REINVENTING THE TOILET
ACADEMIC RESEARCH MEETS DESIGN PRACTICE IN THE PURSUIT OF AN EFFECTIVE SANITATION SOLUTION FOR ALL

Mr. Karl Hurn / Dr Diane Gyi / Mr. Paul Mackereth
Loughborough Design School, Loughborough University, United Kingdom
k.m.hurn@lboro.ac.uk / d.e.gyi@lboro.ac.uk / P.Mackereth@lboro.ac.uk

1. INTRODUCTION

It is estimated that 2.5 billion people lack access to effective sanitation around the world (WHO, UNICEF, 2013) and that around 700,000 children die every year from diarrhoea caused by unsafe water and poor sanitation (Water Aid, 2013). Ban Ki-Moon, UN Secretary General stated that adequate sanitation is crucial for poverty reduction and sustainable development. Further to this, as part of its 8 Millennium Development Goals, the UN aims to halve by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation (UN, 2013).

The Bill & Melinda Gates Foundation's Water, Sanitation & Hygiene program focuses on developing innovative approaches and technologies that can lead to radical and sustainable improvements in sanitation in the developing world (Gates Foundation, 2014). In 2011 they initiated the 'Reinvent the Toilet Challenge' to fund and support the development of sustainable sanitation solutions that can be implemented worldwide for people that don't have access to safe, affordable sanitation.

Grants were awarded to sixteen researchers from around the world that were developing innovative engineering approaches for the safe and sustainable management of human waste. Loughborough University's Water, Engineering and Development Centre (WEDC), within the School of Civil and Building Engineering were developing a Hydrothermal Carbonisation Reactor (HCR) that would provide the capability to convert human waste into char, a safe, valuable material that could have many applications such as being used as a fuel, for fertiliser and even as a possible building material.

As the project progressed, the University and the team believed a holistic approach to the redesign of the toilet was needed in order to create a solution that not only processed the human waste effectively, but also focused on the needs of the users. To implement this, a multidisciplinary team was created from WEDC and Loughborough Design School (LDS). LDS has expertise in Industrial Design, Ergonomics and Sustainable Design and was therefore tasked with conducting research to help make the toilet environmentally friendly, user-friendly, accessible and socially acceptable. The team welcomed the exciting opportunity to investigate a fresh approach to an invention that revolutionised the world but hasn't been changed since the 18th Century (Nimmo, 2012).

2. RESEARCH METHODS

2.1. PHASE 1: USER RESEARCH

Phase 1 of the project involved research to develop a detailed understanding of how the new hydrothermal carbonisation process could potentially affect sanitation behaviors' in users. Recognising that users are important stakeholders in design where relationships with products are formed (Gyi, Sims, *et al*, 2013), the role of Loughborough Design School was initially to facilitate thinking about the diversity in people by ensuring user engagement.

Workshops were conducted with a multidisciplinary team of experts in design, ergonomics, materials science, chemical engineering and water and waste management systems that provided a series of documented guidelines that would help define the process going forward.

Alongside this, in-depth interviews were conducted with expert personnel from charitable organisations and support agencies. Their backgrounds included engineering (civil, mechanical) as well as social sciences and disability needs. Experts had between 6 and 39 years of experience of working in the area of sanitation in developing countries. The specific countries that they had worked in (and lived in, in two cases) included South Africa, Uganda, Cambodia, Bangladesh, Ethiopia, Niger, Nigeria, Ghana, Burkina Faso, and Malawi (Gyi, 2012). The expert personal provided useful insights allowing the team to understand the context of implementing new technologies in developing countries.

Focus groups and user engagement trials with primary users and secondary users were then conducted which provided valuable insights into the opportunities and pitfalls for designing an effective solution for both primary users who would be using the toilet, and secondary users who would be involved in their cleaning and maintenance. A purposive sampling strategy was used to increase the range of data and to maximise the identification of key themes for primary users.

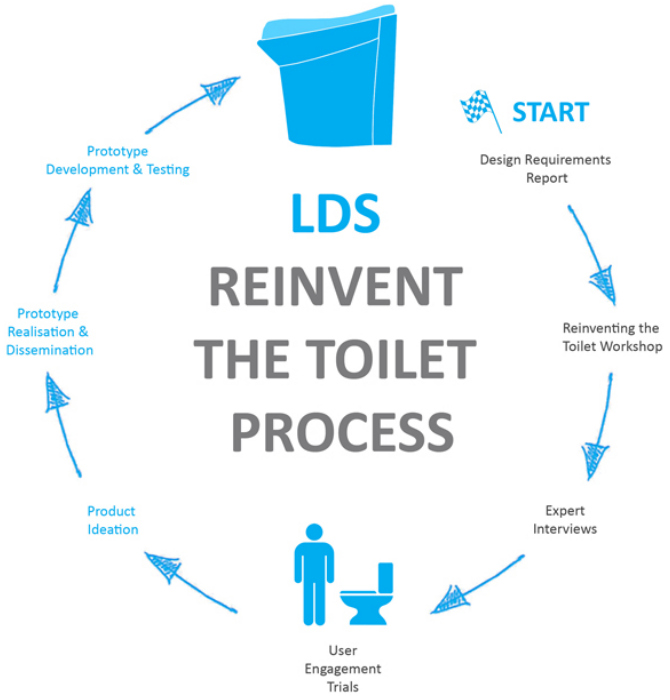

Figure 1. Process undertaken from initial research to prototype realisation.

2.2. PHASE 2: DESIGN RESEARCH

Following the initial expert interviews and user insights at phase 1, phase 2 of the project required product focused design research to enable the realisation of a design specification that would provide an adaptable and inclusive solution, using sustainable materials and manufacturing options.

For phase 2, the project team was grown to include a full time Research Associate. A Research Associates role would normally focus on the gathering and analysis of data with a view to supporting publishing in academic journals. However, for this project a graduate of the Industrial Design undergraduate programme with 2 years' experience in industry was employed as the project sought to realise a toilet design to work with the hydrothermal carbonisation process being developed by WEDC. The industrial design focus was to improve the toilet experience and add value by ensuring aesthetic qualities that are desirable and intuitive as well as functional.

Initial design research to aid ideation centred on ‘context mapping’ with prospective users allowing them to express their experiences in a playful way and at the same time become more aware of their experiences (Van Boeijen, 2014). Cultural diversity was flagged early on as both a challenge and an opportunity therefore it was fortunate that for this phase Loughborough Design School is blessed with both staff and students from a wide range of countries and cultural backgrounds, including target areas such as South America, China, Africa and India.

Existing product solutions both for affluent Western markets and competitor products from charities, aid agencies and research Universities were analysed to identify strengths and weaknesses. This product analysis helped to establish a range of both qualitative and quantitative criteria, including functional requirements and more subjective performance levels (Milton & Rodgers, 2013).

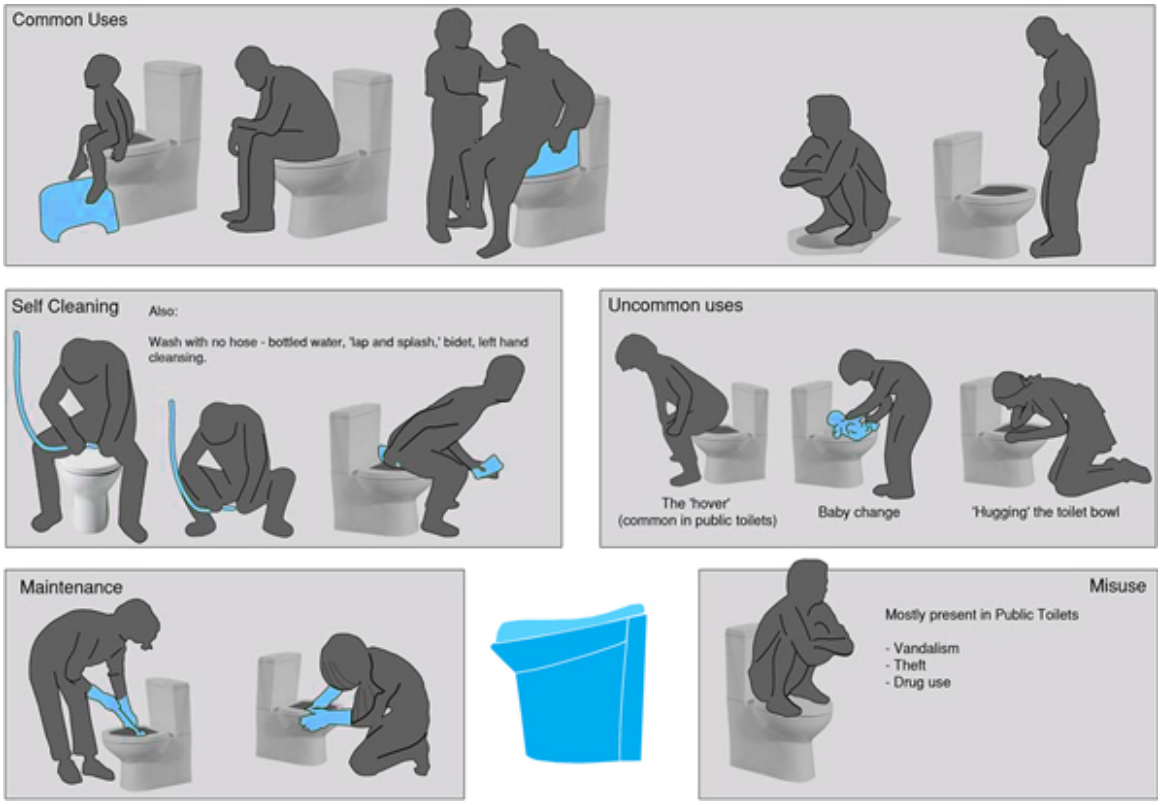

Figure 2. Diversity of use in existing Western toilets

The Indian subcontinent was identified by the Gates Foundation as one of the key areas of the world that could benefit from a reinvented toilet. Therefore a design research field trip was organised with the help of the aid agency Saath to Ahmedabad, India to conduct interviews, workshops and ethnographical research with users and manufacturers in a range of socioeconomic communities.

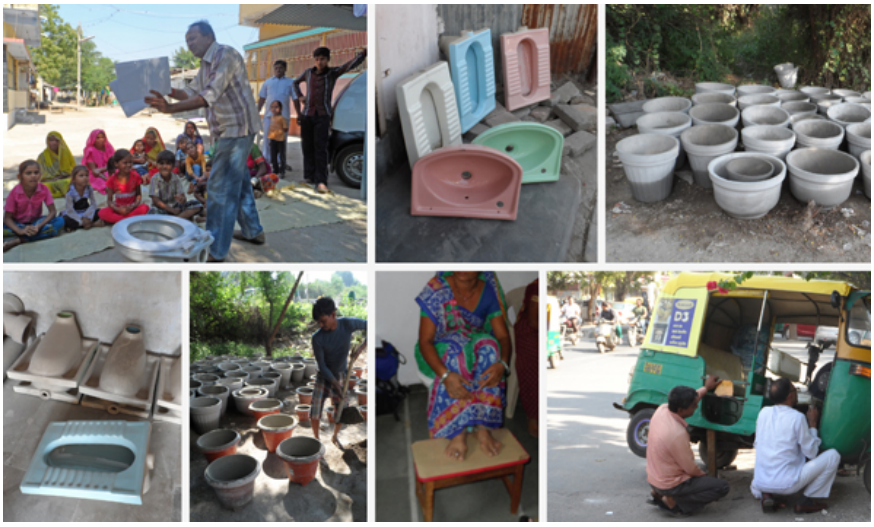

Figure 3. Design research in India provided cultural, behavioral, economic, material and manufacturing insights

The team visited different areas of Ahmedabad (affluent, slum, rural) and discussed sanitation behaviours with primary users, who were shown initial concepts ideas for them to comment on and discuss in groups. Delhi public toilet providers and toilet retailers were also interviewed to gain insights into local cultural preferences and habits. Visiting the slum areas in Ahmedabad and remote rural areas allowed the researcher to experience the different contexts of toilet use. Established design research methods such as those sighted by Milton and Rodgers were used to build a detailed picture and therefore understanding of the users encountered, drawing on everything from users personal belongings, scenarios and persona mapping.

The Saath aid agencies involvement was a key factor as it facilitated access to a broad spectrum of users (including parents and the elderly). This allowed the team to be exposed to not only cultural and economic diversity, but also physical and cognitive diversity that could feed more considered inclusive solutions.

Following the field trip, the informed ideation process continued through an iterative design approach which produced a range of sketched concepts that were used in focus groups for purposive sampling with a small group of users (UK and non UK) with diverse needs and backgrounds.

Observational studies were also conducted with research students and fellow designers in the design school to try to understand not only what appealed to them, but also what they would intuitively understand and want to use (Hurn, 2007). This was achieved using conceptual blue foam sketch models (Evans, 2010) for explorative idea generation (Hallgrimsson, 2012) to investigate and optimise sit, semi-squat and squat positions as well as seat and pan design.

Figure 4. Iterative design development process using sketch development prototypes

Concurrently during the product ideation cycle, technology and manufacturing research was undertaken through consultation with prototyping consultants, materials technologists and manufacturing industry and through visits to trade and design fairs such as 100% Design in London. This led to valuable insights that informed material and manufacturing process selection with a view to allowing the design to be flexible enough to be produced anywhere at a price point that was sustainable for the developing world.

3. RESULTS

Drawing together all of the data gathered from the 2 phases of the research, the team could see that there were plenty of clearly definable user and product requirements. These could be worked up into a fairly robust design specification that could then be taken forward and used during the design development phase.

3.1 RESEARCH RESULTS

The user focused research showed that any design that was to be effectively deployed and maintained in developing countries must be adaptable and flexible. A number of different users, young, old, able bodied and disabled would be encountered during its use, and this would also include sitters, squatters, hoverers, washers and wipers, all of whom should be catered for. The design also had to work effectively in a range of different applications, from single households to community toilets, and even, as specified in the brief from the Gates Foundation, from low end markets all the way up to a possible high end application.

Privacy and safety, especially for females was highlighted in feedback from prospective users, as this is also a major concern in developing countries. This aligned with concerns that secondary users, those who would clean and maintain the toilets had with regards to the robustness of any proposed design solution, as vandalism, both accidental such as putting the wrong things down the toilet, or malicious damage would need to be reduced or eradicated if possible through innovative design. A possible vehicle for this would be to encourage ownership of the toilets through positive social and cultural manipulation, such as encouraging customisation and personalisation as part of a core feature of any design proposal.

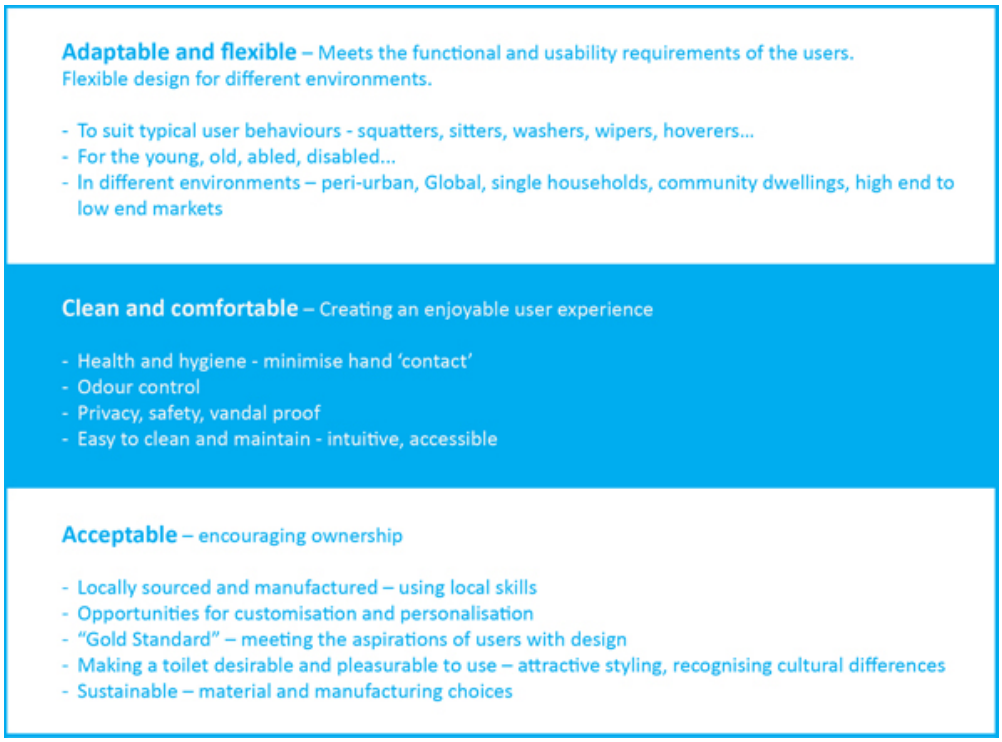

Table 1. Benchmarks for design specification from phase 1 research

Both phases of the research found, using different research methods that the product should be designed with local manufacture in mind as this could be beneficial on a number of counts, from sustainability and cost, through to ownership, maintenance and repair.

A key finding from the visit to India for the team in phase 2 of the research helped settle a long running debate regarding the divide between sit type toilets in developed countries, and squat type toilets in some developing countries. It was found that, contrary to some popular beliefs in the West, a notable proportion of users (certainly in a domestic context) in Ahmedabad at least aspire to own a sit type toilet, despite the documented health benefits of squat toilets. This discovery gave the team confidence in the option for a product along the route of a hybrid solution (as part of the product range).

From a manufacturing perspective, the team had been considering different materials for the toilet before the India field trip, favoring the scalable characteristics of the concrete for low end cost effective applications through to fashionable high end applications in Western bathrooms. During the visit to India, the team was taken to a roadside piece of wasteland where local men were making concrete plant pots by mixing up the concrete in cheap plastic plant pots. This encouraged the team that concrete as a manufacturing material would work well with less skilled workers using cheap moulds to manufacture the toilet design locally.

The knowledge gained from the user research at phase 1 and the design research at phase 2 became the key points of the design specification that drove the design development and prototype manufacture that followed.

3.2 DESIGN OUTCOMES

The final design outcomes that were produced for the Reinvent the Toilet Fair showcased a number of innovations in terms of their concrete construction. Not only was the concrete found to easily offer a range of scalable appearances straight from the mould, such as raw finish, dying and a high end polished finish. An innovative solution in the moulding process which involved casting the toilet bases upside down allowed the tool to be filled to four different levels at different angles, providing a squat height, semi-squat (hybrid), a full height toilet and even a urinal from the same mould. Cost effectively allowing the design to cross cultural boundaries and work effectively with a range of physical abilities.

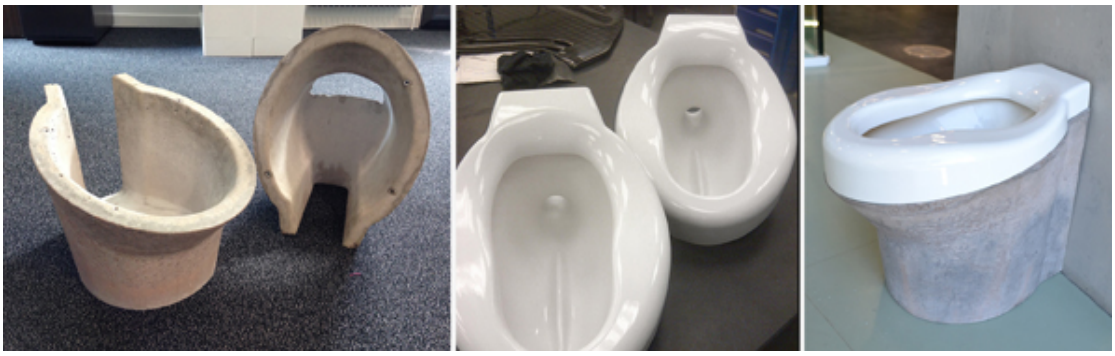

Figure 5. Final design provides full height, semi-squat & urinal design from one mould. Two piece GRP bowl/urinal & seat provide reduced shipping footprint

Further to this, poorly moulded or damaged toilet bases were also found to be easily repairable using plastic strands to keep the form in any instances where the base would crack. Then allowing repair with fresh concrete, an obvious advantage over expensive and non-repairable porcelain. The mould tool design for the bases was kept as simple as possible so that it could be replicated easily by roadside semi skills pot makers such as those encountered in India or sold to them by charitable organisations at cost.

The two piece glass reinforced plastic (GRP) moulding for the seat and bowl design is cheap and simple to produce, with no undercuts or complex inserts. These again could be made locally or the components could be scaled up to be injection moulded and produced in larger volumes, perhaps at a main hub in a large city. But with the main concrete bases still produced locally, these small and light seat and bowl components have a considerably smaller shipping footprint than standard toilets.

Ergonomic improvements to the seat include a larger, flatter surface area and large radiuses for gentler skin contact and easy cleaning. Also, the seat has, in side profile, a concave contour to encourage a slight squat type position to aid evacuation.

As an aside from the main developments, bio char, the waste material from the combustion process within the hydrothermal combustion reactor, was mixed with a casting resin as a bulking material. This waste material from the process aims to be safe to use for irrigation and as a fuel for cooking, but as industrial designers the team were curious to see if they could make a toilet from it and complete the cycle, and they found that they could.

4. DISSEMINATION

The final toilet prototypes were exhibited at the Reinvent the Toilet Fair in Delhi, India in March 2014 alongside the hydrothermal carbonisation process they have been developed to work with. The holistic solution was well received and design development is ongoing with a view to moving to field testing later this year.

Figure 6. Reinvent the Toilet Fair in Delhi, India. Where the final design prototypes were presented to the Gates Foundation, industry and the public in March 2014

5. CONCLUSIONS

In response to the user, manufacturing and process needs outlined in the initial brief from the Gates Foundation and in the findings of the research conducted, the user centred reinvented toilet proposal looks to have answered most of the key problems facing primary and secondary users in developing countries. Not only this, but it also effectively addresses external factors that arise from poor infrastructure and limitations that can be imposed on solutions due to cost and cultural boundaries.

Arguably, issues such as vandalism have been addressed through the use of repairable concrete, but there is still scope for improvement in terms of safety for female users, but this will need to be addressed in the wider context of cubical/enclosed space/environment design. It is clear that studio based design development can only take the project so far, and there are still several challenges ahead for the toilet design and process as it moves forward into field testing in China in late 2014.

Extensive user testing in the field will no doubt highlight issues that still need to be addressed, as well as possible flaws in the initial design. The challenge will be to tackle these but still maintain the research led, user centred aspects that make the design suitable for deployment in the developing world and that have brought the project this far.

ACKNOWLEDGEMENT

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