–designers

An important goal of participatory design is the creation of a common language between users and researcher–designers (Spinuzzi 2005; Steen 2011). The initial exploration of work (Stage 1) provided a strong platform for users and researcher-designers to develop a common vocabulary for sanitation-related terminology.

> 'We can learn from the language of the builders. It helps us to speak with their words. Researcher–designer, Nkhata Bay'

The three main types of sanitation technologies identified during the design sessions were categorised as unlined, nkhokwe (woven wooden-, reed- or bamboo-frame that is cylindrical in shape) and brick-lined with cement mortar pit latrines. The advantages and disadvantages of existing sanitation technologies aligned with the findings of market research previously conducted by the researcher–designers (described in Cole *et al*. 2012). The Stage 1 process offered a significant benefit of allowing the two parties to speak confidently and openly about the challenges presented by existing sanitation technologies.

Divergence of attitudes towards hardware subsidy programmes

A significant challenge arose during the discovery process where some users (builders and householders) insisted on the inclusion of cement as a building material for latrine construction. Researcher–designers (government staff) argued that including cement in the latrine design would make it unaffordable for the majority of households. The users argued that Government should provide the cement through a subsidy programme. This created debate amongst the group on the role of Government in the provision of hardware subsidies in sanitation programmes. Two main themes emerged from the users' perception of cement. The first was that cement is an essential component of a strong and modern latrine, and the second was that subsidy programmes for cement can be successful if managed appropriately.

> 'Cement is progress, why would we want to use wood? Wood is a primitive way for latrines. Cement is a part of progress. User, Nkhata Bay'

> 'The other (cement) subsidy programmes were not well managed, we can manage them better. The fertiliser subsidy is working, why can't we do the same for cement? User, Nkhata Bay'

Malawi has a long history in the provision of subsidised cement through Government and non-government sanitation programmes (DeGabriele 2009). It is therefore unsurprising that users assumed a hardware subsidy would be provided in future sanitation programmes. To counter this assumption, the researcher–designers stated that subsidies were no longer promoted by National Government policy (as described in the Open Defecation Free by 2015 Strategy [MoAIWD 2011]). Researcher–designers also presented their personal experiences of subsidised programmes that had failed under various forms of management.

> 'You build 10 toilets with a subsidy then go away. You come back in five years and still only 10 toilets have been built in that village. People are waiting for the subsidy to come back. I've seen this too many times. Researcher–Designer, Mangochi'

The dichotomy of views toward the inclusion of cement as a building material created a tension between users and researcher-designers. Participatory design scholars recognise that overcoming disagreement in design objectives is an important process that must be mediated (Nieusma 2004). To overcome this tension, the first author recommended that the group recognise the important characteristics of cement while creating designs that reduce or eliminate its use.

> 'I have heard that you like the cement slab because it is strong and durable, they like it because the children can use it and are not scared and because termites cannot eat it and it is easy to clean … but now I want to ask you, can we keep these five things, these five characteristics, but push the price down to allow households the capacity to buy a latrine on their own? First author, Nkhata Bay'

The instruction not to include cement in the building materials encouraged the design teams to explore latrine designs that did not rely on a cement slab. The instruction resulted in design teams exploring numerous design options that replicated the attributes of a cement slab (that is, strength, water- and termite-resistance) while keeping material costs affordable. The resulting design options included metal frames, wrapping of logs with plastic, widening of the roof structure accompanied with surface water diversion channels and self-supporting brick-domes. Users and researcher–designers identified the self-supporting brick-dome as a potentially viable design that offered the same attributes of a cement slab at a significantly reduced cost (as discussed further below).

Consistent design themes identified for clay soils

The design sessions in Mangochi and Nkhata Bay identified a consistent design direction for environments with clay soils. The design overlaid burnt bricks to form a self-supporting brick-dome to create the floor and slab of the pit latrine (Figure 1). Corbelling is an established building practice for pit latrines. It overlaps one brick over another to reduce the diameter of the pit (Government of Zimbabwe n.d.).

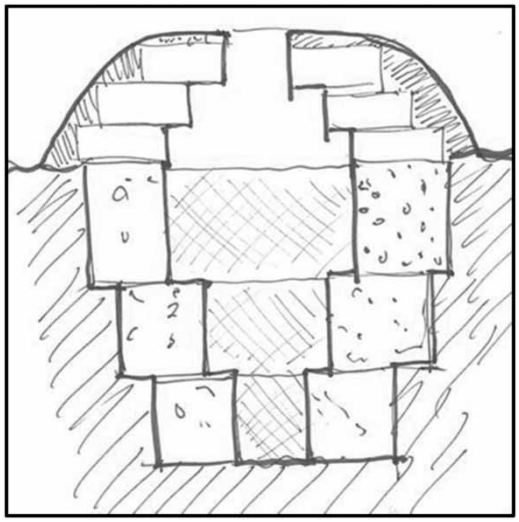

Figure 1 | Diagram of corbelled pit lining, flooring and slab.

Existing designs (such as the Blair VIP Latrine) apply corbelling to reduce the size of the cement slab. In contrast, the design that emanated from the design sessions in both Mangochi and Nkhata Bay used corbelled bricks to form the slab (Photo 5). Users stated the benefits of brick corbelling was that it eliminated the need for: (a) wood, which is commonly attacked by termites resulting in an unstable floor; and (b) cement, which is unavailable in local markets and is prohibitively expensive for the majority of households. All participants identified burnt bricks as widely available in clay soil environments. The construction of burnt bricks requires the collection of local clay, a wooden frame to shape the brick and wood and other plant-based fuels to fire the bricks.

The identification of the corbelled design provided evidence of the participatory methodology drawing out the tacit knowledge of users. Users reported the corbelled design was inspired from building technologies observed both within and beyond their local villages.

> 'I saw this approach in Nhkota Kota. It is used there but I hadn't used it before to build a latrine. I just thought we could try it and then other people in my group said 'yes, that is a good idea'. User, Nkhata Bay'

> 'This approach is very common in the areas around the lakeshore in Mangochi. We have been using this approach for many years. User, Mangochi'

Lead users created innovative designs

The Mangochi and Salima design sessions were conducted in areas that had previously been exposed to sanitation programmes. In Mangochi, sanitation suppliers from one group village had been exposed to innovative sanitation technologies through a Swiss-funded subsidy-based programme (Photo 6).

In Salima, a CLTS programme had been conducted two years prior to the design session. The CLTS programme had encouraged sanitation suppliers to develop innovative sanitation designs. Using the terminology of human-centred design, these suppliers were recognised at lead-users. The lead-users identified the challenges of existing sanitation designs and offered immediate solutions. One solution combined the widely used nhkokwe but wrapped the frame in plastic and then reinforced it with sandbags (Photo 7). The sand-bags were constructed by cutting and re-sewing locally

Photo 5 | Bricks and mud mortar are used to form the pit opening.

Photo 6 | Masons use trapezium shaped bricks to form a circular pit lining.

Photo 7 | Nkhokwe (wooden frame) wrapped in plastic with additional sand-bag reinforcement.

available maize bags. This innovative design shows how engaging villagers who have been exposed to CLTS triggering events brings lead-users to the design team who are able to use their previous experiences to enhance the participatory design outcomes.

Responding to criticism

The feedback sessions were intended to allow design teams to 'present solutions with a neutral tone, highlighting both pros and cons of a solution' (IDEO 2009: 80). During the feedback sessions users found it difficult to engage in an open and honest exchange of ideas, criticisms and feedback. The ability to 'design on the fly' is a challenging task and the majority of users found the feedback process both challenging and confronting. The researcher–designers recorded the villagers' feedback so that it could be fed into future iterations of the prototypes. The feedback sessions did create tension between the users and researcher-designers. Users were reluctant to respond to criticisms while researcher–designers embraced the feedback. Future design sessions could overcome this tension by providing additional time (up to one week) for villagers to provide feedback to the design team. This would allow the design team to hear the feedback in an informal setting without being pressured by time.

Reflections on power, ownership and participation

Recognising the inherent power of the researcher–designer and the ability to exert that power is an important reflective element of participatory design (Steen 2011). During the design sessions the first author instructed the design teams to minimise the amount of cement used in the designs. This decision was taken to increase the affordability and accessibility of the designs. This decision challenged a number of users who were unwilling to move away from the concept of the Government providing a hardware subsidy for cement. It is clear that the inherent power of the first author (as a foreign researcher) played a part in directing the boundaries of the participatory design process. While it could be argued the use of this inherent power may contradict the principles of a genuine participatory process, it is important to recognise the necessity for establishing specific design criteria and boundaries when applying participatory approaches.

The question of ownership of the designs is a vexed question that was not discussed during the design sessions. It could be argued the intellectual property of the designs should retain with the original designer or design team. Indeed, in Western cultures new ideas are regarded as the property of individuals or corporations. However this sits in contrast to numerous African cultures where ideas and knowledge 'are 'owned' by ancestors or the land' (Winschiers-Theophilus *et al.* 2012). The issue of ownership is further complicated as some designs, including the brick corbelled design, were created at multiple design sessions. It could also be argued the potential value of a new design to improve public health outweighed the rights of the individual's intellectual property. The issue of ownership deserves further attention in follow-up sessions with the users.

Participatory design is an iterative process that requires continual participation, actual use of prototypes and sustained reflection (Spinuzzi 2005; Brereton & Burr 2008). The methodology described in this paper offers only a preliminary glimpse into the potential tacit knowledge of villagers and builders to design appropriate sanitation technologies. The programme has been designed to continue engagement with the users through returning to discuss, redesign and test the revisions and iterations suggested by the National ODF Taskforce and the structural engineer's report. It is hoped that continuing the prototyping process will allow users to 'critically reflect on the implication of the research results for their own work' (Spinuzzi 2005).

CONCLUSIONS

Be prepared to discuss and debate the issue of hardware subsidies with users

The research found that encouraging an open discussion on the role of hardware subsidies provided a forum for dialogue between the users and researcher–designers. Although not all members of the two groups reached consensus, the process created a space for dialogue. The dialogue should aim 'not to convince each other of the rightness of one's opinion or to merge individual pre-factored ideas, but rather aims to jointly create something new by talking' (Winschiers-Theophilus *et al.* 2012:168).

Develop specific design criteria in a small team that are familiar with the findings of the formative market research

Clear and specific design criteria, framed in human terms, is an essential ingredient of successful and productive design processes (IDEO 2009). This research developed the design criteria in a small team that was engaged in the collation and analysis of the formative market research. Developing the criteria in small, well-informed teams ensured the design sessions were suited to the specific environmental, socio-economic and market conditions of the three study sites.

Identify and engage with lead users and innovators in the local sanitation sector

Engagement with leading thinkers and innovators is an established approach in the field of human-centred design (Steen 2011). Members of the design team that had been previously exposed to CLTS programmes were found to drive the innovation process within their team and the wider group.

Participatory design methodology can be integrated into CLTS and sanitation marketing programmes

The participatory design methodology aligns with the philosophical and methodological approach applied in both CLTS and sanitation marketing programmes. At the philosophical level, the use of participatory approaches in designing sanitation technologies naturally aligns to the historical development of CLTS from participatory rural appraisal and PAR. At the methodological level, participatory design sessions allow the community to innovate and produce local sanitation products and services (Kar & Chambers 2008).

The sessions also align with the development of an integrated sanitation marketing programme. Sanitation marketing programmes have evolved from the discipline of social marketing. Key characteristics of social marketing are its consumer orientation and the exchange process (Donovan 2011). By engaging users in the design process, the participatory sessions increase the likelihood the final product will align with both the needs and preferences of the end-user/consumer. The participatory sessions also establish relationships with existing sanitation suppliers and may encourage them to exchange a broader range of sanitation products and services.

The case studies do not suggest that participatory design is a 'silver bullet' in identifying sanitation products and services for sanitation marketing programmes. Indeed sanitation products and services designed without participatory methodologies have demonstrated rapid uptake in Vietnam (Sijbesma *et al.* 2010). For these case studies, the use of participatory design was chosen after extensive market research and supply chain analysis (described in Cole *et al.* 2012). The formative research identified the majority of rural consumers had limited access to cash and water, combined with poor transport infrastructure and limited distribution channels for prefabricated sanitation products (such as plastic- and cement-slabs and ceramic pans). In the future, however, market conditions may change and the introduction of a range of prefabricated sanitation products may become favourable. This may require engaging local shop owners to provide distribution and sales points for the prefabricated products. Widening the availability, price-range and attributes of sanitation products may increase the size of the target audience and hence the coverage of improved sanitation across rural Malawi.

Technical review is vital prior to the commercial release of new sanitation technology

The structural engineer report provided vital input into the iterative development of the original prototypes. The

report provided recommendations on the safety and durability of the designs and offered suggestions for locally managed trials to test improvements and certain aspects of the designs. Failure to include this stage could result in unsafe designs being released into the market.

The engineer's report will be used to test and refine the designs at Mzuzu University's SMART Centre. Testing will include mortar strength rating, load testing and standardisation of designs. Throughout the second-half of 2013 the new round of designs will be presented to the design teams in two group villages in each district. The new designs will be presented with drawings and images that identify any changes or additions to the original design. This will allow users and researcher–designers to understand the strengths and limitations of their original designs and offer an opportunity for them to provide ongoing feedback and input into the design process.

Need to provide focus on hand washing facilities

The design sessions missed the opportunity to engage participants on the design of hand washing facilities. Future sessions should include hand washing facilities as an essential component of the latrine design.

Overall, the participatory design methodology was engaging and highly productive. Users and researcher–designers displayed high levels of engagement throughout the three-day design sessions. The participatory design methodology, supported with ongoing technical feedback, offers a potential mechanism to create safe, affordable and desirable sanitation technologies that match a range of local conditions.

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