UNDERSTANDING CO-PRODUCTION THROUGH SANITATION INTERVENTION CASE STUDIES IN SOUTH AFRICA

By

LORRAINE AMOLLO AMBOLE
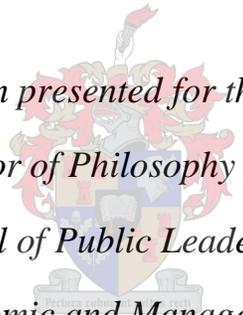
Dissertation presented for the degree of

Doctor of Philosophy in the

School of Public Leadership,

Faculty of Economic and Management Sciences at

Stellenbosch University

Supervisor: Prof. Mark Swilling (SU)

Co-supervisor: Prof. Mugendi K. M'Rithaa (CPUT)

March 2016

DECLARATION

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

March 2016

ABSTRACT

I argue that informal urban sanitation is a complex problem that is best understood through a transdisciplinary (TD) approach. This is because the TD approach provides a multi-dimensional methodology for tackling complex problems. A multi-dimensional methodology is however challenging and therefore requires facilitation. Design as a generative discipline offers facilitatory approaches that can be useful for TD methodology.

To unpack this argument, I studied three cases of sanitation interventions in South Africa. The sanitation interventions were carried out in three informal settlements in the Western Cape province of South Africa, between 2012 and 2014. A brief snap-shot study of two of the cases and a prolonged ethnographic study of the third case provided in-depth insights of how a diverse group of actors engaged in real-world situations. I collected varied forms of data from the cases and organised them through a social constructivist lens.

The arguments and findings of the dissertation are presented in three journal-type (unpublished) articles, which correspond to the research questions of the dissertation. Diverse literature sources were used to locate two intersecting themes, namely informal urban sanitation and knowledge co-production. These two themes support the findings in the three journal articles.

The first journal article articulates an integrative socio-technological approach for informal urban sanitation. This is informed by the cross-case synthesis of the technical configurations of the piloted systems in the three case studies, vis-à-vis the social interactions between the stakeholders who enabled the implementation of the sanitation interventions. The emergent model of socio-technological reciprocity has three interfaces: interfaces between technology components, interfaces between people and technology, and interfaces between users and providers. The model is theoretically significant for planning informal urban sanitation exercises. The article concludes by embedding the empirical findings in the broader sanitation discourse in South Africa.

The second article unveils the challenges of carrying out TD research in an informal settlement context by unpacking the inter-relationships between researchers, experts and co-researchers in the Enkanini case. A critical discourse analysis of interactions in the group brings to the fore asymmetries, which I

use to systematise themes for knowledge co-production. The themes are useful guides for future field work in TD settings. The findings of the article build on the methodological base of TD research.

In the third article I explore the facilitatory role of design in TD research by providing an auto-ethnographic account of my participation as a researcher-designer in the Enkanini case. In this way, I articulate design ethnography as a method that can facilitate relationships amongst social actors in the TD process of solving informal urban sanitation. The article concludes by proposing design ethnography as a method that can overcome some of the challenges of carrying out TD research in under-served contexts.

The main conclusion of the dissertation relates the findings from the journal articles to broader theories of change in answer to the need for transformative knowledge in TD research. Conceptual models for knowledge co-production in the context of incremental urbanism are proposed to open up avenues for further research.

OPSOMMING

Ek redeneer dat informele stedelike sanitasie 'n ingewikkelde probleem is wat die beste aan die hand van 'n transdissiplinêre (TD) benadering verstaan kan word. Die rede is dat die TD-benadering 'n multidimensionele metodologie bied om ingewikkelde probleme aan te pak. 'n Multidimensionele metodologie bied egter bepaalde uitdagings en moet daarom gefasiliteer word. Ontwerp as 'n generatiewe dissipline bied fasiliterende benaderings wat nuttig by 'n TD-metodologie gebruik kan word.

Ten einde hierdie argument duidelik te kan uiteensit, het ek drie gevalle van sanitasie-intervensies in Suid-Afrika ondersoek. Die sanitasie-intervensies is tussen 2012 en 2014 in drie informele nedersettings in die Wes-Kaap-provinsie van Suid-Afrika gedoen. 'n Kort momentopname van twee van die gevalle en 'n langdurige etnografiese studie van die derde geval het diepte-insigte gebied rakende die wyse waarop 'n diverse groep rolspelers in werklike situasies betrokke is. Ek het verskillende soorte data uit die gevalle versamel en hulle aan die hand van 'n sosiaal-konstruktivistiese lens georganiseer.

Die argumente en bevindings van die proefskrif word in 'n drietal vaktydskrif-tipe (ongepubliseerde) artikels aangebied, wat met die navorsingsvrae van die proefskrif ooreenstem. Verskillende literatuurbronne is gebruik om twee kruisende temas, naamlik informele sanitasie en medekennisskepping, te bepaal. Hierdie twee temas ondersteun die bevindings in die drie vaktydskrifartikels.

Die eerste vaktydskrifartikel verwoord 'n integrerende sosiaal-tegnologiese benadering tot informele stedelike sanitasie. Dit word toegelig deur die kruisgevallesintese rakende die tegniese konfigurasies van die loodsstelsels in die drie gevallestudies, vis-à-vis die sosiale interaksies tussen die belangegroepe wat die implementering van die sanitasie-intervensies in werking gestel het. Die sosiotegnologiese resprositeitmodel wat daaruit voortvloei bevat drie raakvlakke: raakvlakke tussen tegnologiekomponente; raakvlakke tussen mense en tegnologie; en raakvlakke tussen gebruikers en verskaffers. Die model is teoreties van belang vir die beplanning van informele stedelike sanitasie-oefeninge. Die artikel sluit af met die plasing van die empiriese bevindings binne die breër sanitasiediskoers in Suid-Afrika.

Die tweede artikel onthul die uitdagings om TD navorsing in 'n informele nedersetting uit te voer deur die onderlinge verbande tussen navorsers, kundiges en medenavorsers in die Enkanini-geval uiteen te sit. 'n Kritiese diskoersanalise van die interaksies in die groep bring 'n asimmetrie na vore, wat ek gebruik om temas vir medekennisskepping te sistematiseer. Hierdie temas is nuttige wegwysers vir toekomstige veldwerk in TD omgewings. Die bevindings van die artikel bou voort op die metodologiese basis van die TD navorsing.

In die derde artikel ondersoek ek die fasiliterende rol van ontwerp in TD navorsing aan die hand van 'n outo-etnografiese weergawe van my deelname as 'n navorser-ontwerper in die Enkanini-geval. Daarvolgens doen ek aan die hand dat ontwerpetnografie as 'n metode gebruik word om verhoudings tussen maatskaplike rolspelers in die TD proses te fasiliteer terwyl die ondersoekproses na informele stedelike sanitasie aan die gang is. Die artikel kom tot die slotsom dat ontwerpetnografie gebruik kan word as 'n metode om die uitdagings wat die uitvoer van TD navorsing in kontekste van ondervoorsiening bied, te oorkom.

In die belangrikste gevolgtrekking van die proefskrif word die bevindings uit die vaktydskrifartikels met wyer teorieë oor verandering in verband gebring, in antwoord op die behoefte aan transformatiewe kennis in TD navorsing. Konseptuele modelle vir medekennisskepping in die konteks van inkrementele verstedeliking word voorgestel ten einde verdere navorsingsmoontlikhede te verken.

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AbM	Abahlali Basemjondolo
ANC	African National Congress
ANT	Actor Network Theory
BMGF	Bill and Melinda Gates Foundation
BOP	Base of the Pyramid
CA	Conversation Analysis
CDA	Critical Discourse Analysis
CLTS	Community Let Total Sanitation
COHRE	Centre for Housing Rights and Evictions
CORC	Community Organisation Resource Centre
CSIR	Council for Scientific and Industrial Research
DOS	Design Oriented Scenarios
DST	Department of Science and Technology
DWS	Department of Water and Sanitation
ERC	Enkanini Research Centre
ERCA	Enkanini Research Centre Association
ESC	Enkanini Sanitation Co-operative
HCD	Human-Centred Design
ISUG	Informal Settlement Upgrading Group
JMP	Joint Monitoring Programme (WHO/UNICEF)
MDG	Millennium Development Goal
MNC	Multi National Co-operation
NRF	National Research Fund
O&M	Operation and Maintenance
OD	Open Defecation

ODF	Open Defecation Free
OPP-RTI	Orangi Pilot Project Research and Training Institute
PD	Participatory Design
PFT	Portable Flush Toilets
RDP	Reconstruction and Development Programme
SAHRC	South African Human Rights Commission
SDG	Sustainable Development Goal
SI	Social Innovation
SU	Stellenbosch University
TD	Transdisciplinary
UD	Universal Design
UN	United Nations
UNICEF	United Nations Children's Fund
VIP	Ventilated Improved Pit (Latrine)
WHO	World Health Organisation
WRC	Water Research Commission
WSP	Water and Sanitation Programme (World Bank)

CHAPTER ONE

1.0   INTRODUCTION TO THE DISSERTATION

1.1 Background of the study

1.1.1 Global Environmental Changes and Responses

The world today is faced with an acceleration of environmental, economic and social changes that have become a cause for concern. These accelerated changes have resulted in global problems, which manifest themselves as a conglomerate of problems, calling for sophisticated solutions and extensive problem-solving processes (Brundiers, Wiek & Redman, 2010; Swilling, 2012A). Examples of such extensive problem-solving processes have been instituted through global initiatives that are aimed at tackling the complexity of global environmental changes (GECs). *'Future Earth'* is one of the latest of such initiatives that combines existing global efforts into a ten year international research programme. This combined effort provides a global research platform that supports the co-design and co-production of relevant knowledge through partnerships between science and society (Future Earth, 2015).

Such partnerships can enable the path towards sustainable development at the global, regional and local levels. Figure 1.1 shows how such a path can be crafted by global, regional and local partners, who integrate their knowledge by developing a common vision. The success of *Future Earth* is therefore firmly based on the active collaboration between nations, disciplines, programmes, researchers and stakeholders to ensure that knowledge is generated in partnership with the very users of science. The overarching research questions of such partnerships are further articulated through deliberative dialogues amongst researchers and other stakeholders who embrace the concept of the new 'social contract' between science and society (ibid).
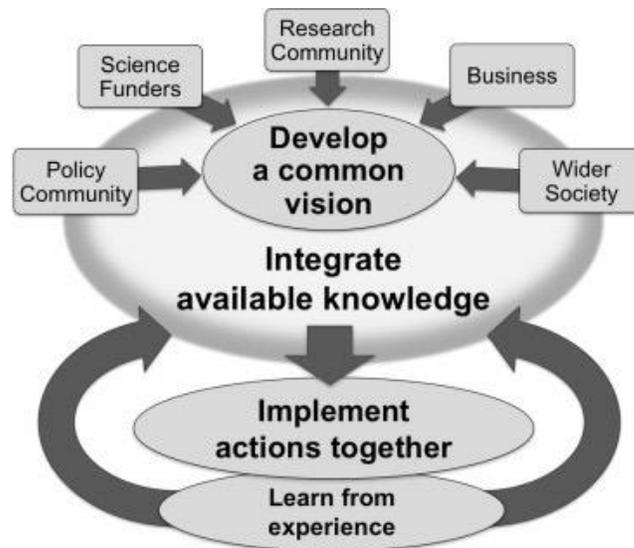
Figure 1.1 Future Earth's co-design and co-production model (Source: Future Earth 2015)

1.1.2 Global Environmental Change Effects in Sub-Saharan Africa: Accelerated Urbanism and Informality

A social contract between science and society is expressly needed in the Global South region, where populations are most vulnerable to the acceleration of global changes (Maathai, 2009; Parnell & Walawege, 2011; Stern, 2007). Sub-Saharan Africa in particular is facing a combination of economic and ecological challenges, but unlike all the other continents, Africa is confronting these challenges without the advantage of a sufficiently well-developed knowledge infrastructure to drive innovations that would withstand the complexity of a global 'polycrisis' (Swilling, 2010).

If more relevant knowledge infrastructures are to be developed, then it is necessary to consider how the *Future Earth's* global agenda for co-design and co-production translates within different contexts, such the expanding urban areas of Sub-Saharan Africa. To understand how co-production and co-design would be carried out within an African urban context, it is necessary to engage with local realities such as informal urban patterns, with their attendant opportunities and inadequacies (Obeng-Odoom, 2014; Pieterse 2013; Swilling, 2012B; Watson, 2014).

Informal urban patterns are not unique to Africa. China has the highest absolute number of people living in its slums, which is around 37% of its urban population. India has the second highest number, which accounts for 55% of the urban population; while Brazil has 36% of its population in slums. What stands out in Africa is the shear percentage of urban dwellers in slums. In the State of the World's

cities' report (2012/2013), the UN-Habitat reported that 61% of the urban population in Sub-Saharan Africa lives in slums. This is the highest percentage in the developing regions of the world (UN-Habitat, 2013). In looking at specific countries, the report shows that South Africa has the lowest percentage of urban slum dwellers in Sub-Saharan Africa at 23%. Other countries in Sub-Saharan Africa have much higher percentages of urban slum dwellers: Kenya has 54%, Nigeria has 62% and Tanzania has 63%. The highest percentage is that of the Central African Republic which stands at 95% of the urban population.

In general, urban dwellers in informal settlements have to contend with complex challenges around housing cost, tenure security, service provision, safety and proximity to job opportunities. UN-Habitat (2004) defines a slum household as a household in an urban area that lacks one or more of the following:

> *'Durable housing of a permanent nature that protects against extreme climate conditions; Sufficient living space which means not more than three people sharing the same room; Easy access to safe water in sufficient amounts at an affordable price; Access to adequate sanitation in the form of a private or public toilet shared by a reasonable number of people; Security of tenure that prevents forced evictions.'*

These five deprivations may be experienced in different degrees. For instance, the fifth deprivation of tenure insecurity is what is used to distinguish between formal and informal categories in slum housing by Davis (2006). However, in South Africa slums are generally referred to as informal settlements and tenure insecurity is a common problem in such settlements (Groenewald, Huchzermeyer, Kornienko, Tredoux, Rubin & Raposo 2013).

The UN-Habitat (2013) attributes the growth of slums globally to unbalanced development and policies that have turned cities into places of deprivation and inequality. In Sub-Saharan Africa, the rapid growth of slums is attributed to several factors including poor urban planning: Many African governments have inadequate planning systems, planning laws and building standards. They also have heavily bureaucratic systems and a shortage of qualified expertise in urban planning. Additionally, there is often a clash between Western urban perspectives with local cultures (Silva, 2012). The slum upgrading programmes initiated by the UN-Habitat in African cities are examples of Western urban perspectives that are incongruent with local cultures in African cities. Such programmes promote

neoliberal perspectives of improving slums through 'financialisation' (Jones, 2012). As such, there is an urgent need to develop public actions in the field of urban planning and urban governance, which are consistent with the local realities in slums (Silva, 2012).

Another factor that has contributed to the growth of informal settlements in Africa is the widespread European colonisation of Africa (Silva, 2013). According to Fox (2014), colonial era investments and institutions in Sub-Saharan Africa have resulted in a disjointed type of modernisation that has produced urban slums. Looking further at the correlation between colonisation and slums in Africa, Njoh (2015) argues that countries that were colonised more intensely have fewer incidences of slums. These contrary views are reminiscent of the contradictory trajectories of development that have produced slums alongside skyscrapers in African cities.

By way of example, Kenya is one of the countries that gained its independence from British rule over half a century ago. Today, the country has very high incidences of slums, concentrated mainly in the capital city of Nairobi. As such, there is a significant amount of research on Kenyan slums that look at slum upgrading, livelihoods in slums, health and security threats among other challenges (Archambault, de Laat & Zulu, 2012; Greif, 2012; Gulyani & Talukdar, 2010; Harris, 2014; Huchzermeyer, 2008; Kabiru, Beguy, Ndugwa, Zulu, & Jessor, 2012; Muhula, Memiah, Sibhatu, Ndirangu & Kyomuhangi, 2015; Oti, Van de Vijver & Kyobutungi, 2014). There is additional research on Sub-Saharan Africa that confirms informality as a dominant paradigm of city making in the region (Gulyani, Bassett & Talukdar, 2014; Pieterse, 2010; Roy, Lees, Palavalli, Pfeffer & Sloot, 2014; Swahn, Braunstein & Kasirye, 2014; Turok, 2013).

Informality thus remains a paradox that invites both admiration and criticism because of its complexity. Indeed, informality may be used erroneously to describe several distinct urban phenomena (Perry, Maloney, Arias, Fajnzylber, Mason & Saavedra, 2007). As pointed out by Guevara (2014), policy makers, practitioners and researchers hold dissimilar and even conflicting views on how to deal with informality. Guevara articulates several conceptualisations of informality to systematise the variety of understandings. These are: semi-informality, squatting informality and hybrid informality. In each of these concepts, there is an aspiration towards formality.

Its contradictions notwithstanding, informality is a useful heuristic model that has been employed in various disciplines. In urban design, Owen, Dovey and Raharjo (2013) have developed a design course that prepares urban designers to deal with the growing reality of informal urban settlements. This is

based on their detailed fieldwork to explore ways in which informal settlement formation can be taught in design studios through the use of games. These games simulate the incremental practices of 'room-by-room accretion', which is a method of transformation used by slum dwellers. The pedagogical goals of such a course are to blur the traditional distinctions between the expert and the slum dweller. In other words, the slum dweller can also be viewed as an expert of their own reality. In the same vein, Zappulla, Suau and Fikfak (2014) speak of slums as 'dynamic laboratories for urban pattern making' in which certain conceptualisations of slum making can be identified by analysing several slums from around the world. From the analysis, terms such as 'randomized' and 'transformative patterns of spatial activation in slums' emerge (ibid).

In geography, a socio-spatial perspective has also been used to understand informal urbanism: Vasudevan (2014) discusses the geography of squatting and identifies the complexity and provisionality of informal urbanism: In its provisionality, informal urbanism is a makeshift approach to inhabiting the city. The squatters are therefore 'urban combats' who activate an alternative form of urbanism that is precarious as it is shaped by the immediate need for survival, and is often characterised by violent dispossession (ibid).

These descriptions of squatters or slum dwellers as active agents of a new form of urbanism can however be interpreted as the romanticisation of the slum. Dovey and King (2012) discuss this fascination with informal urbanism and the 'aestheticisation' of poverty that lead to trends such as *slum tourism*. This aestheticisation of slums inadvertently promotes the status quo in slums for the pleasure of the rich, who associate deprivation with nostalgia for primal living and raw ingenuity. There is therefore need for a balanced view of slums as places requiring urgent interventions to improve quality of life, as well as places where opportunities can be harnessed.

The ingenuity and innovation in slums is often a response to economic competition and spatial contestation. As such, emerging cities may in fact depend on the existence of cheap labour from slums, since slums are the entry points to the city for the poor. In urban India for example, slums are an eyesore but they also serve as a reminder to the elite that the rural poor are desperate enough to leave their rural homes and inhabit city slums (Aiyar, 2014). In this way, the visibility of slums can be a motivation for action since the elite are more often than not the holders of power. Unfortunately, the elite in government frequently respond through confrontational methods of dealing with informality in Asian and African cities, and they therefore fail to acknowledge the economic value that the urban poor bring to the city (ibid).

In Tokyo, Japan, an appreciation for informality helped rebuild the city after the devastation of World War II: The residents of Tokyo rebuilt their city by themselves, while the government only provided the infrastructure. As such, Tokyo is a conglomeration of 'villages' that are a living tribute to the self-help urban processes of slum living (Echanove & Srivastava, 2014). The lesson here is that unplanned urban growth needs to be acknowledged and negotiated rather than denied or eradicated. South African urban strategists and policy makers can learn to explore urban informality in this way, and employ technological innovation to manage informality, while moving away from a static, single-track trajectory of urban formality (Huchzermeyer, 2014A). In situ development of slums is motivated by this constructive framing of informality.

In urban development, slum urbanism is thus an alternative agenda that has to be included in any future city planning in Africa alongside other large-scale urban development programmes (Grant, 2014). A dual approach that incorporates both non-formal and formal perspectives is a productive and sustainable way forward, which will promote new urban mega-projects while focusing special attention on the needs of the urban poor. In this way, slum urbanism will celebrate 'African self-help urbanisation' which is largely composed of informal development (ibid). In emphasis, Pieterse (2011A) calls for a '[…] rethinking of African urbanism from the slum'. Such a reorientation will offer vital clues about alternative urban organisation and urban governance. Nevertheless, the strict dichotomy between formal and non-formal should be handled with care as it may fail to capture the diversity in African cities. It is thus necessary to acknowledge a wide range of other heterogeneous concepts that fall in-between the formal and the non-formal conceptualisation of the urban space (Jaglin, 2014).

1.1.3 Slums (Informal Settlements) in South Africa

The shift in terminology from 'squatter settlement to 'informal settlement' in South Africa was facilitated by the *Urban Foundation* in the 1990s (Groenewald et al., 2013; Hunter & Posel, 2012). Prior to that, South Africa's informal settlements had a long history dating back to the Apartheid era. In the 1940s, the Apartheid government instigated the bulldozing of urban informal settlements which were mainly inhabited by black Africans looking for work in the city. With the eradication of informal settlements, the black population was to be restricted to formal townships or to rural areas. Blacks were viewed as 'temporary sojourners' in cities (Weiss, 2014). Other communities such as Coloureds and Indians, were also evicted from their homes in order to create buffer zones, separating Whites from

6

other ethnic groups (Greyling, 2013). In effect, the South African Apartheid city was a modern urban existence for a few and a 'refugee camp' for the majority (Simone, 2006: 243).

With the onset of the post-Apartheid dispensation in 1994, the democratically elected African National Congress (ANC) government promised to deliver formal housing to the disadvantaged through the *Reconstruction and Development Programme* (RDP). Given the Apartheid history, RDP housing is to this day, seen as a symbol of social transformation in South Africa (Hunter & Posel, 2012).

By 2007, the ANC government wanted to institute a new approach that would allow it to eliminate and prevent the re-emergence of informal settlements in urban areas. This move was seen as a return to the draconian measures of the Apartheid government. The legality of this approach was therefore challenged in court by Abahlali baseMjondolo (AbM), which is a well-known shack dwellers movement from Durban (ibid). Nonetheless, the post-Apartheid government has conducted 2 million evictions of informal settlement dwellers, which is reminiscent of the 3.5 million evictions by the Apartheid government (Greyling, 2013).

The ANC government has misinterpreted the Millennium Development Goal (MDG) of achieving 'slum-free cities' as a mandate to eradicate informal settlements. The eradication of informal settlements has been carried out through forced evictions that destroy livelihoods and social networks. Consequently, the result is an inadvertent increase in poverty rather than a decrease (Huchzermeyer, 2014B). Informal settlements therefore remain as highly contested spaces in the post-Apartheid South Africa despite the fact that the new constitution protects all South Africans from arbitrary evictions. In other words, addressing spatial inequalities and promoting integrated urban communities in South Africa remains an unfinished business even in the post-Apartheid era (Skuse & Cousins, 2007; Strauss & Liebenberg, 2014).

Informal settlement dwellers nevertheless find opportunities for maximising the shared value of the informal urban spaces that they inhabit. In this sense, informal urban dwellers in South African cities are city-builders in their own respect. They do this for instance by self-organising and engaging in economic activities such as running: 'spaza' (tuck) shops, vegetable and fruit markets, kitchenettes, salons, taverns, shoe repairs business and crèches (Mpe & Ogra, 2014). Informal settlement dwellers also engage in political urban processes, which need to be recognised as such. More often than not, political action emerging from informal settlements is frequently presented as being outside the

political domain (Pithouse, 2014). The successes of political agency emerging from informal settlements are exemplified in the political mobilisation activities of the AbM movement (Chance, 2012).

Informal settlements in South Africa also offer opportunities for informal settlement dwellers to earn a living in the city, mostly as casual labourers. It therefore follows that informal settlement dwellers are resistant to being relocated to areas further away from economic opportunities, as is the case when they are relocated to RDP houses far away from thriving economic hubs. The need to maintain these socio-economic opportunities is a justification for the upgrading of slums in situ, rather than through relocations (Hunter & Posel, 2012).

Aside from the opportunities, informal settlements in South Africa have disadvantages that cannot be ignored. Informal settlements sometimes turn into 'battlefields' from which urban protests emerge in cities (Jürgens, Donaldson, Rule & Bähr, 2013). More specifically, 'militant local political protests' have become frequent occurrences in informal settlements and townships across South Africa since the mid-2000s (Dawson, 2014). Xenophobia is one of the most alarming occurrences during such protests. Xenophobic attacks were most prevalent in 2008, resulting in the death of 60 foreigners and the displacement of over 100, 000 others (Hickel, 2014). Other disadvantages of living in informal settlements in South Africa are: poor health outcomes (Shortt & Hammett, 2013), frequent floods and fires (Baptist & Bolnick, 2012; Ziervogel, Waddell, Smit & Taylor, 2014), parental anxiety (Meth, 2013) and segregation (Dik, 2014).

A better understanding of the hybrid logic of informality is therefore necessary if these disadvantages are to be tackled and the opportunities harnessed (Oldfield & Parnell, 2014; Parnell & Robinson, 2012; Roy, 2014). This dissertation ostensibly contributes to a better understanding of a hybrid logic of informality, by using three sanitation intervention case studies in South Africa, in which inadequacies as well as opportunities are unveiled. One of those inadequacies is in the area of sanitation provision. Analysing the complexities of sanitation provision in the case studies helps to articulate a hybrid logic for informality.

1.1.4 Inadequate Sanitation: A Global Challenge

Sub-Saharan Africa and Southern Asia are the worst affected regions it terms of sanitation (Figure 1.2). A majority of Sub-Saharan countries have less than 50% of the population using improved sanitation

(WHO/UNICEF, 2014). Yet sanitation is often ignored by politicians and thus dominated by top-down approaches and standardised technologies that are incongruent to the unique needs of marginalised and under-served groups such as informal settlement dwellers (Movik & Mehta, 2009).
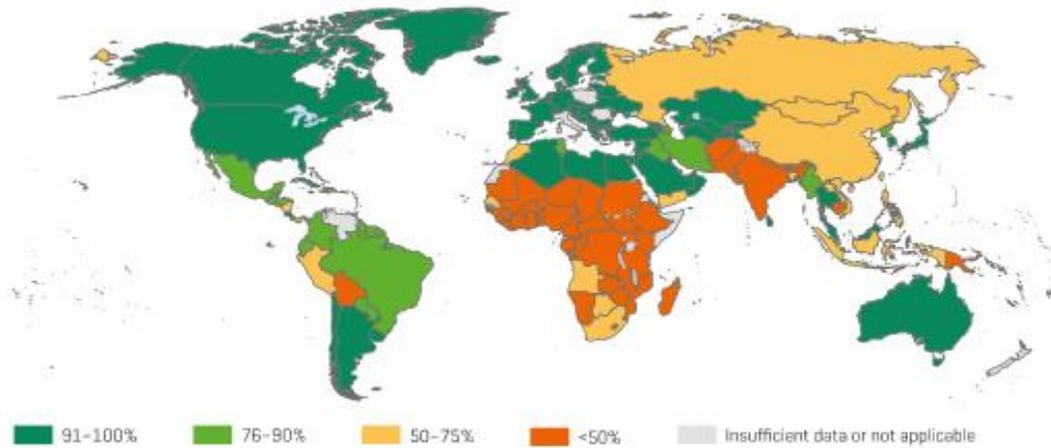
Figure 1.2 Global sanitation coverage (Source: WHO/UNICEF, 2014)

Globally, the agenda on sanitation is to 'halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation' (UN 2015). However, projections show that if current trends continue, this Millennium Development Goal (MDG) target will not be met (WHO/UNICEF, 2014). The projected statistics show that the percentage of those with improved sanitation globally in 2015 will only get to 67% as opposed to the 75% goal of the MDG target on sanitation as shown in figure 1.3 (UNICEF, 2003).
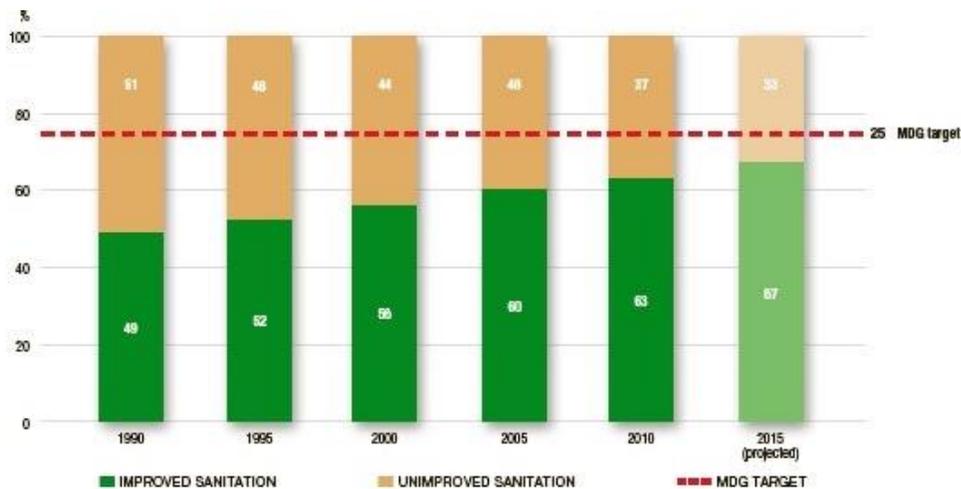
Figure 1.3 Trends in global sanitation coverage 1990-2011, projected to 2015 (Source: UNICEF, 2003)

Beyond 2015 and the MDGs, the United Nations is working on new global goals known as the Sustainable Development Goals (SDG). The 6th SDG goal is to 'ensure availability and sustainable management of water and sanitation for all'. One of the targets of the 6th SDG goal to be attained by 2030, is to '[…] achieve access to adequate and equitable sanitation and hygiene for all, and end open defecation (OD), while paying special attention to the needs of women and girls and those in vulnerable situations'. Within the same time frame, another target is to '[…] expand international cooperation and capacity-building support to developing countries in water and sanitation related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies'. A third target is to support the participation of local communities in improving water and sanitation management (Sustainable Development Knowledge Platform, 2015).

The SDG goals are thus more ambitious that MDGs as they incorporate a more vigorous co-productionist agenda of including community members in searching for solutions to water and sanitation problems. The move from MDGs to SDGs is an acknowledgement that sanitation is one of the global issues that present enduring challenges, which will take time to resolve. The SDG on water and sanitation further acknowledges the need to support developing countries which are the least industrialised economies that constitute a majority of countries in Sub-Saharan Africa.

One fundamental question that is yet to be answered however is what is meant by 'improved sanitation' when it comes to sanitation provision in informal areas. The WHO/UNICEF joint monitoring programme for water supply and sanitation defines an improved sanitation facility as '…one that hygienically separates human excreta from human contact.' Further, such facilities should not be shared for them to be considered improved (WHO/UNICEF 2008). This is because shared facilities are often over-crowded and compromise on privacy, safety and cleanliness (COHRE, WATERAID, SDC & UN-HABITAT, 2008; Tumwebaze, Niwagaba, Günther & Mosler, 2014). Nevertheless, there is research carried out in urban slums in Kampala that shows that some shared facilities, of not more than four households, can be considered acceptable or improved (Günther, Niwagaba, Lüthi, Horst, Mosler & Tumwebaze, 2012). Shared facilities can therefore be made acceptable if a set of minimum standards is met. These standards relate to aspects of ownership, management, location and finance, which can be configured to achieve the minimum acceptable standards (Mazeau, Reed, Sansom & Scott, 2013).

The technology used also determines whether a sanitation facility is improved or not. According to WHO/UNICEF (2008), the technologies that are considered improved are: a flush toilet, a pour-flush toilet, piped sewerage, a septic tank, a *ventilated improved pit* (VIP) latrine – a pit latrine with a slab and a composting toilet. Unimproved facilities are pit latrines with no slabs, hanging toilets and open defecation. The categorisation of sanitation as improved or unimproved is however unhelpful in certain instances because it does not solve the sanitation problems of those who are extremely poor. This is because the poor have unique needs and circumstances that may require further attention beyond technical categorisations of improved facilities (Satterthwaite, Mitlin & Bartlett, 2015).

1.1.4.1 Research and Innovation in Sanitation

To meet the challenge of sanitation provision, research on sanitation has been carried out in a variety of ways around the world. Some studies are highly technical in their approach: researchers in Indonesia have looked at the material and value flow analysis for sustainable design of sanitation systems (Ushijima, Irie, Sintawardani, Triastuti, Hamidah, Ishikawa & Funamizu, 2013). Others have looked at the fate of sanitation-related nutrients in shallow sandy aquifers below urban slum areas in Africa (Nyenje, Havik, Foppen, Muwanga & Kulabako, 2014). Engineers have also developed tools to evaluate the long-term operational costs of sanitation systems in slums in Nairobi (Holderness, Kennedy-Walker, Alderson & Evans, 2013). In Kampala, researchers have looked at the emptying, transportation and disposal of faecal sludge in informal settlements (Murungi & van Dijk, 2014).

In literature, one of the most comprehensive discussions on sanitation technologies is compiled in a compendium by the Swiss Federal Institute of Aquatic Science and Technology (Eawag) written by Tilley, Ulrich, Lüthi, Reymond and Zurbrügg (2014). The compendium discusses both current and emerging technologies in sanitation, ranging from conventional, large scale technologies to innovative, small-scale solutions. The most significant contribution of the compendium is that it transforms a highly technical discourse into accessible language while remaining rigorous and comprehensive. The compendium provides clear descriptions of technical terminology along with detailed descriptions of systems components and gives their advantages and disadvantages. Tilley et al. (2014A) argue for a holistic approach to sanitation provision, by insisting that sanitation systems consist of 'context-specific' technologies. They therefore provide a wide range of options by discussing technology combinations to suit diverse circumstances. The advantages and disadvantages of each combination is also provided to assist in decision-making.

In practice, several sanitation innovations have been demonstrated in informal areas. In Pakistan, the Orangi Pilot Project-Research and Training Institute (OPP-RTI) aims is to improve sanitation provision for informal areas in Karachi. In Karachi, 60% of the population of 15 million live in *katchi abadis* or 'unofficial sector'. 72% of these abadis are now recognised by government, a recognition that is attributed to the persistent community advocacy supported by the OPP-RTI. The OPP-RTI manages community processes such as: low cost sanitation, housing, education and training, water supply and women's savings programmes (Hasan, 2006; OPP-RTI, 2012). The OPP-RTI's main approach is to support groups of residents in an informal settlement, to plan, implement and finance the 'internal components' of the sanitation system. These internal components are: latrines inside their houses, simplified underground sewers in the lanes outside their houses and neighbourhood collector sewers. The local governments are in turn supported to finance the larger conventional trunk sewers that transport the waste from lanes to treatment plants. Using this approach, 300 locations in Pakistan have been connected to sewers through community financing and participation (Hasan, 2008).

The condominial approach used in the Orangi project was developed in Brazil during the 1980s as a response to the challenges of servicing ever-expanding informal urban neighbourhoods. Simplified piping has however been successfully applied even in more affluent urban areas and is now considered a generic design for sewerage (Melo, 2005). Central to the design is the interaction between service providers and users. Thus, the 'condominium' is not just a physical unit of service provision; it is also a social unit for facilitating collective decisions and organising communal actions. Members of the condominium are expected to select the appropriate design of the condominial service and commit themselves to participating in activities such as sanitary education, construction and/or maintenance processes (Nance, 2013). The success of the condominial method has spread in South America to other countries such as Peru, where it has been implemented on a large scale (Hubbard, Sarisky, Gelting, Baffigo, Seminario & Centurion, 2011).

Community-Led Total Sanitation (CLTS) is another innovative methodology in sanitation provision in under-served areas as it is used to mobilise local communities to completely eliminate open defecation (OD). Communities are facilitated to conduct their own appraisal and analysis of OD in their areas, and to take their own action to become OD free (ODF). CLTS practitioners acknowledge that the mere provision of a toilet does not guarantee its use, nor result in improved sanitation and hygiene. In contrast to technocratic approaches, CLTS focuses on the behavioural change needed to ensure real and sustainable improvements. Consequently, the main objective of CLTS is to trigger communities to

collectively change their situation, thus empowering people to take action. In this way, CLTS encourages bottom-up innovation, mutual support and localised solutions and sustainability. CLTS was pioneered by Kamal Kar in 2000 in a village in Bangladesh (Kar 2012; Kar & Chambers, 2008). CLTS has now become an action learning methodology because it involves intense community participation. Participation is realised through participatory workshops which are a way of collecting creative experiences that are then fed into a wider network. The workshops go beyond the mere sharing of ideas to the co-generation of knowledge (Chambers, 2012).

In Kenya, onsite treatment systems such as the biocentre model have been piloted in various informal settlements in Nairobi. The biocentres consist of shared toilets that empty into anaerobic digesters that do not require connection to centralised sewers (Umande Trust, 2014). The model is appropriate for dense informal settlements, as it also incorporates other public services such as water, energy and even recreation. Consequently, the model reduces costs for the users, save on space, and forms part of the wider poverty alleviation agenda (ibid).

To tackle sanitation problems at a regional level in Sub-Saharan Africa, UNICEF (2014) recommends that innovation in sanitation technologies in Eastern and Southern Africa should be planned at a regional level. UNICEF envisions 'multi-country innovation hubs' that would be supported by regional trade in sanitation commodities. So far, the report identifies three existing production hubs in South Africa, Kenya and Tanzania. Creating innovation hubs would concentrate skills and technology within a geographical area, which will improve access to finance and competition and provide economies of scale. Such hubs would also take advantage of the ongoing but still nascent innovation capacity in the region (ibid).

The challenges of sanitation in fast urbanising regions in the Global South region have further spurred the interest of innovators worldwide. In this regard, one of the most concerted efforts to improve sanitation through innovation is a global challenge funded by the Bill and Melinda Gates Foundation (BMGF) (Bill and Melinda Gates Foundation, 2014). A BMGF fund to 'reinvent the toilet' was awarded to 16 research teams from around the world. As grantees of the fund, these research teams have so far exhibited some revolutionary technologies that radically move away from the conventional waterborne sanitation system of the industrial age. Some examples are the 'blue diversion toilet' developed by Eawag and the design studio EOOS. This toilet is a 'grid-free' dry diversion toilet with three separate waste streams of faeces, urine and flush water. The technology that separates the waste

13

streams uses a membrane separation and electrochemical treatment. The developers of the technology recommend that the blue diversion toilet can be used in slums (Larsen, Gebauer, Gründl, Künzle, Lüthi, Messmer, Morgenroth, Niwagaba & Ranner, 2014).

Another example of a BMGF funded technology is the 'mini multi product plant' by TU Delft. The core technology in the system is a plasma gasification that transforms human excreta into energy. Beyond the technology, the system is envisioned as a product-service system that can serve the needs of urban slums in Delhi, India (Fuentes, 2012).

Another grantee of the Gates foundation is a multi-disciplinary team from Loughborough University that is composed of researchers from the engineering and design schools. The engineering researchers have developed a 'hydrothermal carbonisation reactor' to convert human excreta into char that can be used a fuel or fertiliser. The design researchers on the other hand have expertise in industrial design, ergonomics and sustainable design. They have therefore focused their attention on users' needs and preferences and have led the field research on user participation (Hurn, 2014). This collaboration between engineers and designers is of interest to this study as it resonates with the integrative approach that is argued for in the articles. A team from University of KwaZulu-Natal, South Africa is another grantee that has developed a community bathroom block that recovers clean water, nutrients, and energy. This system is designed to safely dispose of pollutants and recover materials such as water and carbon dioxide from urine. It also separates the urine from the faeces and extrudes the faeces into thin strands for faster drying and stabilisation (Bill and Melinda Gates Foundation, 2014).

Another beneficiary of BMGF has invented the 'omniprocessor' that turns human waste into drinking water. According to its inventors from Seattle, the omniprocessor is a waste treatment plant that can process sewage for a community of about 100,000 people. Unlike modern sewage plants, the technology combines incineration, steam power and filtration technologies to ensure that no energy is wasted in the process. The processor derives enough energy from the faecal matter as it incinerates to run the unit, with 150kw a day to spare and export to the grid. It also produces ash, which can be used to improve soil (Slavin, 2015).

Overall, the BMGF grantees in the 'reinvent the toilet challenge' have proposed revolutionary technologies that move away from the traditional flush toilet that has changed very little since the 18th century (Hurn, 2014). However, the applicability and sustainability of these revolutionary technologies remains to be tested. For now, inadequate sanitation remains a complex problem, more so in the

context of informal urban settlements that are often the least serviced areas in burgeoning African cities. As these African cities continue to grow, so does the problem of informal urban sanitation. Informal urban sanitation is therefore an area of research that still requires the attention.

1.2 Research Questions and Objectives

Following an interest in *Future Earth's* co-production agenda, I started off my study as an exploration into how knowledge is co-produced within an informal urban sanitation context. The problem of informal urban sanitation presented an opportunity for a problem-focused approach to co-production. Three informal settlements, in which sanitations interventions were being carried out, were identified as worthwhile prospects for such an exploration. The investigation into knowledge co-production was therefore contextualised by the informal sanitation situations of the three settlements. I adopted this case study approach as it would allow for an in-depth understanding of the contextual conditions of knowledge and service co-production within the real-world settings of the sanitation interventions in the three case studies.

Initially, the main research question was: what is the nature and role of knowledge co-production in informal urban sanitation contexts? Guided by this general question, I observed and participated in various capacities in the three sanitation interventions. My observations and activities in the cases were an opportunity to better understand sanitation needs in informal settlements and the complexity of co-producing sanitation systems to meet those needs. My disciplinary background in design further offered a specific theoretical perspective within the transdisciplinary (TD) setting of the research. Subsequently, the initial fieldwork and preliminary review of diverse literatures were used to refine the research questions as follows:

- How are social and technological considerations configured in the sanitation interventions in the three informal settlements?

  Objective: To gain an integrative overview of informal urban sanitation in the sanitation interventions in the three cases

- What are the challenges of co-producing knowledge in an informal settlement context?

  Objective: To reveal the challenges of knowledge co-production and TD research in the sanitation working-group in the Enkanini case

- How can design methods enhance participation in contexts such as informal settlements that have traditionally been under-served by professional design?

  Objective: To articulate the importance and role of design methods for TD research in informal contexts

The objectives of the dissertation are realised in the analyses and arguments of the corresponding journal articles in chapters three, four and five respectively.

1.3 Conceptual Framework

The conceptual framework of this dissertation is guided by its main empirical argument that informal urban sanitation is a complex problem that requires co-production and is thus best understood through a TD approach. This is because transdisciplinarity provides the multi-actor and multi-perspective approach that is required to understand and tackle the complexity of informal urban sanitation. A multi-dimensional approach is however challenging, more so in cases where researchers have to work with marginalised or disempowered groups such as informal settlement dwellers. The theoretical argument of the dissertation answers to this empirical need by proposing that design ethnography can facilitate relationships amongst social actors in the TD process of solving informal urban sanitation.

To unpack this argument, the three case studies of sanitation interventions in informal settlements from South Africa are used to illustrate how service and knowledge co-production was initiated in real-world contexts. The case studies are interpretive because they offer deep insights into the particular problem of informal urban sanitation and knowledge co-production. I used these insights to create integral arguments and explanations about informal urban sanitation in chapter two; TD research and knowledge co-production in chapter three and the expanding role of design in TD research in chapter three. The theory thus provides the interpretive lenses that are used to understand the empirical material (Andrade, 2009; Yin 2011).

The sanitation interventions in the three cases were carried out in three informal settlements in the Western Cape province of South Africa, between 2012 and 2014. A brief snap-shot study of two of the cases and a prolonged ethnographic study of the third case provided the in-depth insights of how a diverse group of actors engaged in collaborative micro-processes in real-world situations. As an observer and participant in the cases, I collected varied forms of data in visual, text and audio formats, and then organised them through memoing, holistic coding and analytical coding (Richards, 2009;

16

Saldaña, 2013). The coding method was informed by my intuitive knowledge of the case studies, which meant that I could manually assign meaning (codes and memos) to images and conversations more holistically rather than piecemeal. I analysed the coded data through cross-case synthesis (Yin, 2009), critical discourse analysis (Fairclough, 2005; Wall, Stahl & Daynes, 2014) auto-ethnography and thematic and narrative analysis (Vaismoradi, Turunen, & Bondas, 2013; Wattsjonson, 2009).

Based on the analysis of data, the arguments and findings of the dissertation are presented in three journal-type (unpublished) articles, which correspond to the research questions and objectives of the dissertation. Diverse literature sources were used to locate two intersecting themes, namely informal urban sanitation and knowledge co-production. These two themes support the findings in the three journal articles. Figure 1.2 summarises the conceptual framework of the dissertation.

Knowledge co-production in sanitation intervention case studies, South Africa			
Case studies	Research questions	Corresponding articles	Literature synthesis
Klein Begin community	How are social and technological considerations configured in the sanitation interventions in the three informal settlements?	Socio-technological reciprocity and innovation in informal urban sanitation	Informal urban sanitation • A multi-dimensional problem • Service co-production with informal settlement dwellers • The South African sanitation situation
Klipheuwel settlement			
Enkanini settlement	What are the challenges of co-producing knowledge in an informal settlement context?	Challenges of TD research in an informal settlement context	Knowledge co-production • Transdisciplinary research: definitions and schools of thought
	How can design methods enhance participation in contexts such as informal settlements that have traditionally been under-served by professional design?	Design facilitation for TD research	• Reflexivity in TD research • Design methods for TD research • The role of researcher-designer

Table 1.1 Conceptual Framework of the Dissertation

1.4 Literature Overview

The synthesised literature reveals that informal urban sanitation is a complex problem that is shaped not just by technological concerns, but also by social, institutional and political concerns. Technological concerns have however been the most prominent considerations in informal urban sanitation, leading to failed sanitation interventions across Sub-Saharan Africa. In light of these failures, social scientists have been more vocal about the relevance of social, institutional and political perspectives in improving informal urban sanitation. These different perspectives are underscored by the concept of service co-production. The concept of service co-production in informal urban sanitation is premised on the argument that the participation of informal settlement dwellers can improve the implementation of sanitation services, given the unique needs of informal settlements. Informal settlement dwellers should therefore be engaged in different phases of the implementation process based on their capacities and resources.

In practice however, participatory processes and user-involvement in informal urban sanitation are hard to realise because they are time consuming and require broad and extensive consultations with stakeholders. This is opposed to expert-led sanitation interventions, in which decision making is quicker and resources can be maximised. The push for participation of users may also thwart individual agency in favour of collective engagement. The benefits of service co-production are nevertheless visible in successful exemplars where alternative solutions were made possible through co-installations, co-management or co-financing with informal settlement dwellers. In this way, innovative technologies that are cheaper than conventional trunk sewerage systems have been successfully piloted in various informal settlements in the Global South region through participatory processes.

The situation of informal urban sanitation in South Africa is then discussed because it forms the specific geographical context of the case studies under investigation. In that discussion, it is revealed that the provision of sanitation in informal urban settlements in South Africa is a highly contentious issue despite the fact that South Africa is one of the few Sub-Saharan countries that was on track to meet the 2015 MDG goal for improving sanitation. The complexity of providing sanitation in informal urban settlements has thus led to calls for greater user involvement and participation in sanitation interventions in South Africa, as in elsewhere in the Global South region.

The push for service co-production is echoed in TD research as non-academic partners are invited to co-produce both knowledge and services that have social relevance. This is because non-academic

partners such as community members or professionals have the experience of or expertise on the social issues at hand. However, power asymmetries abound between partners who engage in TD research as they attempt to transcend disciplinary boundaries and academic confines. Non-academic partners such as informal settlement dwellers may be further disadvantaged because of their limited formal education and resources. To overcome these challenges, reflexivity is necessary to expose positionalities in the co-production process. Acknowledging positionality offers avenues for resolving conflicts or in the very least an opportunity for learning from past conflicts and failures. Exposing positionality requires a critical stance, which is possible through methods such as critical discourse analysis and auto-ethnography.

Creative participatory methods such as the visual techniques used in design can also be meaningfully employed to enhance the contribution of non-academic partners. Further, the generative skills of design that focus on the product can be combined with the analytical skills of research for a more wholesome view of the research problem. The role of the researcher-designer therefore fits in well with the integrative approach of TD research. As researchers who are interested in both the product and the context, researcher-designers can employ design ethnography to understand how technologies (such as sanitation) are socialised within different contexts (such as informal settlements).

Ultimately, the reviewed literature builds the argument that TD research provides a multi-dimensional methodology that is suitable for tackling the complex problem of informal urban sanitation. To facilitate the wide-ranging approach of TD research, the generative skills of design can be employed to enhance TD engagements. Further, the broadening agenda of design as a process of socialising technologies is congruent to the new contract between science and society in TD research, as well as the multi-dimensional view of informal urban sanitation as a technological, social and even political problem. In this dissertation, the technological and the social are the key dimensions that are operationalised in the findings of three journal articles.

1.5 Methodological and Epistemological Stance

The underlying paradigm of this dissertation is social constructivist: technology and knowledge are socially co-constructed by relevant social actors. The realities that these social actors construct are complex and messy problem-solving components that are nevertheless meaningful because they answer to the collective interests of the social group (Bijker & Pinch 2012; Baxter & Jack, 2008). In terms of

technology, the 'Social shaping of technology' (SST) approach expounds on the social constructivist stance of this dissertation: there is a mutual influence between technology and society on technological advancement. As such, technological change is a dynamic process that results from the interaction between research, development and application of technologies. In SST, technology is at once a driver of change, and is also an object being driven by societal actors. In other words, technology and society co-produce each other in a complex and hybrid actor network system (Jørgensen, Jørgensen & Clausen, 2009).

In terms of knowledge, I posit that knowledge is a human product, and is socially and culturally constructed. Individuals create meaning through their interactions with each other and with the environment they live in (Kim 2001). Consequently, in the literature review of this dissertation, a social constructivist stance is an overarching frame for the theoretical arguments as follows: i) in informal urban sanitation, the sanitation problem in informal settlements is framed through an integrative socio-technological view; ii) in TD research, the inclusion of non-academic actors in research processes is in acknowledgment of the need to socially construct knowledge and solutions with other actors outside of academia; iii) in inclusive design and innovation, the user is invited to co-construct products that are relevant to their social situation.

In terms of methodology, a social constructivist stance framed my choice of methods and my critical approach because I accept that there are multiple epistemologies based on context (Angrosino, 2007). The methods used in each of the journal articles are therefore not indifferent or external to the realities of the case studies since they are answerable to the problem under investigation. In this sense, my self-reflexivity also means that the methods are reflexive as I engage in a complex interplay of knowledge production and subjectivity, which have shaped the research process and the findings thereof (Ritchie, Lewis, Nicholls & Ormston, 2013).

The reflexive approach of social constructivism carries through in the analysis of the empirical material. I adopted a critical stance towards the data forms, which led to an interest in the covert meanings of naturally occurring interactions (such as Email communications and *WhatsApp* group messages). These covert meanings may not be visible in researcher-controlled processes such as structured interviews (Angrosino, 2007). Additionally, the visual materials produced by participants in one case study expand the generative space of the research beyond my control as a researcher (Mitchell, 2011). The varied data forms from the case studies were further interpreted through holistic coding and intuitive inquiry, in acknowledgement that I too constructed the outcome of the study

21

findings based on my familiarity and personal understanding of the cases (Muller, 2011; Saldaña, 2013).

As an extension of my active role in co-constructing reality, I adopt an auto-ethnographic approach in the third journal article in order to embed my story within the story of the case studies, thereby rounding off the meta-narrative of the findings. The auto-ethnographic account in the third journal article is an intentional and systematic inquiry of my own practice to reveal knowledge about design practice. It is a commitment to my actual experience as a researcher-designer, which I then use to critique design as a field whose interests are expanding into the transdisciplinary space (Hamilton, Smith & Worthington, 2009).

The sanitation technologies in the cases studies are thus handled are socio-technological artefacts that were co-constructed by people (I included), who created social groups around the problem of sanitation provision in the three cases. In turn, the artefacts shaped the social groups by binding the diverse interests of individual actors into a common goal. That common goal was nevertheless challenged by a broader social context; hence the social groups did not have exclusive control over the socio-technological artefact although they had a decisive role in shaping it. Individual roles within the groups varied and were at times conflicting. The socio-technological artefact therefore influenced actors' roles by giving relevance to the grouping and to individual actors.

In short, a social constructivist view underscores my critical stance as a researcher-designer, who believes that technological innovation is socially constructed and is society shaping. The social is therefore activated in a particular way and is the outcome of interactions within the relevant social groups in the case studies. This social making is unveiled through a reflexive look at socio-technological reciprocity, knowledge co-production and design facilitation in the three journal articles respectively.

1.6 Main Findings

The first journal article articulates an integrative socio-technological approach for understanding informal urban sanitation. This approach is informed by the cross-case synthesis of the technical configurations of the piloted systems in the three settlements, vis-à-vis the social interactions between the stakeholders who enabled the implementation of sanitation interventions. The emerging theme from the synthesis is a multi-dimensional view of informal urban sanitation, in which socio-technological

22

reciprocity and innovation are demonstrated as: technological alternatives for sanitation in informal settlements and service co-production with informal settlement dwellers. From these, I propose a model for socio-technological reciprocity, which has three interfaces between technology components, between people and technology, and between users and providers. The article concludes by providing a way forward for informal urban sanitation in South Africa based on discussions from the 'Gates Sanitation Technology Innovation Seminar' that I attended in Pretoria in October 2014. A variety of stakeholders including government officials, experts and community activists attended the meeting; hence their discussions highlighted the current discourse and future proposals for improving sanitation in South Africa. That discourse provides a meta-narrative for the case study findings and emphasises the theoretical significance of the article. This first article sets the empirical basis of the dissertation.

The second article unveils the challenges of carrying out TD research in an informal settlement context by unpacking the inter-relationships between researchers and co-researchers in the Enkanini case. As an active participant in the Enkanini sanitation working-group, I was able to capture the emergent narrative of the group through focus-group discussions and the naturally-occurring interactions in the group. A critical discourse analysis of the data brings to the fore the conflicts and power asymmetries within the sanitation working group. I therefore use the findings from the analyses to systematise themes for knowledge co-production, while also empirically demonstrating the inadequacies of TD research. The themes are therefore useful guides for future field work in TD settings. The findings of the article build on the methodological base of TD research.

In the third article I explore the facilitatory role of design in TD research by first providing an auto-ethnographic account of my participation as a researcher-designer in the Enkanini case, using my journal entries and field photographs. This auto-ethnographic account unpacks my own participation in Enkanini through a design lens, and embeds my story within the meta-narrative on the Enkanini case from the previous article. In this way, I articulate design ethnography as a method that can facilitate relationships amongst social actors in the TD process of solving informal urban sanitation. I build on this argument by unveiling design aspects in the work of other actors in Enkanini: I thematically analyse participant's drawings and technical designs to unpack the core competencies of design as iteration, prototyping and visualisation. The article concludes by proposing design ethnography as a method that can overcome some of the challenges of carrying out TD research in under-served

contexts. In so doing the article consolidates the role of the researcher-designer as a facilitator in the TD process.

The main conclusion of the dissertation summarises the findings from the three journal articles in relation to the theoretical arguments of the reviewed literature. From this summary, the main theoretical argument is that design ethnography can facilitate relationships in the TD processes of solving informal urban sanitation. The findings from the journal articles are then extrapolated by linking them to broader theories of change in answer to the need for transformative knowledge in TD research. One of the broader theories of change that is discussed is incremental urbanism. The concept of incremental urbanism acknowledges the heterogeneous nature of urbanism in Sub-Saharan Africa; hence it extends beyond the conceptual and contextual limits of informality. Incremental urbanism also offers greater opportunities for TD methodology and transformative innovation with informal settlement dwellers, who are themselves creators of an alternative urban logic. Conceptual models for knowledge co-production in the context of incremental urbanism are then proposed to open up avenues for further research. These conceptual models are logic models (Yin, 2009) that fulfil the need to produce transformation knowledge about sustainable social change to compliment the target and system knowledges in the articles.

1.7 Scope and Limitations

The fieldwork was limited to the three case studies of the sanitation interventions. The three cases were chosen through a snowballing effect, which means that they were not sampled from a population. Rather, convenience logic was used in identifying them as cases where studies could be carried out within a reasonable amount of time given the limited resources. I found out about the cases from other Stellenbosch University (SU) researchers who were already working in the Enkanini case specifically. From the Enkanini case, I got to know about the other two sanitation interventions in Klipheuwel and Klein Begin settlements. The limitation in this convenience selection approach was that the cases were not representative of a population of informal urban settlements in South Africa or even in the Western Cape Province.

The use of convenience logic in case study selection is a drawback that makes it difficult to substantiate or statistically generalise case study findings (Poulis, Poulis & Plakoyiannaki, 2013). Convenience logic is nevertheless an opportunity to turn chance occurrences into research situations in an attempt to

24

capture reality as it unfolds (Fujii, 2014). In my own limited capacity I would not be able to instigate the kind of multi-stakeholder engagements that occurred in the three sanitation interventions, but I was able to take advantage of those engagements and unpack their empirical significance.

The three settlements are also highly varied in their characteristics and so cannot be considered as comparative case studies: Klein Begin community is a semi-informal settlement, which is not densely populated and is only considered informal because it lacks basic services such as sanitation and adequate shelter. This is in accordance to the UN-Habitat (2004) definition of slum housing as a place that lacks one or more of the following: durable housing, sufficient living space, access to water and sanitation, and security of tenure. However, the residents in Klein Begin have security of tenure because they jointly own the land. Enkanini on the other hand, is a densely populated settlement in Stellenbosch town, while Klipheuwel is a sprawling informal settlement on the outskirts of Cape Town City. Enkanini residents should therefore have better job opportunities than Klipheuwel residents.

In both Enkanini and Klipheuwel, residents do not have security of tenure and lack basic services. The common factor in all three cases is that the sanitation interventions were carried out by Maluti GSM engineers with funding from the Water Research commission of South Africa (WRC). In each case, Maluti GSM partnered with different stakeholders. In the Enkanini case, SU researchers, funded by National Research Fund (NRF), were already involved in the settlement so they facilitated the sanitation intervention in that settlement.

To mitigate the limitation of the three cases, a thorough analysis of literature was carried out, with the aim of theoretically triangulating the narrow empirical findings. In qualitative research, triangulation is the search for converging evidence from multiple sources of: data, perspectives, researchers, or methods (Yin, 2009; 2011). Further, in interpretive qualitative research, data triangulation is replaced with 'theoretical sufficiency' which is achieved by using localised empirical material to build on generalised theory (Andrade, 2009). In this regard, it was possible to draw some 'cross-case conclusions' (Yin, 2009:28) from the three cases based on the similarity and differences in the sanitation interventions as shown in Chapter three. Further, an in depth analysis of the Enkanini case was used to foreground theoretical arguments about TD research in Chapter four and about design ethnography in Chapter Five.

This dissertation therefore aims for theoretical triangulation and sufficiency by presenting multiple sources of secondary material from theory to support the empirical evidence of the three cases. The findings of this dissertation are thus theoretically transferable to other situations, in which similar processes can be adopted (Andrade, 2009). The social constructivist paradigm that has informed this dissertation also means that the investigations are not limited to the geographic specificities of the cases. Social elements such the social groups in the cases and their interactions provide better opportunities for theoretical generalisation. A further theorisation from the findings is carried out in the conclusion to enhance the theoretical significance of this study.

1.8 Rationale for the Study

One rationale for using case studies of sanitation interventions in informal settlements stems from the urgent need to improve 'informal urban sanitation' (McFarlane, Desai & Graham, 2014). Informal urban sanitation is particularly challenging in Sub-Saharan Africa as many African states find it hard to provide services in expanding informal urban settlements (Hendriksen, Tukahirwa, Oosterveer & Mol, 2012; Lüthi, McConville & Kvarnström, 2010; Otsuki, Gera & Mungai, 2013). In South Africa, providing adequate sanitation in informal settlements is challenged by social, economic and institutional constraints such as: unemployment, fragile social structures, poor management, and the inappropriate terrain of most informal settlements (Lagardien & Muanda, 2014; Mels, Castellano, Braadbaart, Veenstra, Dijkstra, Meulman, Singels, & Wilsenach, 2009; Pithey, 2007). Further, informal urban sanitation in South Africa is shaped by narratives of power that evoke the apartheid history of the country (Robin: 2014). In the face of these challenges, informal urban sanitation should be tackled collaboratively and with openness to socio-technical diversity (Taing, Pan, Hilligan, Spiegel & Armitage, 2013; Tavener-Smith, 2012; Winter, 2010). The three case studies therefore offer an opportunity to interrogate the complexity of informal urban sanitation by studying collaborative processes as they occur in real-world contexts so as to unveil the opportunities for socio-technical diversity and knowledge co-production.

The second rationale for this study is supported by the increasing social agency of the design field, which allows designers to carry out research outside of the traditional boundaries of design practice. In this regard, designers working with complex social contexts can acquire the hybrid role of 'researcher-designers', so as to combine the analytical strengths of research with the generative skills of design (Sanders & Stapper, 2008). Designers are thus focusing greater attention on social and cultural

problems such as homelessness, insecurity, poor health and aging, among others (Brown, 2014; Brown & Wyatt, 2010; Steen, 2011). In particular, sanitation for un-serviced areas has attracted the attention of industrial design research (Hurn, 2014). Further, the emerging fields of design anthropology and design ethnography propose that a designer can become a provocateur, who questions the intersections between context, user and design (Gunn & Donovan, 2012; Lenskjold, 2011). To understand these intersections, researcher-designers need to engage in collaborate processes that take advantage of diversity, as I have done in the three cases, given my background in product and industrial design.

CHAPTER TWO

2.0   LITERATURE REVIEW

2.1 Introduction

This dissertation has two broad theoretical frames: informal urban sanitation and knowledge co-production. 'Informal urban sanitation' is a concept borrowed from McFarlane, Desai and Graham (2014) and is articulated in this dissertation as a complex problem that has multiple perspectives such as the social, technological and institutional perspectives of improving sanitation in informal areas. The multiplicity of perspectives in informal urban sanitation requires the multi-dimensional approach of TD research as a methodology for service and knowledge co-production. The review of literature is thus synthesised into two main sections in support of the argument that informal urban sanitation is a complex problem that is best tackled through the multi-dimensional methodology of TD research.

The attraction of TD methodology is in its push for socially relevant knowledge that transcends disciplinary boundaries and academic confines (Pohl, 2011; Pohl & Hadorn, 2008). In transcending academic boundaries and confines, TD researchers are nevertheless hard pressed to fulfil their scholarly obligations. One solution would be to form TD teams that promote interdisciplinary exchanges and non-academic participation. In such exchanges, disciplines such as design can provide generative problem-solving skills that enhance participation for under-served users, such as informal settlement dwellers (Stappers & Visser, 2007; Gunn & Donovan, 2012).

The challenging situation of informal settlement dwellers as under-served users is a concept that carries through the review of literature: In informal urban sanitation, the complex challenge of improving sanitation in informal settlements in partnerships with informal settlement dwellers is brought to the fore. In TD research, the challenges of service and knowledge co-production in informal settlements are discussed. In design and innovation literature, the challenge of meeting the needs of under-served users at the bottom of the economic pyramid is discussed. The proposed solutions to these inadequacies and challenges call for a reflexive and critical stance in TD research. Within TD research, design methods can facilitate interrelationships between actors as well as between the social and the technological components of informal urban sanitation.

2.2 Informal Urban Sanitation

Informal urban sanitation is a complex problem, evidenced by the multiplicity of disciplinary perspectives used in studying it, such as development studies, sociology, post-colonial studies, public health, geography and industrial design (McFarlane, Desai & Graham, 2014; Hurn, 2014). The inadequacies of informal urban sanitation are most dire in Sub-Saharan Africa compared to other regions of the world: sanitation coverage in African cities is below 50%, and 25% of the urban population practice open defecation (Otsuki, Gera & Mungai, 2013). Worse still, the urban poor have to pay 10 to 100 times more than the rich to access urban services such as sanitation (UN-Habitat, 2013). Despite the efforts made, little or no progress has been made in improving the urban sanitation situation in Africa between 1990 and 2010 (Okurut, Kulabako; Chenoweth & Charles, 2015).

The main challenge of informal urban sanitation is in Sub-Saharan Africa is in providing large-scale, top-down infrastructures in un-serviced areas (Satterthwaite, Mitlin & Bartlett, 2015). Yet many African states continue to pursue large-scale, supply-driven and heavily top-down sanitation infrastructures in urban planning (Lüthi, McConville & Kvarnström, 2010). As such, many recent studies have been carried out in different parts of Sub-Saharan Africa in the search for alternative solutions to the continent's sanitation challenge (Adubofour, Obiri-Danso & Quansah, 2013; Arku, Angmor, Seddoh, 2013; Bhagwan, Still, Buckley & Foxon, 2008; Bolaane & Ikgopoleng, 2011; Chinyama, Chipato & Mangore, 2012; Musemwa, 2010).

The consequences of inadequate sanitation are severe. People living in poorly serviced areas are at a higher risk of getting infections such as cholera, diarrhoea and other deadly diseases, which jeopardise education, productivity, and the quality of life, in the event that they do not result in death (Bulaya, Mwape, Michelo, Sikasunge, Makungu, Gabriel, Dorny & Phiri, 2015; Hawkins, Blackett & Heymans 2013; Koola & Zwane, 2014).

Persistent cholera epidemics in poorly serviced regions can be dealt with decisively by improving water and sanitation services. The current provision of antibiotics and vaccines is only a stop-gap measure that has failed to eliminate cholera outbreaks (Waldman, Mintz & Papowitz, 2013). The debilitating effects of cholera epidemics are all too evident. One of the largest recent cholera epidemics to affect a single country took place Haiti in 2010 after a devastating earthquake that struck the nation's capital.

By December 2011, 522 335 cholera cases and 7001 deaths had been reported in Haiti (Periago, Frieden, Tappero, De Cock, Aasen & Andrus, 2012).

Improving access to sanitation is therefore not just as a way to improve quality of life but also a life-saving strategy (Zakaria, Garcia, Hooijmans & Brdjanovic, 2015). Being a public good, the consequences of poor sanitation are not just limited to un-serviced areas; there are spill-over effects such as health risks, which affect even affluent households that have their own proper sanitation (McGranahan, 2015).

2.2.1 Social and Institutional Dimensions of Informal Urban Sanitation

The ardent search for solutions to the enduring sanitation challenge globally has led to many revolutionary technologies in numerous interventions which unfortunately end up in failure (Morales, Harris & Öberg, 2014). The once highly acclaimed *Ecosan* dry technologies for example, have failed in several parts of Sub-Saharan Africa (Hendriksen et al., 2012). A purely technocratic approach to sanitation provision in un-serviced urban areas is therefore ill-advised as it fails to capture the complexity of the problem. A common strategy of the technocratic approach to urban sanitation has been to simply provide more toilets in informal settlements. This strategy has failed because it does not pay attention to other aspects of sanitation provision such as behavioural change of users or the economic opportunities of improving sanitation (Tilley, Strande, Lüthi, Mosler, Udert, Gebauer & Hering, 2014).

In light of these failures, informal urban sanitation should not be tackled merely as a technological problem, but also as a social and institutional one (Hegger, Van Vliet & Van Vliet, 2007; Lopes, Fam & Williams, 2012; Murphy, McBean & Farahbakhsh, 2009). In this regard, social scientists are now lending their own expertise in a bid to widen the discourse on sanitation (Van Vliet, Spaargaren & Oosterveer, 2010). The social sciences can offer disciplinary perspectives that look at: i) the nature of socio-technical change in sanitation provision; ii) issues of multilevel governance; and iii) the role of the citizen-consumer in improving sanitation. Social scientists have the expertise to unpack the interfaces between consumers and providers of sanitation services, as well as the interfaces between people and sanitation infrastructures (Van Vliet, Spaargaren & Oosterveer, 2010; Van Vliet, Spaargaren & Oosterveer, 2011).

A social and institutional approach conceives of sanitation provision as a service delivery package that consists of services such as customer services, public services and infrastructure development. Customer services are the front-end services involving users; hence they have a large private goods component. Public services are more downstream and have a public goods component. Infrastructure development is also seen as a public good component that is often provided at the national or provincial level (Hawkins, Blackett & Heymans, 2013). Further, the monitoring of sanitation provision should be based on the function of sanitation systems rather than on the performance of predefined sanitation technologies (Kvarnstrom, Mcconville, Bracken, Johansson & Fogde, 2011). This suggestion puts further emphasis on a systemic approach to service provision as opposed to a singular focus on technologies.

A systemic approach to informal urban sanitation may require a re-conceptualisation of sanitation as a socio-spatially differentiated concept that is affected by a complex set of social processes (McFarlane, Desai & Graham, 2014). It is therefore necessary to address the social arrangements that support sanitation technologies (O'Rielly & Louis, 2014); so as to incorporate multi-dimensional sustainability considerations into the selection of sanitation options for poorly serviced areas. Appropriate technologies therefore need to be screened across environmental, economic, and socio-cultural dimensions (Flores, Buckley & Fenner, 2009). In the case of informal settlements, a systemic approach means that the unique needs of informal settlement dwellers need to be taken into account.

2.2.1.1 Service Co-Production for Informal Urban Sanitation

Informal settlements are challenged by constraints such as: unemployment, fragile social structures, poor management, and inappropriate terrain that make it difficult to implement top-down standardised systems (Lagardien & Muanda, 2014; Pithey, 2007; Taing et al., 2013). Consequently, the involvement and participation of users in sanitation provision in informal areas is currently a hot topic especially in dominant development discourse. Development agencies such as the World Bank and the United Nations are aggressively pushing for the greater involvement of users in informal urban sanitation provision (Nance, 2013). Involving marginalised communities in sanitation projects is an empowering process for such communities, as well as a guarantee that intervention can be sustained by the empowered users themselves (Nance & Ortolano, 2007; Tinoco, Cortobius, Grajales & Kjellén, 2014).

User-participation and service co-production in sanitation is encouraged by the work of Elinor Ostrom, who advocated for the inclusion of non-state agents in the production of services. To demonstrate the

benefits of citizen co-production, Ostrom used the example of sanitation projects in Brazil and Nigeria (Ostrom, 1996). Another advocate of co-production is Mitlin (2008) who used the famed 'Orangi pilot project' in Karachi to demonstrate how informal settlement dwellers can co-produce their own sanitation services. Participation is therefore promoted by an increasing number of co-productionist approaches that seek to include users in the design and implementation of their own services (Joshi, Fawcett & Mannan, 2011; McGranahan, 2013; Patel, 2015; Tukahirwa, Mol & Oosterveer, 2013). Co-producing such services with informal settlement dwellers is best tackled within a broader agenda of poverty alleviation. In so doing, poor urban residents can be empowered, authorities can be held accountable and collective action and co-production can be achieved to provide low-cost sanitation (McGranahan, 2015).

Service co-production in sanitation should further be conceived as 'reflexive community deliberations' that are influenced by policy and institutional frameworks (Otsuki, Gera & Mungai, 2013). Shack dweller federations in different African countries such as Malawi, Tanzania, Zimbabwe and Zambia have adopted reflexive community deliberations to enable low-income households to access sanitation services based on their financial capabilities. These deliberations are thus conduits towards city-wide sanitation provision and greater social inclusion (Banana, Chikoti, Harawa, McGranahan, Mitlin, Stephen, Schermbrucker, Shumba & Walnycki, 2015).

Its benefits notwithstanding, user-participation in sanitation provision in informal contexts remains a challenge to implement. One challenge is in ensuring that decision making is based on informed choice. Another challenge in participatory processes is to ensure that elements of public good and public interest are not sacrificed for individual interests (Zurbrügg & Tilley, 2009). Community collaborations may also become coercive as individual members are compelled to participate in public exercises as in the case of CLTS drives. In such drives, 'shaming' members in public settings is used as a coercive technique in the quest for ODF communities (Bartram, Charles, Evans, O'Hanlon & Pedley, 2012).

Further, co-producing sanitation services with low-income communities in informal settlements is done with the assumption that there is capacity in the settlement for self-management or co-financing for implemented projects. This may however not be the case. Participatory processes are also often time consuming requiring wide and intensive consultation with participants who may know little about sanitation options. Expert-led projects on the other hand may be easier to manage during the

implementation phase, as there are fewer decision makers. Participatory planning is also unpredictable and case-specific, and requires an extremely good understanding of the enabling environment (Lüthi, Mcconville & Kvarnström, 2010).

To meet these challenges, a systemic and integrated view should be adopted so that a wide range of possible approaches and solutions for sanitation improvements are considered (Zurbrügg & Tilley, 2009). Participation should also be variegated and not all-inclusive for everyone so that different stakeholders are able to contribute to specific phases of the implementation process (Nance & Ortolano, 2007). For instance, informal settlement dwellers can construct and maintain 'internal components' such as simplified piping within and around their homes, while local governments are better places to finance and manage 'external components' such as connections to treatment plants (Hasan, 2008).

In summary, informal urban sanitation provision should be approached as a service that includes both 'software' and 'hardware' issues (Okurut, Kulabako, Abbott, Adogo, Chenoweth, Pedley, Tsinda & Charles, 2015). The hardware issues are the technological components of sanitation systems that are filtered through software considerations of the implementation process. Relevant social groups with diverse interests play a decisive role in the implementation process. Experts and government officials have an obvious role in instigating the implementation process, but informal settlement dwellers, as the beneficiaries of the implemented systems, are the social actors who ultimately determine the appropriateness of the systems. Informal urban sanitation is therefore a complex problem that involves different actors in interplay at multi-scalar levels. In this dissertation, the complexity of informal urban sanitation is filtered through a socio-technological lens, meaning that consideration is given to sanitation technologies and the social aspects that shape them. Other important perspectives such as the political, environmental and financial requirements of informal urban sanitation are beyond the scope of this research.

2.2.2 Sanitation Provision in South Africa

South Africa is considered to have one of the most progressive legislative frameworks for water and sanitation services in the world (COHRE et al., 2008). This is attributed to the policy review that promulgated the *National Sanitation Policy* in 2001. The policy was accompanied by a national strategy that aimed to eliminate the sanitation backlog in the country by 2010 (Gounden, Pfaff, Macleod & Buckley, 2006). The *Joint Monitoring Programme* report by WHO/UNICEF shows that

South Africa was performing relatively well as of 2012. It was also ranked as one of the 40 countries that have increased sanitation coverage while also increasing equality, as opposed to other countries such as Tanzania that have increased sanitation coverage but decreased equality. South Africa is also among one of the only nine countries in Africa that are on track to meeting the MDG sanitation target of 2015 (WHO/UNICEF, 2014).

In relative terms therefore, South Africa is performing well in sanitation provision. Using a supply-driven and infrastructure-focused approach, South Africa has managed to provide over 70% of its citizens with improved sanitation facilities. Going forward, this method is not well suited to addressing the challenge of providing improved sanitation to the remaining 26% of the population that have poor or no access (Water & Sanitation Programme –WSP, 2011). According to the WSP, the high densities in informal urban areas, coupled with insecurity of tenure, and complex community dynamics make it hard or almost impossible to plan and implement standard infrastructure solutions in informal areas (ibid).

The South African Human Rights Commission (SAHRC) has recently published a comprehensive report on 'the Right to Access Sufficient Water and Decent Sanitation in South Africa' (SAHRC, 2014). In its report, it refers to improved sanitation as being of 'RDP acceptable level'. RDP is acronym for Reconstruction and Development Programme that is aimed at providing decent housing for all South African citizens. The access to RDP-acceptable sanitation is around 71% according to the commission (Table 2.1). The SAHRC figures concur with the WHO/UNICEF (2014) figures in (Table 2.2).

Province	RDP-Acceptable			Not RDP-Acceptable		
	Flush Toilet	Chemical Toilet	Ventilated Pit Latrine	Unventilated Pit Latrine	Bucket Latrine	None
Eastern Cape	43.0%	3.0%	13.9%	20.2%	2.3%	12.7%
Free State	67.1%	0.6%	87.0%	13.5%	5.5%	3.1%
Gauteng	85.4%	1.1%	2.4%	7.4%	1.8%	1.1%
KwaZulu-Natal	45.0%	8.2%	14.4%	20.7%	1.7%	6.3%
Limpopo	21.9%	0.9%	15.1%	52.9%	0.6%	7.2%
Mpumalanga	43.8%	1.4%	12.1%	33.9%	0.9%	6.3%
North West	45.4%	0.8%	11.3%	34.2%	1.0%	5.8%
Northern Cape	66.0%	0.6%	9.1%	10.7%	4.0%	8.0%
Western Cape	89.6%	0.9%	0.6%	0.6%	3.7%	3.1%
South Africa	60.1%	2.5%	8.8%	19.3%	2.1%	5.2%

Table 2.1 Sanitation provision in South Africa by province (Source: SAHRC, 2014)

South Africa	Sanitation coverage estimates					
	Urban (%)		Rural (%)		Total (%)	
	1990	2012	1990	2012	1990	2012
Improved facilities	75	82	40	62	58	74
Shared facilities	13	14	7	12	10	13
Other unimproved	10	3	26	16	18	8
Open defecation	2	1	27	10	14	5

Table 2.2 Sanitation coverage estimates for South Africa (Source: WHO/UNICEF, 2014)

The SAHRC report states that flush toilets are only available to about 60% of households, which implies that flush toilets are the most acceptable form of sanitation. Table 2.1 shows this apparent hierarchy of acceptability, by listing flush toilets, chemical toilets and VIP latrines in that order, within the RDP acceptable category. For the commission, households in informal settlements are among the most deprived, as revealed by the large number of complaints from informal settlement dwellers that the commission has received.

The challenge of sanitation provision in South Africa is also reflected in policy. The *White Paper on Basic Household Sanitation* of 2001 defined basic sanitation as the provision of a toilet facility for each household. In contrast, The *Free Basic Sanitation Implementation Strategy* of 2009 '[…] is deliberately vague, stating that the concept of "free" basic sanitation has become a controversial issue and acknowledging that there is no universal approach which can be adopted by municipalities' (Tissington, 2011). In this regard, the strategy provides little guidance on sanitation provision in illegal settlements or on private land. Two of the cases of this dissertation are considered illegal: Enkanini is on government land while Klipheuwel is on private land. As such, policy does not adequately address the sanitation problem in such settlements.

As far as technology is concerned, the sanitation challenge in South Africa, is addressed by the *Sanitation Technology Demonstration Centre* that has been set up by the *South African Council for Scientific and Industrial Research* (CSIR) as a facility where people can acquaint themselves with a variety of sanitation technologies. The centre targets local, provincial and national officials as well as private sector consultants, researchers, and even community members, who want to make informed decisions about sanitation technologies. The centre is jointly funded by the WRC (Council for Scientific and Industrial Research, 2007).

2.2.2.1 Informal Urban Sanitation in South Africa

Despite the achievements made in South Africa, there is growing discontent over existing sanitation challenges in informal settlements. The government has not been able to deliver on its promise to eradicate the sanitation backlog by 2010. There has been slow progress in the delivery of basic sanitation infrastructure especially in dense urban informal settlements. This is partly attributed to the lack of a common interpretation of the sanitation policy (Mjoli & Bhagwan, 2012). Several aspects of the policy have been misunderstood or misinterpreted by municipalities, who are charged with providing sanitation infrastructure. In particular, there has been a poor interpretation of the principle of access to basic sanitation as a human right. There is also a lack of integration of hygiene education into the delivery of basic sanitation services. Additionally, the evaluation of sanitation provision is limited to the counting of toilets and number of jobs created. Such a simplistic evaluation does not measure the impact of improved sanitation infrastructure on the quality of life for the urban poor (ibid).

Informal urban sanitation has thus attracted a lot of research in South Africa. This review will focus largely on studies done in and around Cape Town. This is because the three cases of this dissertation are in the Western Cape Province, where Cape Town is the provincial capital. Most of the available studies in the Western Cape have thus been done in informal settlements within and around the city of Cape Town.

In one such study, a multi-stakeholder project of note was carried out in a settlement known as 'Barcelona'. The project is referred to as the 'Barcelona Settled Sewerage Pilot Project', whose goal was to test the viability of a settled sewerage system in the settlement. To carry out the project, a collaborative partnership was established between researchers from the University of Cape Town (UCT), City of Cape Town Water and Sanitation officials and Barcelona Informal Settlement Street Committee members. The partnership faced several challenges. The researchers from UCT admit that the partnership was poorly set up and so partners did not have clear roles and responsibilities. They conclude that in the South African context, such partnerships need to be led and managed by the municipality as the partner responsible for sanitation in informal settlements (Taing et al., 2013).

The view that municipalities have the main responsibility for sanitation service delivery in informal settlements is emphasised in the 'Water Dialogues Synthesis Report' (2009). From a study of metropolitan areas, the report reveals that areas such as Cape Town and Johannesburg are struggling to provide adequate services in rapidly expanding informal settlements. In particular, the City of Cape

Town and its surrounding areas are reported as having poor regulatory frameworks for contracting small-scale private sector providers. Such providers have been contracted to provide services such as the emptying of bucket toilets in informal settlements. If such contracts are to be regulated, there is a need to better understand the role of the private sector, although it is stressed that municipalities remain responsible for the way services are provided in informal areas, even where certain services are outsourced (The Water Dialogues Synthesis Report – Cape Town Case Study, 2009).

The City of Cape Town considers basic sanitation as: 'the provision of a shared toilet (at a ratio of not more than 5 families per toilet) which is safe, reliable, environmentally sound, easy to keep clean, provides privacy and protection against the weather, well ventilated, keeps smells to a minimum and prevents the entry and exit of flies and other disease-carrying pests.' Furthermore, the provision of basic facilities should be accompanied by appropriate health and hygiene education. Full sanitation is considered to be 'on-site waterborne, conservancy tank or suitable waterless technology'. Additionally, the roles of different levels of government are clearly outlined as follows: The local government is accountable for the provision of sanitation services, the provincial government is responsible for supporting local governments in achieving their objectives, and the national government is in charge of overall coordination through several government departments (City of Cape Town, 2008).

As of 2007, the City of Cape Town had not provided over 30,000 of its inhabitants with basic sanitation facilities. One of the recommendations is that the City should explore alternative and decentralised sanitation technologies (Pithey, 2007). One alternative that has been piloted with mixed results is communal sanitation. In a research on communal sanitation facilities in Cape Town, it was revealed that communal sanitation solutions are highly complex and are affected by the distance from facility, social relationships amongst neighbours and the number of users sharing a facility. The research also showed that informal dwellers are generally dissatisfied with the servicing and maintenance of communal facilities (Hilligan, Spiegel & Armitage, 2012). Shared facilities are after-all an interim measure according to the national government's informal settlement upgrading programme (Crous, Haarhoff & Buckley, 2013).

In another study, the condominium approach is recommended as an option for Cape Town. Using the condominial approach, informal settlement dwellers can be incentivised to form user-groups and connect to systems through the support of the City authorities and of NGOs. In this sense, sanitation provision will not only be about providing toilets but will further be related to improving livelihoods by

taking into account cultural and gender issues (Winter, 2010). As earlier discussed, such a condominial approach has been used successfully in the Orangi pilot project in Pakistan and in the *favelas* of Brazil. Shared facilities have also been deployed with some success in the slums of Nairobi, Kenya. More practical research is required to test the viability of such alternatives in South Africa.

2.2.2.2 'Poo Politics' in the Western Cape Province of South Africa
The political angle of informal urban sanitation is exemplified in the 'poo politics' discourse in the Western Cape Province. The discourse was highlighted in 2013, when nine protesters dumped faeces at the Cape Town international airport and on the steps of the Western Cape legislature. They did this to protest against the portable flush toilets (also referred to as the bucket system) that the city was providing in informal settlements. The protest was dabbed by the Western Cape ruling party (Democratic Alliance) as a political stunt that was staged by the ANC party to render Cape Town ungovernable in the run-up to the 2014 elections (Underhill, 2013).

The portable flush toilets (PFT) have been defended as a technology that is sound if it is used properly. The suppliers of the technology claim that the proper utilisation of the PFT elsewhere around the word shows that it is a proven method. PFTs have been used for decades in the United States and Europe as safe and effective means of disposing of human waste. Currently, there are approximately three million portable restrooms being used in 115 of 195 countries around the world. The suppliers insist that PFTs have improved the lives of millions of people and allowed countries and communities to advance beyond the suffering and poverty caused by poor sanitation (Portable Sanitation Association International, 2015).

In another incident, protests erupted when the premier of the Western Cape showed up at a 'SAHRC Water and Sanitation Hearing' of the province. The SAHRC was forced to close the hearing an hour earlier, and asked for written responses rather than oral presentations. Before the protests erupted, several communities from rural and urban areas such as Rawsonville, Zwelethemba, Ceres, Villiersdorp, and Khayelitsha had presented their grievances over the violation of their human rights. According to the commission, the communities reported high incidences of rape in areas with poor sanitation provision. They also complained of homes where toilet drains and water supply were reticulated through the same pipe. Poor sanitation in these communities also meant that children were constantly struggling with diarrhoeal infections from dirty water. The SAHRC also heard from civil society groups who described how the lack of maintenance rendered communal toilets unusable. The

groups also attributed the absenteeism of girls from school to the lack of adequate sanitation. In light of these presentations, the commission found it regrettable that the premier as head of provincial government was not able to contribute to the hearings on the day (Mangena, 2012).

The paradox is that Cape Town has the highest sanitation coverage of all metropolitan areas in South Africa according to the 2011 census (Statistics South Africa, 2012). According to SAHRC (2014), The Western Cape Province has the highest percentage of RDP acceptable sanitation facilities. The Cape Town government for its part prides itself in having the best serviced informal settlements in all South African metros. Cape Town authorities say that they provide free basic water and sanitation to approximately 144 000 informal households, by providing and maintaining over 46 000 toilets in the city. Although most informal settlements in Cape Town have waterborne flush toilets, the authorities admit that it is not always possible to install waterborne sanitation in informal settlements. This is because informal settlements are often in flood-prone areas, former solid-waste disposal sites or on private land. Informal settlements also tend to be densely populated and therefore there is little room to install infrastructure. Such settlements have to therefore make do with alternative sanitation technologies such as chemical toilets, container toilets and portable flush toilets. The City says it has plans to install additional full flush toilets in informal settlements throughout Cape Town (City of Cape Town, 2015).

As pointed out by Robins (2014A; 2014B), sanitation and politics have always been intertwined. Sanitation is therefore not an apolitical matter despite the technical orientation given to it in urban infrastructure planning. Providing the examples of London and France, Robins argues that even highly industrialised countries struggled with sanitation politics during the industrial age. In London for example, the 'Great Stink' of the River Thames in 1858, was the turning point for legislation in sanitation as members of parliament could not stand the stench that overwhelmed their parliament building. Similarly, the aim of the protesters in Cape Town was to overwhelm the middle and upper classes of the Province with the same stench of human waste that they were forced to live with in their homes (ibid).

The political contentions surrounding informal urban sanitation in South Africa therefore calls for more research into innovations that account for the technological, social and even political dimension of sanitation. TD research as a methodology provides the necessary multi-actor, multi-process approach to tackle the complex problem of informal urban sanitation.

2.3 Knowledge Co-Production and Transdisciplinary (TD) Research

Co-production between science and society through TD research is necessary if today's intractable problems (such as informal urban sanitation) are to be tackled. In such collaboration, TD researchers transcend their disciplinary boundaries in order to provide a more comprehensive methodology for tackling the complex societal problem at hand. This approach has informed this dissertation, in which I have moved beyond my own discipline of design in order to better understand the complex problem of informal urban sanitation. In particular, the challenge of working in a TD setting is expounded on in Chapter four using the Enkanini case. More generally, a TD case research approach has framed this dissertation, in which real-world interventions are used to unpack a complex societal problem, by adopting a reflexive and self-critical stance.

2.3.1 Definitions and Schools Of Thought in TD Research

The definitions used in TD research are highly varied. For example, inter-, multi- and trans- are sometimes used interchangeably to refer to TD research (Darbellay, 2015). Pohl (2011) defines TD research as a progression from multidisciplinary to interdisciplinary then eventually to transdisciplinary research. Regeer and Bunders (2009) provide an alternative categorisation of TD research into the knowledge-types produced in science. These are: *Mode-0 knowledge* (emphasis on science), *Mode-1 knowledge* (includes natural and social sciences) to *Mode-2 knowledge* (includes experiential knowledge). Darbellay (2015) further defines disciplinary categories as follows:

    i) *Multidisciplinarity* is the study of a single theoretical or practical problem from two or more unconnected disciplinary perspectives. These perspectives are employed separately as no attempt is made to integrate them.

    ii) *Interdisciplinarity* goes a step further and uses a collaborative study approach that integrates two or more disciplinary perspectives in order to solve a problem jointly

    ii) *Transdisciplinarity* as a process transcends the disciplinary boundaries in order to attain a systemic and integrative perspective of knowledge.

At a practical level, TD research is a method that brings together academic and non-academic actors in a collective endeavour to construct new knowledge that can solve pressing societal problems. The difference therefore between interdisciplinary and transdisciplinary research is the appreciation for

knowledge outside of the disciplines (ibid). In this appreciation, there is a need for: participation, transcending of disciplinary boundaries and knowledge integration. Researchers carrying out TD work are also expected to deal with complexity and diverse perspectives while developing: descriptive, normative, and practical knowledge (Pohl, 2011). These three types of knowledge concur with systems knowledge, target knowledge and transformation knowledge respectively (Hadorn, Hoffmann-Riem, Biber-Klemm, Grossenbacher-Mansuy, Joye, Pohl, Wiesmann & Zemp, 2008).

Further, Gaziulusoy and Boyle (2013) articulate five characteristics of TD research as: problem-orientation, evolving methodology, interdisciplinary coordination and collaboration, participation of external stakeholders, normativity and transformational agenda. Similarly, Wickson, Carew, and Russell (2006) provide a set of six characteristics for TD research which are: responsive goals, broad preparation, evolving methodology, significant outcome, effective communication and communal reflection. In an ideal and typical process of carrying out TD research, TD research can also be carried out in the three phases of: collaborative problem framing; co-creation of solution-oriented and transferable knowledge; and integration and application of the co-created knowledge (Lang, Wiek, Bergmann, Stauffacher, Martens, Moll, Swilling & Thomas, 2012).

In the different schools of thought in TD research, there is disagreement whether transdisciplinarity should focus more on philosophical reflection or social relevance (Klein 2015). The need for social relevance falls under the discourse on problem solving, while philosophical reflection and cultural critique are based on the conceptions of a post-normal science. In post-normal science, scientists break away from reductionist and mechanistic approaches of modernist science (ibid). The TD approach in this dissertation leans towards the need for social relevance given the glaring social problem of informal urban sanitation in the selected case studies.

Another quandary in TD research is that it uses a broad yet unclear set of methods in knowledge production. There is no common glossary and no commonly shared research framework. Practitioner involvement in TD research also varies in intensity and rarely results in the empowerment of the practitioner. TD researchers are therefore hard pressed to explain their methods and to differentiate them from other more established methods such as participatory action research (Brandt, Ernst, Gralla, Luederitz, Lang, Newig, Reinert, Abson & Von Wehrden, 2013; Bracken, Bulkeley & Whitman, 2014). TD methodology therefore needs to be clearly framed and supported by common terminology

and a suite of applicable methods in the future. The lack of a clear methodology for TD research is an opportunity in this dissertation to articulate methods that are shaped by a real world case study.

2.3.2 Reflexivity in TD research

Reflexivity in TD research is fundamental because it unearths the social positions of stakeholders in the knowledge co-production process as well as the challenges of implementing TD research (Rosendahl, Zanella, Rist & Weigelt, 2015). For instance, the power asymmetries between the natural and social sciences can be dealt with, so that stronger linkages are created between disciplines. Non-academic actors can also be empowered to contribute more meaningfully to the co-production process (Buizer, Ruthrof, Moore, Veneklaas, Hardy & Baudains, 2015; Pohl, Rist, Zimmermann, Fry, Gurung, Schneider, Speranza, Kiteme, Boillat & Serrano, 2010).

To be reflexive, TD researchers should adopt more inventive research methods that are specific and relevant to the research problem. The methods are therefore not indifferent or external because they need to be answerable to the problem at hand. In this sense, methods are just as reflexive as the researchers themselves; researchers and their methods are engaged in a complex interplay of power, knowledge production and subjectivity, which shape the research process and the findings thereof (Lury & Wakeford, 2012; Ritchie, Lewis, Nicholls & Ormston, 2013).

A reflexive method that can be usefully employed in TD research is critical discourse analysis (CDA). CDA takes on a more philosophical stance on the analysis of discourse because it regards discourse as a controlling force in society. Language is seen as a way of persuading or manipulating individuals and social groups. Discourse is therefore both a product and a changing force that influences and re-constructs social practices and values in either negative or positive ways. As such, critical discourse analysts are not merely interested in understanding how language is used, but also how language is used to maintain the status quo or create social change (Bloor & Bloor, 2013). CDA is thus a method within the TD approach that is both a method and a theory (Fairclough, 2005). Further, CDA has a broadened view of discourse that includes body language, visual images, written and spoken language, as well as music and film (Bloor & Bloor, 2013). Such a broadened view of discourse expands the generative space of the research beyond the control of the researcher (Mitchell, 2011).

2.3.3 Case Study Methods in TD Research

Case study is the most commonly used method in TD research (Muhar, Visser & Van Breda, 2013; Pennington, Simpson, McConnell, Fair & Baker, 2013; Polk, 2014; Wiek, Harlow, Melnick, van der Leeuw, Fukushi, Takeuchi, Farioli, Yamba, Blake & Geiger, 2015). In the social sciences in general, the case study method is one of the principle means by which research is conducted (Angrosino, 2007; Saldaña, 2013). This is because the case study method offers researchers the opportunity to study a phenomenon in context using a multiplicity of perspectives (Baxter & Jack, 2008). Further, the case study approach is premised on the constructivist paradigm, in which reality is socially constructed. As such, the researcher pays keen attention to the views of participants who construct their own reality, and who are therefore collaborators in the research process. The challenge for the researcher is to ensure that the research process is contained within a reasonable scope and yields theoretical significance (ibid).

The constructivist paradigm is most prominent in interpretive case studies that are premised on the ontological assumption that social reality is locally and specifically created through human action and interaction. Hence, the case study findings are literally created as the investigation proceeds. Further, interpretive case studies aim for theoretical sufficiency rather than construct validity; theoretical coding rather than internal validity; and theoretical generalisation rather than external validity. The idea here is that the researcher lays no claim to having completed the research using accurate measures that can be repeated. The researcher instead presents a wholesome and convincing position that is meaningful and relatable for the target audience (Andrade, 2009). The specific techniques used in a case study further depend on the philosophical standing of the researcher. In choosing a critical ethnography approach for example, researchers accept that there are multiple epistemologies that are based on context (Angrosino, 2007).

Theory building in case studies occurs in several stages. These stages are four typologies of how to theorise from case studies (Tsang, 2013). They are:

- Interpretive sensemaking- the researcher seeks an in-depth understanding of a human experience which is embedded in a complex real-world context. In this case, generalisability is not of interest.

- Contextual explanation- emphasis is placed on theories which are abstracted from the real-world context. The derived theories nevertheless remain firmly embedded within the context of the case.

- Identification of empirical regularities- importance is placed on discovering widespread phenomena that are of practical significance, which may or may not lead to theory building. Such empirical regularities may therefore be less universal as they are limited to definite regions of time-space.

- Theory building and testing- theoretical relationships are extracted from the context and used to build a new theory or to test an existing one.

The four methods can be realised sequentially in one research, although each method is sufficient by itself. A case study can start off with the purpose of gaining an in-depth understanding of the context, from which empirical regularities are observed, leading to the explanation, building and testing of a theory (ibid).

2.3.3.1 Limitations of the Case Study Method

Although the case study method offers a rich and in-depth understanding, it does so within a limited scope, which makes it difficult to statistically generalise findings (Thomas, 2011). It is however possible to analytically generalise case study findings through theoretical triangulation (Yin, 2009; 2013). Inquiries using the case study method are after all not interested in statistical procedures; their focus is on understanding the research problem rather than of the quantification of observations (Baškarada, 2014). Case study researchers therefore sacrifice statistical significance for conceptual validity and contextual depth.

The analysis of case-based findings is the least developed and most difficult stage in case study research (Yin, 2009). A set of analytical techniques are therefore recommended to assist in the effort of matching empirical findings to theoretical patterns or propositions, as well as in exposing causal relationships or complex chain of events in the empirical material. The analytical tools for doing this are: pattern matching, explanation building, time series analysis, logic models and cross case synthesis. Further, the reporting of such findings can be linear, chronological or based on theoretical structures. In using theoretical structures, the researcher reports findings based on the logic of the theoretical arguments (ibid). The report of findings can take on different forms that have to create a convincing

narrative. Within the narrative, the findings can appear in the form of perceptual maps, flow charts, tables and matrices (Remenyi, 2012).

By using a case, the researcher seeks to understand many factors within a single or just few cases, and in so doing, engages in an intensive research rather than an extensive research and contextual depth. Contextual depth offers an intimate familiarity with case study contexts so that empirical material can be understood in a more integrative and holistic manner such as through manual and holistic coding (Angrosino, 2007; Saldaña, 2013).

By not employing statistical procedures, the case study method lacks sufficient precision and objectivity (Andrade, 2009). Case study inquirers are hard put to demonstrate scientific rigour as they find it difficult to justify their subjective findings (Baškarada, 2014). Yin himself admits that case studies are methodologically challenging, hence researchers need to rely on theoretical propositions that can ground the descriptive framework of the case (Yin, 2009). In general, qualitative research is challenging especially if it involves extended fieldwork. In this sense, the researcher is not just concerned with methodological or technical considerations. They also have to manage their fieldwork to ensure that it yields significant research findings (Yin, 2011).

The significance of research findings is all the more important in TD research, in which knowledge is geared towards solving social problems and bringing about transformative change. To do this, TD researchers ought to look to other disciplines that already have generative methods for problem-solving. Design is discussed here as a field that offers generative skills such as visualisation which are useful in the problem-focused approach of TD research.

2.3.4 Design and Innovation for Under-Served Contexts

The design discipline is shifting its focus from object to process: design is not just about innovating consumer products; it is also about the philosophical agendas that underlie design practice (Manzini, 2014). Design is therefore becoming more systemic and is used as a catalyst for change and social innovation and transformation (Cipolla & Bartholo, 2014; Manzini, 2010). In this way, design is realigning itself with the call for greater social responsibility of TD research.

The most prominent advocates of the social responsibility of design are Papanek and Fuller. As far back as the 1970s, the two opened up this discussion in their celebrated book: 'Design for the Real

World' (Papanek & Fuller, 1972). Since then, designers have not confined themselves merely to the design of products, services or systems; they are now engaging in critical discourses that shape the broadening design agenda. Further, designers are also adopting an ever widening range of techniques from other fields, while lending their own expertise, in an effort to provide more holistic solutions to today's complex problems (Ceschin, 2013; Manzini & Rizzo, 2011). More particularly, there are designers who are primarily concerned with facilitating participation in the actual context where design technologies will be used (Hagen & Robertson, 2012; Jørgensen, Jørgensen & Clausen, 2009).

Engaging in this type of design is thus appropriately captured in the hybrid role of 'researcher-designer', which combines the analytical strengths of research with the generative skills of design (Sanders & Stapper, 2008). By acquiring such hybrid roles, professional designers can focus greater attention on social and cultural problems such as homelessness, insecurity, poor health and aging (Brown & Wyatt, 2010; Steen, 2011), as well as sanitation in un-serviced areas (Hurn, 2014). Researcher-designers are thus broadening the social agenda of design, in which end-user participation is paramount, and has led to the development of a variety of participatory methods including various human-centred design approaches (Björgvinsson, Ehn & Hillgren, 2012; Nilsson, Peterson, Holden & Eckert, 2011; Quesenbery & Brooks, 2010). In these methods, emphasis is laid on the need for design to be more socially, culturally and environmentally responsive (Cipolla & Bartholo, 2014; Manzini & Rizzo, 2011).

2.3.4.1 Shifts in Design Research and Methodology
There is a plethora of research that interrogates both the practical and theoretical aspects of design. However, most of this research has been done in the Western contexts (Jagtap, Larsson, Hiort, Olander, Warell & Khadilkar, 2014). This means that mainstream design practice is shaped by consumer markets in highly industrialised regions (Van Boeijen & Stappers, 2011). Less industrialised regions have attracted less attention in design research and so little is known about design in such regions. For instance, mainstream journals in design research are all published in and largely for Western contexts. These are journals such as Design Studies' journal by Elsevier, 'Design Issues' by MIT press and 'Co-design' journal by Taylor & Francis publishers.

The Design Studies journal '…is the only comprehensive and interdisciplinary journal on design research…' (Chai & Xiao, 2012). According to the journal, common research themes in design are: design process and design cognition. Protocol analysis is amongst the more popular methods of design

research in the journal. A further look at the journal's publications shows that recent research has focused extensively on design expertise and training in industrial contexts (Carmel-Gilfilen & Portillo 2012; Goldschmidt & Rodgers 2013; Gonçalves, Cardoso & Badke-Schaub 2014; McComb, Cagan & Kotovsky, 2015; Vallet, Eynard, Millet, Mahut,Tyl & Bertoluci, 2013).

'Design Issues' by MIT press, is another journal that provides an indication on the direction of research in the design fields. It is 'the first American academic journal to examine design history, theory, and criticism…' Some of the common themes in the journal are: design history, service design, organisation design, design for development, and product design methodology (MIT press, 2015). A third journal that is considered here is the 'Co-design' journal by Taylor & Francis publishers, which focuses on design areas such as: inclusive, collaborative, co-operative, concurrent, human-centred, participatory, socio-technical and community design (Taylor & Francis Online, 2015). With these three journals, it is possible to form some opinion about what type of design research is going on globally: it is research that is shaped by Western sensibilities that fail to capture the reality of under-served contexts.

As pointed out by Altbach (2013), traditional journals (such as those mentioned above) are not significantly concerned with research or academic issues relating to developing economies. To make matters worse, many of the top journals published by multinational publishing conglomerates, such as Elsevier and Springer have very high subscription fees that are beyond the capacity of universities in developing countries (ibid). This means that research publications in general are not readily available to researchers in the Global South region; hence they contribute little to the global research discourses, since traditional journals remain central to shaping research discourse and dissemination (ibid). The dearth of design literature from the Global South may mean that mainstream design is unprepared to tackle the complexities from this part of the world. Such a glaring gap in research calls for a deep contextual understanding of under-served contexts.

2.3.4.2 Inclusivity in Design

A growing concern for the environment in industrialised economies has caused a shift in product design towards ecologically sensitive design. This has led to eco-design or green design approaches that pay attention to the environmental impact of products. There is now a demand for eco-products such as energy-efficient products and for design tools and methods that have a low impact (Dace, Bazbauers, Berzina & Davidsen, 2014; Santolaria, Oliver-Solà, Gasol, Morales-Pinzón, & Rieradevall,

2011; Yang & Chen, 2011). Eco-design thus aims for cleaner production on the premise that over 80% of a product's environmental impact can be determined during the design phase (Garcia, González & García, 2013). Consequently, the introduction of eco-design principles into the development phase of the product design process is now regarded as urgent (Hossain & Ahmad, 2011).

In the broader concept of sustainability, product design is not just about green products; it is also about designing enabling infrastructures such as renewable energy systems (Shi & Chew, 2012). In this regard, product designers consider how energy systems are designed by a network of actors (Vezzoli, Delfino & Ambole, 2014). In sanitation, ecological concerns have led to concepts such as ecological and complete sanitation. Ecological sanitation has become a common term used to describe sanitation technologies that incorporate ecological concerns. These types of technologies are characterised by 'sanitise and recycle' processes also known as 'nutrient cycling'. In nutrient cycling, the aim is to close the nutrient loop by safely treating human waste and recovering nutrients from the waste thus reducing pollution and protecting the environment. The recovered nutrients can be used as an agricultural resource to improve soil fertility (Andersson, Zehnder, Wehrli, Jewitt, Abbaspour & Yang, 2013; Haq & Cambridge, 2012; Practical Action, 2014).

Another common term for ecological sanitation approaches is 'complete sanitation', which describes sanitation systems that re-use waste-water and faecal sludge (Murray & Buckley, 2010). The reuse of these human waste resources in agriculture is a means of mitigating water shortage while also abating water pollution. More incentives should therefore be provided for re-use oriented sanitation infrastructure rather than for conventional waste-disposal facilities. Developing economies in particular should consider investing in waste-water treatment for agricultural use so that they can fulfil the dual objectives of reducing pollution and saving on water. Additionally, such treatment plants should also be site-specific as is exemplified by innovations in South Africa, Ghana and China (ibid). Further, 'dry sanitation' has become synonymous with ecological sanitation because it drastically reduces the use of water (O'Neill, 2015). In un-serviced areas that have no constant supply of water, dry sanitation is a technically desirable solution (Lundin, 2013). Dry sanitation however requires drastic changes in user behaviour and has met with little success in Sub-Saharan Africa informal settlements (Hendriksen et al., 2012).

The mandate of product designers has thus stretched beyond the product in a bid to bring about systemic changes in the way products are made and used. Sustainable product design could therefore be one of the most important practices for achieving sustainability in the world today (Chen, Zhu, Yu &

Noori, 2012). The broadening ecological concerns in industrial design are captured in the sub-fields such as *design for sustainability* (DfS) and *product-service-systems* (PSS) (Manzini, 2010). In this way, design can deliver, for example, functions such as mobility and thermal comfort to communities, rather than selling a car or air-conditioning equipment to individual consumers (Ceschin, 2014).

The need for customer satisfaction and inclusion has spurred on another sub-field in design known as participatory design (PD). PD is highly regarded and supported by the claim that participatory processes and their outcomes are more likely to be accepted and sustained (Robertson & Simonsen, 2012). PD has its roots in movements toward the democratisation of work places in Scandinavian countries, which took place in the 1970s. Later, PD was introduced into product design with the aim of getting information from potential customers in order to provide them with better products. PD then broadened beyond the material product and into the realm of designing participative projects and infrastructure (Bjögvinsson, Ehn & Hillgren, 2012).

Two strands of PD have roots in the United States (US) and in Northern Europe respectively. In the US-driven approach, the user is a subject in a user-centred design approach. In the Northern Europe approach, the user is a partner in a participatory approach (Sanders & Stappers, 2008). A similar conceptual distinction is given by Miles and Rigby (2013), who show that the user can be a subject who provides information or a partner who participates in the design process. These conceptual distinctions tend to be less clear-cut in practise.

Adopting a different lens, other designers incorporate the needs of users by creating products and processes that are usable by the widest range of people possible, who can operate in the widest range of circumstances, without special or separate design. To design for such a wide range, designers employ UD principles that are also defined as design-for-all principles (What is Universal Design? 2015). UD seems to be in contrast to ergonomics or human factors, which are aimed at improving product performance in accordance with the user's capabilities (Baxter, 2012; Karwowski, Soares & Stanton, 2011). In an increasingly globalising world, user's capabilities and preference vary widely, leading to the need for product differentiation and user-participation (Acosta, Morales, Lagos & Ortiz, 2011).

In self-design, users are facilitated to become designers of their own products that suit their lifestyles. There is now an explosive growth of DIY toolkits that facilitate self-design, and promise to deliver products that embody the highly individualistic tastes of users (Moreau, 2011). In self-design, the end-

49

user is more likely to develop emotional attachment to a product that they make for themselves. Emotional attachment may then induce the user to be more environmentally conscious in their use and disposal of the product (Tseng & Resnick, 2014; Serna‑Mansoux, Popoff & Millet, 2014). Alternatively, easy access to self-design equipment may result in over-production and hence more waste. The proposed approaches are therefore dependent on the context in which they are used.

Other PD approaches bear a stronger social and public agenda. In this regard, 'social technologies' advocate for design outcomes that emerges through the deliberate activities of users. In such deliberations, designers are primarily concerned with facilitating participation in the actual context in which the technologies will be used (Hagen & Robertson, 2012). This means that the technology is shaped by a deliberative process of participation that is inherently social and situated (ibid). In social technologies, participation is just as important as the technology itself, and participants are just as empowered as the designer. The concept of social technologies resonates with the 'Social shaping of technology' (SST) approach that focuses on the mutual influence of technology and society on technological development. As such, technological change is regarded as a dynamic process that results from the interaction between research, development and application of technologies. Proponents of SST argue that it has profound theoretical implications for the way technological change is perceived. Technology is therefore not just a driver of change; it is also an object being driven by societal actors. In other words, technology and society co-produce each other in a complex actor-network system. (Jørgensen, Jørgensen & Clausen, 2009).

The 'Human-Centred Design' (HCD) technique is another approach that has a strong social agenda as it is geared towards the co-creation of socially responsible products (Kuijer & De Jong, 2011). HCD is thus the creation of user-sensitive inclusive design, where participative and empathetic methods promote closer interaction between users and designers (Newell, Gregor, Morgan, Pullin & Macaulay, 2011). Another concept in the expanding role of product design is 'Design for extreme affordability'. Here, the design of products and services are geared towards improving the lives of the world's poorest citizens (Stanford University, 2012). In other instances, designing for the world's poorest is referred to as 'Design for Development' (Donaldson, 2008). Caution is however advised in the use of this term given the derogatory connotations of terminology such as 'development' and 'developing countries.'(ibid). Instead, fundamental questions about development should be addressed, to ensure that

design processes are more consistent with local conditions in less industrialised countries (Donaldson, 2006).

'Design with the other 90' is another common term that refers to designs that address the needs of the poor who happen to make up the majority in the world. At the Smithsonian Museum in the United States of America, 'Design with the Other 90%' is a series of themed exhibitions that focus on design solutions to the most basic needs of the 90% of the world's population, who are not traditionally served by professional designers (Smithsonian design museum, n.d). Closer to home, a ground-breaking conference themed 'Design with the Other 90%: Changing the World by Design' was held in South Africa in 2014, thereby allowing designers from Africa to present their research findings from their own contexts (Cumulus Johannesburg, 2014). Designing with the other 90% implies that mainstream professional design has thus far only served the needs of the rich 10%.

2.3.4.3 Inclusivity in Innovation
The push for participatory design is congruent to the call for inclusivity in innovation. Inclusive innovation is innovation that '[...] can meet basic needs of low- and middle-income groups in developing countries […]' (Papaioannou, 2014). Inclusive innovation therefore benefits those who are disenfranchised and excluded by conventional value creation pathways in business and in professional fields such as design (George, McGahan & Prabhu, 2012). Other terms for such innovations are: grassroots, frugal and below-the-radar innovation (Bhatti & Ventresca, 2012; Papaioannou, 2014).

The call for inclusivity in innovation is driven by the fact that the number of people living in absolute poverty has increased around the Globe except in China. Increasing poverty is produced by the uncoupling of economic growth and social development. Conventional innovation that is large-scale, capital intensive and resource intensive is blamed for this uncoupling (Chataway, Hanlin & Kaplinsky, 2013). In other words, current modes of innovating within science and technology have failed the poor because they do not take into account societal needs and values in a sufficient way. Consequently, proponents of inclusive and responsible innovation seek the opinions of different members of society in a bid to render innovation more socially responsive (Taebi, Correlje, Cuppen, Dignum & Pesch, 2014; Van Oudheusen, 2014). Responsible innovation has gained influence in EU policy programmes in recent years, especially within the European Commission's Science in Society programme (Owen, Macnaghten & Stilgoe, 2012).

Organisations such as multi-national corporations (MNCs), have acknowledged the need to innovate products and services that answer to the specific needs of low-income consumers. This type of innovation can also be referred to as resource-constrained innovation or bottom of the pyramid (BOP) innovation (Pansera & Owen, 2014). According to Prahalad (2012), BOP innovation came into common parlance after his publication: 'The Fortune at the Bottom of the Pyramid'. From then onwards, BOP markets have been viewed as a new source of radical innovation (ibid). For MNCs, developing countries have become increasingly attractive as new markets given that growth has stagnated in industrialised countries, while economic growth has continued to rise in less-industrialised countries. The novelty in BOP markets lies in the potential to create disruptive technologies that are superior to their counterparts in more mature markets. Disruptive technologies can be realised in BOP markets precisely because they are inspired by alternative ways of life (Dahlman & Kuznetsov, 2014).

To create products for BOP markets, the following pathways are suggested:

- The development of new products by MNCs, which are tailored to serve BOP consumers by improving their living conditions.

- The development of disruptive innovations, where the BOP is the lead user site for testing potential products.

- Co-generation of top of the pyramid (TOP) products in BOP locations.

- The development of BOP products by BOP producers themselves (Hall, Matos & Martin, 2014).

These pathways, display the richness that lies in BOP contexts and that is being exploited by MNCs. In this sense, the approach is market-driven, which is opposed to the view that BOP innovation should transcend the logic of mainstream business. Critiques of the market-driven BOP innovation approach claim that it pays little attention to the social and environmental consequences of such innovation. In particular, MNCs are accused of adopting a romanticised view of the poor and under-emphasising the role of public institutions in poverty eradication. Worse still, the technocratic approach to BOP innovation by the private sector reinforces neo-colonial configurations of power asymmetry and exploitation of vulnerable communities (Karnani, 2012). According to Hall (2014) previous BOP research is exploratory with a strong focus on the MNC perspective. In more recent BOP research, there is a shift towards a more complex understanding of the BOP as an interaction between customers, potential suppliers and partners who are influenced by foreign and local firms, government and NGOs.

The complex understanding of the BOP context also acknowledges that it is a paradox that is at once rich and vibrant, but also messy and chaotic (ibid).

Additionally, certain myths abound within the BOP innovation approaches that are primarily geared towards profit. In these approaches, there is often a belief that existing BOP markets are disorganised and non-innovative. As such, MNCs respond to these 'inadequacies' by introducing consumer educational programmes to promote their products in BOP markets. Deskilling is also built into such products because BOP consumers are assumed to be low-skilled. In these approaches, MNCs display a lack of knowledge about existing industrial eco-systems and entrepreneurial networks in BOP markets (Murphy, 2008).

These seemingly opposed views of BOP innovation can be hybridised according to Pansera & Owen (2014). BOP innovation should take into account both the market approach and the social-environmental approach. In this way, BOP innovations can be supported by formal research and development programmes, capital investment and strong entrepreneurial capacity, while also taking advantage of the grassroots approach with its low-scale social initiatives. Further, there is need for empirical research that can shed light on how innovation actually occurs in BOP contexts, so as to support critical reflection on the framing of BOP innovation (ibid).

An integrated BOP approach is also advised for by Hahn (2008:458), who offers a 'hybrid technological innovation' heuristic. In this heuristic, the three aspects of eco-efficiency, eco-effectiveness and sufficiency are regarded as important design considerations in BOP products. Additionally, Davidson (2008) insists that BOP innovation should take into account the ethical concerns of working with marginalised communities. Unlike well-resourced consumers, BOP consumers are marginalised and disempowered and so they face more challenges such as illiteracy and poor access to information. Consequently, BOP innovators should incorporate poverty reduction and empowerment into their business strategies. Integration and hybridisation in BOP innovation is further articulated by Kandachar and Halme (2008).

The inappropriateness of foreign innovation for BOP contexts is partly blamed on the lack of demand for domestic knowledge. This means that BOP economies have not made adequate use of indigenous knowledge to develop their own economies. By way of example, foreign consultants continue to dominate the supply of knowledge to government, industry and aid donors in Global South countries.

As such, the innovation processes in these countries are fragmented and are yet to realise their full potential (Trojer, Rydhagen & Kjellqvistt, 2014).

To provide enabling policy, some governments in Africa have instituted national systems of innovation (NSI), although their effectiveness in promoting innovation has been questioned (Daka & Toivanen, 2014; Koria, Bartels, Andriano & Koeszegi, 2014). NISs in developing countries have performed poorly due to poor governance (Watkins, Papaioannou, Kale & Mugwagwa, 2014). There is therefore need to build sustainable knowledge infrastructures that can drive innovation to tackle enduring problems such as informal urban sanitation.

In short, a multi-perspective approach is necessary in working with BOP contexts given their complexity. Hybrid models that incorporate co-creation with users, social entrepreneurship and disruptive technologies should be considered. Such a multi-faceted approach is useful for innovation in the informal urban sanitation context of this dissertation.

2.3.4.4 Challenges of User-participation in Design and Innovation processes
Despite its advantages, the difficulties of participation in design and innovation cannot be overlooked. These difficulties emanate from the assumption that design outcomes that are produced collaboratively should be more creative than individually produced design. However, there is experimental evidence that shows that group-work in creative processes can be less productive than individual work. This is attributed to the social influences on creativity that prevent groups from realising their synergistic potential. These social influences on creativity are: i) production blocking, which results from asynchronous verbal interaction, ii) evaluation apprehension, which is the fear of criticism, and iii) free riding, which is social loafing of members who contribute little to the group (Warr &O'Neill, 2005).

Another challenge of participation is the actual capacity of users to participate. Anderson, Curtis and Wittig (2014) argue that certain users may be so marginalised that they are unable to contribute to the design process. For example, work done with immigrant groups in Europe show that immigrant groups are so impoverished that they cannot actively participate in the social processes that are designed to ameliorate their situation. In this regard, empowerment rather than active participation should be the goal in working with such groups (ibid).

This view is similar to that of Hussain, Sanders and Steinert (2012), who argue that empowering users is just as important as improving their situation using technology. As a design team working with poor users, they found it was necessary to build capacity and trust as part of the PD process. They therefore had to tackle other challenges such as language barriers and creating appropriate remuneration of participants. They further point out 'differentiating circumstances' that make participation more challenging in marginalised communities. The differentiating circumstances as: human, social, cultural, religious, financial, time-frame and organisational. To deal with these circumstances, it is important to ensure that PD with marginalised people is aimed not just at developing empowering products but also at creating empowering situations (ibid). This dissertation concurs with the view that design engagements with marginalised communities (such as the informal settlement dwellers in the case studies of this research) should aim at developing empowering outcomes for the community, beyond the material benefits of design products (such as the sanitation technology installed in the cases).

Another problem with participation in design is that it has failed to stem conspicuous consumption that continues unabated in the Global North regions. Green products are in fact a paradox because, individually they have less ecological impact, but collectively they have failed to stem the overall consumption of natural resources. This is because green products have in fact had a boomerang effect by encouraging over consumption, since consumers are enticed into buying more 'green' products that they do not need. The advice therefore is that design should move away from a technocratic culture that does not pay enough attention to the socio-cultural implications of design. As such, it is advised that design in general should encourage 'dematerialisation', which refers to the overall reduction of consumer goods (Vezzoli & Manzini, 2008:16-18).

To stem the tide of over-consumption, there is need for a 'slowing' down of design in an effort to establish more mindful usage of products. The purpose is to encourage product attachment and the accompanying sustainable benefits of long term use. 'Slow design' is realised through 'slow technologies' that encourage reflective consumption, appreciation and emotional attachment to products (Grosse-Hering, Mason, Aliakseyeu, Bakker & Desmet, 2013; Odom, Selby, Sellen, Kirk, Banks & Regan, 2011). In informal urban sanitation, slow design is desirable and perhaps occurs by default in the case of alternative solutions, which have not yet been standardised over time. Sanitation solutions in this sense are design artefacts that bring about product attachment because they are complex systems that require time to implement and test, and are to be used by everyone.

Ultimately, the mainstream design and innovation narratives show a limited understanding of sustainable development in the context of the poor. This is because design approaches remain firmly embedded in the development discourses such as '[…] market environmentalism, populism and ecological modernisation'. In this discourses, the focus is on short-term goals of technology innovation. Such goals have failed to substantially change the livelihoods of people at the bottom of the economic pyramid (Melles, Kuys, Kapoor, Rajanayagam, Thomas, & Mahalingam, 2015). Similar development narratives in sanitation provision have driven technocratic approaches that have failed to capture the complexity of informal settlement needs (Hendriksen et al., 2012).

Designers and design thinkers should therefore continue participating in larger debates such as inadequate sanitation. To do this, it is necessary to articulate integrative philosophical lenses that can support co-design and co-innovation narratives.

2.3.4.5 An Integrative View of the Social and the Technological

The design and innovation discussions above are underscored by the need for a problem-solving approach that includes users. In this inclusion, technologies are perceived as holistic entities that are comprised of technical, scientific, social, political and economic perspectives. As such, technology and society are a seamless web, since technological artefacts are culturally constructed and interpreted by people (Bijker, Hughes, Pinch & Douglas, 2012). In this sense, the technological artefact or '…infrastructure is a complex surrounds…' that '…residents put together and are themselves put together through a continuous interchange of materials and the expressions these interchanges make possible' (Simone, 2015).

In actor-network theory (ANT), both humans and technologies are 'actants' as they mutually constitute each other. Humans, like technological artefacts are objects that contribute to the assemblage of the world (Farais, 2010; Latour, 2005). In this dissertation however, more emphasis is laid on human actants as the drivers of technological advancement: it is human qualities such as reflection and motivation that drive socio-technical change (Beveridge and Guy, 2011). Consequently, concepts of ANT (such as mutuality between humans and technology) are given consideration, even though ANT as a whole is not used as a theoretical frame in this dissertation.

The significance of human agency in driving social-technological innovation means that cultural construction and interpretation of technology is carried out by relevant social groups, who collectively

interpret social artefacts, thereby giving those technologies an interpretive flexibility (Bijker et al., 2012). Interpretive flexibility allows technological artefacts to be understood and designed in different ways. Social groups therefore interpret technologies by for instance agreeing whether the technology has solved the problem at hand. This is known as rhetorical closure of the technology. Arriving at a rhetorical closure is however a messy process, which alludes to the complexity and messiness of technological systems (ibid). Social groups are themselves messy and at times contradictory as individual members group and regroup and the relevance of the group is reinterpreted (Latour, 2005).

This social constructivist view of technology is the underlying philosophical paradigm in the previous arguments of this literature review as follows:

i)   In informal urban sanitation, the complex sanitation problem in informal settlements is filtered through an integrative socio-technological view.

ii)   In TD research, the inclusion of non-academic actors in research processes is in acknowledgment of the need to socially construct knowledge and solutions with other actors outside of academia.

iii)   In inclusive design and innovation, the user is invited to co-construct products that are relevant to their social situation.

In short, a social constructivist view underscores my stance as a researcher and a designer, who believes that technological innovation is socially constructed and is society shaping. The sanitation technologies discussed in the cases studies are thus handled as socio-technological artefacts that were co-constructed by people, who created social groups around the problem of sanitation provision. Being a researcher-designer echoes the role of the 'engineer-sociologist' who engaged in sociological analyses of technical devices (Callon, 2012:78). Technical devices become objects of engagement that allow designers, engineers and even sociologists to think about the metaphorical capacities of those devices '…to generate aspiration and expectation, deferral and abandonment.' (Appel, Hannah, Anand, Nikhil, Gupta & Akhil, 2015). The sanitation technologies in the three case studies serve this metaphorical purpose: they are boundary objects that generated aspirations, expectations, deferral and abandonment amongst fluid groups of actors.

2.3.4.6 The Researcher-Designer as a Design Ethnographer

Design ethnography borrows from anthropology, which has a long tradition of intensive participant observation (Gunn & Donovan, 2012). Using anthropological techniques, the designer can interrogate encounters that intersect the categories between production and consumption (Halse, 2012). Further, design anthropology and ethnography is especially useful in complex social contexts where design ideas lie in the collective imagination, rather than with the individual designer (ibid). Design ethnography can therefore improve the understanding and development of alternative design narratives that are contextualised in the realities of under-served users.

In carrying out ethnographic work, designers also employ interdisciplinarity to extend the impact of design participation on social development (ibid). The classical roles that separated designers, users and researchers are also merged in the effort to integrate disciplines. According to Sanders and Stapper (2008), the designer and the researcher collaborate in order to provide design and research tools for the user. In the hybrid 'researcher-designer', a broader set of skills is required to manage both the design and research processes (ibid). The theoretical basis for the broadening of design methods is provided in the assertion that perspectives in design research have moved beyond visual and form, and are now focused on ecological and social literacy (Bærenholdt, Büscher, Scheuer & Simonsen, 2010; Holm, Søndergård & Hansen, 2010). This means that design research can shift from problem to project, and from design to design thinking.

Design research can bring about radical innovation if it can address the fundamental questions of new meanings and interpretations in technology. Taken in a wider sense, radical innovation in the society can be achieved if design research can address the fundamental questions of new social meanings and methodological interpretations. This is especially true in places (such as informal settlements) where social problems need to be ameliorated urgently (Norman & Verganti, 2012). Dealing with social problems means that the design process may be slow as designers have to deviate further from mainstream methods (Hussain, Sanders & Steinert, 2012). If so, the researcher-designer should be flexible enough to deal with non-conventional situations. Informal urban sanitation is a non-conventional situation that calls for the creative problem solving of design that is best informed by the depth of ethnographic approach.

The role of the researcher-designer is therefore to facilitate and promote co-design with various stakeholders in the search for solutions and strategies to complex issues (Bjögvinsson, Ehn & Hillgren,

2012; Hillgren, 2013; Manzini & Rizzo, 2011). In so doing, the boundaries between design disciplines become blurry, as the mandate of the designer is even more expansive. This means that product designers who become design facilitators can facilitate design processes that are not necessarily focused on realising tangible products (Manzini & Rizzo, 2011). The rationale for design facilitation is based on the idea that designers already possess the skills needed to support co-design activities. These skills are the creative methods of traditional design, which are: visualising, experimenting, prototyping, gathering feedback, and re-designing (Razzouk & Shute, 2012). The argument therefore is that these design skills can be translated and used in contexts that are entirely different from those of traditional design.

Co-designed processes can bring about socially innovative solutions in the face of today's intractable problems (Hillgren, Seravalli & Emilson 2011; Munyai & M'Rithaa, 2010). As such, social innovation and design are mutually constituting. Consequently, 'design for social innovation' (DSI) has gained popularity in design practice and academia. In DSI, prototyping, visualisation and 'infrastructuring' are valuable design methods that can be used to create networks for long-term transformative innovation (Hillgren, Seravalli & Emilson, 2011). In such networks, experimentation and prototyping in real-world contexts is highly encouraged. In particular, infrastructuring is a process that supports open-ended networks. Such open-ended networks are opposed to project-based networks that are short-term and too rigid to experiment with a wide range of solutions. In open-ended networks, infrastructuring allows participants to imagine and visualise social and technical infrastructures that can be tested and improved collaboratively over time (ibid).

Despite its strengths, design practice has weaknesses that may render it inappropriate as an analytical tool. Designers may lack the economical and organisational skills that are necessary for the successful implementation of projects. Additionally, designers often charge high consultancy fees, and such costs may be prohibitive in social projects (Schaper-Rinkel & Wagner-Luptacik, 2014). The remedy to such deficiencies would be to collaborate with other professionals with the necessary competencies (Bjögvinsson, Ehn & Hillgren, 2012). Alternatively, designers may have to develop more analytical skills that will enable them to facilitate the realisation of practical goals.

Design facilitation is therefore not a preserve of designers. Non-designers can use the techniques of design to create value to organisations or societies that want to innovate and bring about change (Smulders, Dorst & Vermaas, 2014). In design thinking theory and practice are closely interconnected,

which means that design thinkers are also concerned with the philosophical underpinnings of design practice (Von Thienen, Noweski, Meinel & Rauth, 2011).

The changing discourse in design is thus a shift from object (the product), to process and theory (the action and the thinking). In this shift, the agenda of design has also morphed from being purely consumerist to having a more transformative agenda with growing concern for social complexities. The object however remains a central focus of product design in particular. Using the analogy of object, process and theory, the sanitation technology in this dissertation is an *object* that is used to understand the *process* of change in informal settlements, a change that is embedded in the underlying *theory* of transforming urban processes in under-served informal contexts. In this way, design lends to the expanding field of TD research and theory that is noble in its goals but is short on methodological underpinnings that can guide actual field work.

2.4 Conclusion of the Reviewed Literature

The reviewed literature builds the argument that informal urban sanitation is a complex problem that requires co-production between various stakeholders and across various perspectives. Consequently, TD research is an appropriate methodology that provides the multi-dimensional approach required to tackle informal urban sanitation. However, the TD approach lacks a coherent methodology; hence it can be strengthened by introducing the generative skills of design. This is because design has broadened its social scope beyond consumerist models of mainstream innovation. As such, design offers creative techniques that are informed by the need for technological innovation, as well as the interest in the social contexts within which those technologies are instituted. This type of thinking is driven by a social constructivist paradigm, in which technology is socially constructed through interactions amongst individuals with common interests.

The dissertation therefore offers a socio-technological view of informal urban sanitation, as a complex problem shaped not just by technological concerns, but also by social concerns such as multi-stakeholder engagement and user-participation. This is in contrast to the prevalent technocratic approaches that have resulted in failed sanitation interventions across Sub-Saharan Africa. In light of these failures, social scientists (such as designers) are now more vocal in sanitation discourse because they are interested in facilitating integrative, participatory processes.

In practice however, participatory processes and user-involvement in informal urban sanitation are hard to realise because they are time consuming and require broad and extensive consultations with stakeholders. This is opposed to expert-led sanitation interventions, in which decision making is quicker and resources can be maximised. The push for participation of users may also thwart individual agency in favour of collective engagement. The benefits of service co-production are nevertheless visible in successful exemplars where alternative solutions were possible through co-installations, co-management or co-financing with informal settlement dwellers. In this way, innovative technologies that are cheaper than conventional trunk systems have been successfully piloted in various informal settlements in the Global South region through participatory processes.

In the context of South Africa, user-participation in the design and implementation of sanitation technologies has been demonstrated, but still remains a challenge. This is partly because informal urban sanitation in South Africa is a highly contentious issue despite the fact that South Africa is one of the few Sub-Saharan countries that was on track to meet the 2015 MDG goal for improving sanitation. The complexity of providing sanitation in informal urban settlements has thus led to calls for greater user involvement and participation in sanitation interventions in South Africa, as in elsewhere in the Global South region.

The push for service co-production is echoed in transdisciplinary (TD) research as non-academic partners are invited to co-produce both knowledge and services that have social relevance. This is because non-academic partners such as community members or professionals have the experience of or expertise on the social issues at hand. However, power asymmetries abound between partners who engage in TD research as they attempt to transcend disciplinary boundaries and academic confines. Non-academic partners such as informal settlement dwellers may be further disadvantaged because of their limited resources and formal education. To overcome these challenges, reflexivity is necessary to expose positionalities in the co-production process. Acknowledging positionality offers avenues for resolving conflicts or in the very least an opportunity for learning from past conflicts and failures. Exposing positionality requires a critical stance, which is possible through methods such as critical discourse analysis and auto-ethnography.

The creative and generative methods of design such as iteration, visualisation and prototyping can be meaningfully employed to enhance the contribution of non-academic partners. Further, the generative skills of design that focus on the product can be combined with the analytical skills of research for a

more wholesome view of the research problem. The role of the researcher-designer therefore fits in well into the multi-perspective approach of TD research. As researchers who are interested in both the product and the context, researcher-designers can employ design ethnography to understand how technologies (such as sanitation) are socialised within different contexts (such as informal settlements).

CHAPTER THREE

3.0   SOCIO-TECHNOLOGICAL RECIPROCITY AND INNOVATION FOR INFORMAL URBAN SANITATION

3.1 Introduction

Complex societal problems, like inadequate sanitation in informal settlements, require innovative solutions. This article argues that such innovations have to be both social and technological. This is because informal urban contexts lack the institutional and infrastructural frameworks that would support a purely technocratic approach to innovation. Additionally, a purely social approach to innovation is inadequate because informal settlements are materially deprived and require urgent technological interventions, hence the need to develop a more integrative socio-technological approach to solutions for informal urban contexts. This article uses three case studies of sanitation interventions in three informal urban settlements in South Africa, to open up the debate on socio-technological innovation for informal urban sanitation. An analysis of the technical configurations of the piloted sanitation systems and the social interactions that enabled the interventions demonstrate socio-technological reciprocity in the illustrations of technological alternatives and service co-production from the case studies.

Socio-technological reciprocity is further articulated as a model that has three interfaces: technology components interface; people-technology interface and user-provider interface. These interfaces are useful for planning informal urban sanitation exercises because they capture nuanced interrelationships between and within technology and people. The article ends by proposing a way forward for informal urban sanitation in South Africa based on discussions from the 'Gates Sanitation Technology Innovation Seminar' held in Pretoria. Even though it was a seminar on technology, the need for a broader perspective to solving informal urban sanitation in South Africa was emphasised. Ultimately, this article contributes to a more nuanced understanding of informal urban sanitation as a complex, multi-dimensional problem that requires the input of various disciplines including the social sciences.

3.1.1 Technological Dimension of Sanitation

Providing adequate sanitation requires infrastructure that can provide a series of services known as the 'sanitation service chain'. This chain consists of: containment, removal, transport, treatment, and, reuse or disposal of human waste (Hawkins, Blackett & Heymans, 2013). In low-income, informal areas with inadequate sanitation, one or more of this services is not appropriately provided for (ibid). In high income areas, the sanitation service chain has traditionally been provided through a large-scale centralised system of trunk sewerage and flush toilets (Tilley et al., 2014A). Trunk sewerage has thus become the conventional method of providing urban sanitation, and it has changed little since the 18th century (Hurn, 2014). Conventional trunk systems of sanitation have been successful in Western countries but have generally performed poorly in Sub-Saharan Africa. This is because conventional sanitation systems are incongruent with the widespread informal urbanisation patterns of many African cities (Oosterveer & Spaargaren, 2010; Nilsson, 2006). As such, the options for informal settlements are alternative systems, which may be cheaper and easier to install. Simplified sewerage is an example of an alternative technology that has proven to be cheaper and easier to install compared to conventional trunk sewerage (Tilley et al., 2014B).

3.1.2 Social Dimension of Sanitation Provision

One of the causes of poor sanitation in developing areas is blamed on the incapacity of governments that lack the national policies and programmes necessary to transform the sanitation sector. The high urban population growth in developing areas adds further constraints to the proper management of urban sanitation infrastructure and services (Mara, 2012; Mara & Broome, 2008). Social scientists are thus lending their own expertise in a bid to widen the discourse on sanitation beyond technological concerns (Van Vliet, Spaargaren & Oosterveer, 2010). In particular, the social sciences can offer disciplinary perspectives that look at: governance issues, the nature of socio-technical change in sanitation provision, and the role of the citizen-consumer in improving sanitation. Using these perspectives, social scientists can study the interfaces between consumers and providers of sanitation services, as well as the interfaces between people and sanitation infrastructures (Van Vliet, Spaargaren & Oosterveer, 2011).

A purely technocratic approach to sanitation provision in developing regions is therefore ill-advised as it fails to capture the complexity of the problem. One of the common strategies of the technocratic

approach in un-serviced areas has been to simply provide more toilets. This strategy has failed because it does not pay attention to other aspects of sanitation provision such as behavioural change of users or the economic opportunities of improving sanitation (Tilley et al., 2014B). Involving users in sanitation provision in informal areas is therefore advocated for as a way of cutting costs and guaranteeing the use and sustainability of alternative technologies (McGranahan, 2013; Patel, 2015; Tukahirwa, Mol & Oosterveer, 2013).

In South Africa, the poor delivery of basic sanitation infrastructure in dense urban informal settlements is partly attributed to the lack of a common interpretation of the sanitation policy (Mjoli & Bhagwan, 2012). Providing adequate sanitation in informal settlements is further challenged by social, economic and institutional constraints such as: unemployment, fragile social structures, poor management, and the inappropriate terrain of most informal settlements (Lagardien & Muanda, 2014; Mels et al. 2009; Pithey, 2007). The informal urban sanitation discourse is also shaped by narratives of power that evoke the apartheid history of the country (Robin, 2014). In the face of these challenges, informal urban sanitation in South Africa should be tackled collaboratively and with openness to socio-technical diversity (Taing, et al., 2013; Tavener-Smith, 2012; Winter, 2010). The three case studies of this article are thus used to demonstrate socio-technical diversity.

3.2 Method

The Water Research Commission (WRC), through Maluti GSM consulting engineers, provided the funding for the pilot of the pour-flush system in three informal settlements in the Western Cape province of South Africa. The sites for the sanitation interventions were: Klipheuwel, Klein Begin and Enkanini informal settlements. These three sites are the cases that are reported on in this article. In Enkanini, the funding was supplemented by the National Research Foundation (NRF) through Stellenbosch University (SU). As a researcher from the University, I was involved in the interventions in all three cases in varying capacities. It was thus possible to gather primary data from the three cases through participant-observation during the design and installation phases of the interventions. The secondary data on technical specifications and cost estimations were taken from the Maluti GSM report (2014). I use a cross-case synthesis (Yin, 2009) to analyse the technical configurations of the piloted sanitation systems and the social interactions that enabled the interventions in all three cases. That synthesis is the basis for the theoretical articulation of socio-technological reciprocity in informal urban sanitation.

The primary data was drawn from the interactions and relationships that took place in each of the interventions. I was an observer in the first two cases (Klein Begin and Klipheuwel) that took place over a period of two months: March-April 2013. In the third case, I was an active participant in a TD research team known as the Enkanini sanitation working group, over a period of two years: August 2012 to July 2014. The three settlements are also highly varied in their characteristics and so cannot be considered as comparative case studies.

Given my background in industrial and product design, I was keenly interested in the technology as well as in the human relationships that enabled the implementation of the technology. My philosophical standing was therefore social constructivist in understanding the technology as a social construct (Beveridge & Guy 2011; Bijker, Hughes & Pinch 2012). Reciprocally, the technology was a boundary object that shaped the multi-stakeholder interactions (Pohl et al., 2010).

3.3 Case Studies

The case studies are three informal settlements in the Western Cape Province of South Africa (Map 3.1). In all three cases, the technical installations were done by Maluti GSM consulting engineers. The implementation and social arrangements were however different for each settlement. The discussion will analyse the technical specifications of the installed sanitation system in each case, and the social interactions that emerged, more so in the third case, where it was possible to engage more intensely and for a longer period with a multi-stakeholder group.
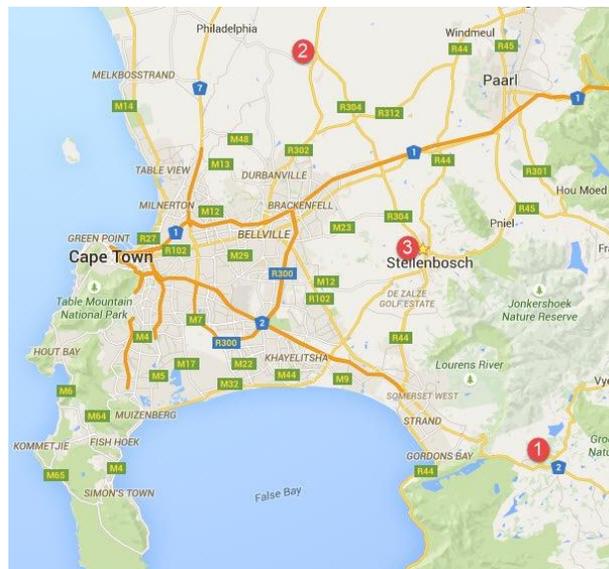
Figure 3.1 Map showing portion of the Western Cape Province with the case studies as: 1) Klein Begin community, 2) Klipheuwel informal settlement, 3) Enkanini informal settlement (Source: Google maps, 2015A)

3.3.1 Klein Begin Community

Figure 3.2 Map of Klein Begin community in Grabouw (Source: Google Earth, 2015B)

The Klein Begin community is a semi-informal settlement in Grabouw town of the Western Cape Province in South Africa. Grabouw is 65km South West of Cape Town and is managed by the Theewaterskloof municipality. The settlement has 39 households that are serviced by shared toilets connected to soak-away pits. The settlement is not a typical informal settlement because it is not crowded; the householders have relatively spacious housing. Nevertheless, the houses are run down, most of the waterborne toilets are non-functional and most of the residents are unemployed. The settlement would thus qualify as a slum according to the UN-Habitat (2004) definition of slum housing as housing that lacks one or more of the basic infrastructural requirements. The settlement's land is jointly owned by the householders so the settlement is not entitled to the basic services that municipalities in South Africa are mandated to provide for informal settlements (Maluti GSM, 2014; Mjoli & Bhagwan, 2012).

I made three site visits to the settlement in the company of the civil engineer from Maluti GSM who was in charge of installations. Several email communications had taken place between the engineer and a member of Lighthouse mission, who runs a crèche in the settlement. The social situation in the settlement is complicated by the high incidences of alcohol and drug abuse, a situation which the Lighthouse mission has been working to ameliorate over a few years. According to their website, the Lighthouse Mission was started in January 2010 and is a non-profit company that has been working in the Klein Begin informal settlement for two years. They work with children with the aims of re-building the family unit (Lighthouse Mission n.d).

Given the limits of WRC funding, the engineer relied on the member of Lighthouse Mission to facilitate interactions with the householders so as to select the sites. The actual installation of the pour-flush system, were carried out between March and April of 2013. Three pour-flush toilets replaced three broken down full-flush toilets. The three pour-flush toilets were connected to the existing soak-away pits of the derelict full-flush toilets. The fourth one was installed in the crèche run by Lighthouse mission, and connected to a 2500 litre anaerobic digester. The digester was a donation to the Lighthouse mission by Sustainable Engineering Solutions (Pty) Ltd.

Figure 3.3 From left to right: Two previously broken down toilets replaced by the pour-flush toilets (Author, 2013)

Figure 3.4 From left to right: Installations at the crèche and the crèche toilet (Author, 2013)

3.3.2 Klipheuwel Informal Settlement

Figure 3.5 Klipheuwel informal settlement is on the outskirts of Cape Town in the Western Cape Province (Source: Google

Earth, 2015C)

Klipheuwel settlement falls under the municipality of Cape Town. It is an informal settlement on private land with about 800 residents. Klipheuwel settlement is also not entitled to municipal services because it is on privately owned property (Maluti GSM, 2014). However, the residents do not own the property; hence they do not enjoy security of tenure. I made four site visits to the settlement, three of them in the company of the civil engineer and one in the company of the construction team. I made two other visits to Biocycle organisation which facilitated meetings between Maluti GSM and a community leader in Klipheuwel. Biocycle has been collecting human waste from the settlement to use as feed for black soldier flies (BSF). The larvae of the BSF are then dried and turned into protein feed for chicken. According to their website, Biocycle is concerned with the sanitation problem; hence it is developing commercially viable and scalable processes for the 'bio-conversion' of human faecal waste into valuable products, using BSF larvae. Human waste is thus turned into a valuable resource to improve sanitation services and increase food security through closed loop nutrient recycling (The Biocycle n.d).

Klipheuwel is not connected to any conventional sanitation but is supplied with 500 Afrisan urine diversion dehydration (UDD) toilets that were installed in an earlier sanitation intervention. The City of Cape Town has provided an additional number of chemical toilets and also pays for the cleaning of the existing UDD toilets. Many of these UDD toilets are broken down due to improper usage. For instance, the separation of urine from faecal matter requires the turning of a lever, a process which proved complicated even for the civil engineer from Maluti GSM. The toilet bowls are also very large and ill-fitting for the small concrete cubicles that house them, while water needs to be added often into an evaporation system to avoid a malfunctioning of the entire system.

The installations of the pour-flush toilets were done between March and April of 2013; five pour-flush toilets were installed to serve individual households in a newer part of the settlement that is completely un-serviced. This area was identified by the community leader who, from observation, enjoyed the respect of most people in the settlement. In each of the visits, the leader led the tours and had a list of the households in the settlement. He therefore pointed out the would-be beneficiaries, based on the engineer's advice that the toilets should be installed close to each other so that they could share the piping and the septic tank. After selection, the five beneficiary households in the settlement were asked to choose suitable areas near their homes where the toilets would be constructed. Most chose to have the toilets as far from their house as possible, probably due to their experience with smelly pit latrines. The pour-flush toilet however does not smell because it maintains a water seal in its outlet just like a

conventional toilet bowl. The five toilets were then connected to a 2200 litre septic tank via simplified piping. Based on household demand, it is estimated that the tank can serve up to 100 individual household toilets (Maluti GSM 2014). The intention is for the septic tank to be retrofitted with a solid waste trap at its inlet for periodical emptying by Biocycle. Biocycle has already established a BSF plant

near the settlement and has continued to collect human waste from the settlement.

Figure 3.6 From left to right: Visit to Klipheuwel with the engineer. We met with Victor, the settlement's de facto leader; The contractor discussing the technical details of the installation with one of the residents involved in the construction (Author, 2013)

71

I was able to observe the installations more in Klipheuwel and learn more about the technical specifications of the pour-flush toilet: It is connected via simplified (shallow) piping. The piping is simple to install as it does not require the deep trenches of standard trunk sewerage piping. Due to its smaller diameter, the piping can also be bent more often around irregular spaces. It has rodding eyes, which are simplified inspection chambers that are cheaper than manholes. The contractor worked with a few local residents to put up the toilets. I helped to paint the doors of the toilets. This gave me a chance to speak further to the contractors and the beneficiaries.

3.3.3 Enkanini Informal Settlement

Figure 3.7 Map of Enkanini informal settlement in Stellenbosch (Source: Google Earth, 2015D)

Enkanini informal settlement is in Stellenbosch Town and falls under Stellenbosch municipality. It emerged in 2005 from an invasion of municipal land zoned off for agriculture. The shacks that make up the settlement lie between the Kayamandi Township, the Nature reserve of Papegaaiberg, a wine farm and the industrial area of Plankenbrug. The Stellenbosch Municipality, under the control of the Democratic Alliance (DA) political party, had applied for a court order to remove the initial intrusion

of approximately 100 shacks. Approval was granted but the court order was not carried out promptly and so the settlement grew rapidly in the next few years. This means that the settlement's status is precarious since there is an eviction order over it, although that order may be impossible to execute now that the settlement has over 2400 shacks (Seeliger & Turok, 2014).

Enkanini is a vulnerable community because its residents live in danger of hunger, ill-health, fire outbreaks, crime and social marginalisation. The vulnerability and instability in the community also undermine the possibilities of collective organisation. Enkanini has not been electrified because of its informal status and so residents have tapped illegally into the electricity boxes of businesses in the industrial area and homes in the adjacent township. The precarious overhead or underground cable installations, with exposed wiring between shacks, make young children particularly vulnerable to electric shocks. Enkanini residents are also blamed for 'desecrating' local heritage because they have encroached on a nature reserve of cultural, ecological value. For instance, the hilltop of Papegaaiberg is home to a critically endangered plant species known as 'renosterveld', and the historical founder of the town, Simon van der Stel, used the area for shooting practice. Prehistoric stone implements have also been found on the western slope, giving the area some archaeological significance (ibid).

The only enumeration exercise in the settlement was done by the Stellenbosch Municipality in collaboration with an NGO known as community organisation resource centre (CORC). The enumeration report, titled the 'Enkanini (Kayamandi) household enumeration report', shows that Enkanini settlement has about 2,500 households with a population of about 4,200. Most of these residents are from the neighbouring Kayamandi Township, where there is a shortage of space in family homes (Stellenbosch Municipality, 2013). Enkanini residents are mostly job seekers who look for work in the wine farms and in the rich suburbs of Stellenbosch. Stellenbosch town is the second oldest 'white' settlement in South Africa after Cape Town. It is therefore rich in colonial architecture whose long history is markedly opposed to the transience of Enkanini's shacks (Grundlingh & Scott, 2012).

In Enkanini, a team of SU researchers, funded by NRF, had been involved in a variety of research projects since 2011. The researchers had also been working with co-researchers who are residents of Enkanini, and so a TD research process was already underway when the sanitation intervention took place. The SU researchers were therefore able to facilitate the sanitation intervention in Enkanini. Five shared pour-flush toilets were installed and connected to an anaerobic digester via simplified sewerage in phase one of the intervention in 2013.

The anaerobic digester was the first component of the system to be installed in March 2013. According the company that supplied the digester, the Biogaspro-6 digester installed in Enkanini can handle a maximum of 1000 litres of water per day. The digester has a height of 2,225 mm and a diameter of 2,160 mm (Biogaspro Agama Energy, 2014), hence it had to be buried underground below the Enkanini research centre (ERC). The day of installing the digester was an opportunity to engage with the residents when they came to inquire about the digester. The daily loading limits of the digester are specified as: cow manure – 50kg/day; food waste – 35kg/day; grass silage – 25kg/day. Each cubic metre of biogas produced from the digester has the heating value of 0.43 kg LP gas (Biogaspro Agama Energy, 2014). The human waste in the digester was therefore supplemented from time to time with cow manure from a neighbouring farm and food waste from Enkanini households. Adding food waste to the digester meant that there was less food waste finding its way into the settlements open waste skips, thereby reducing the potential for vermin invasion of the skips.

The estimate is that the digester, at optimal capacity, can serve up to 10 shared toilets or 40 individual toilets in households. So far, the five pour-flush toilets are the only ones connected to the digester and so the gas production is not yet optimal. The continued research engagements in Enkanini allowed for a phase two of the intervention in 2014, which was ongoing at the time of submitting this dissertation. In phase two, the pour-flush toilets were to be upgraded to automated micro-flush toilets. Biogas trials were also carried out in phase two of the intervention. In these trials, daily data was collected on the amount of food waste loaded into the digester, and the length of time it took to cook with the gas produced. So far, the gas is being used at the kitchen of the ERC only, but the plan is to supply the beneficiaries with the gas in future.

3.3.4 Technical Configurations and Social Interactions in the Three Case Studies

Maluti GSM engineers had funding for the technical installations of the pour-flush system, but it was necessary for them to work with other stakeholders who had already established relationships in the settlements to facilitate the interventions. In Klein Begin and Klipheuwel, the interactions were short-term (two months) and were dependent on pre-existing working relationships, for example between Maluti GSM engineers and engineers at Biocycle, Sustainable Engineering Solutions and Agama Energy. In Enkanini, SU researchers were already engaged in the settlement and it was possible to extend the sanitation intervention over a period of two years and beyond. The social interactions were

thus interrelated and bounded around the technical installations. These interrelationships brought about the reciprocity between technology and society (Peine & Herrmann, 2012). In the particular case of sanitation, reciprocity is urged for in the work of Lopes, Fam and Williams (2012), who conclude that sanitation technologies need to be 'socialised' if they are to be successful in specific social contexts. In the three cases of this article, the sanitation technology was socialised differently through the interrelationships described above.

After the installations in all three settlements, Mr. Jayant Bhagwan, the executive manager in charge of water use and waste management at WRC, visited the three pilot sites in August 2013. I was present during these visits in which Mr. Baghwan expressed his satisfaction with the installations. However, in Klein Begin, the installed toilets appeared to be run down already after such a short time. One of the householders explained that there was a fight between two users who vandalised one of toilets. Another resident nailed the door of the toilet shut to prevent his neighbours from vandalising it. The high incidences of drug abuse resulted in frequent violent altercations in the settlement according to the Lighthouse mission manager. Consequently, the pour-flush toilets, though technically sound, failed to serve their purpose in this settlement because of the social situation there: the technology was poorly socialised.

In the other two sites, the toilets were functioning properly at the time of the visit. Users expressed satisfaction when asked about the toilets. In Klipheuwel, one householder whose toilet was installed close to her home took great pride in the toilet and had decorated it with mats. After the visits, the civil engineer in charge of installations was called later in the year to unblock a pipe in Klipheuwel. In Enkanini, SU researchers facilitated the extension of the sanitation intervention, resulting in a better understanding of the socialisation process as will be discussed in the subsequent chapters. Table 3.1 summarises the cross-case synthesis.

Sanitation intervention Case studies	Socio-technological reciprocity	
	Technical configurations: Installed by Maluti GSM supported by WRC	Social interactions:
Klein Begin: 39 Households Existing shared flush toilets	• 4 toilets: Shared amongst 2-3 households per toilet • 1 crèche toilet • Connection to existing soak-away pits via simplified piping • Crèche toilet connected to anaerobic digester: 2500 litres capacity; 500g LPG equivalent per day at optimal levels • Onsite system	Lighthouse mission Sustainable Engineering Solutions (Pty) Ltd.
Klipheuwel: 800 residents Existing chemical toilets and Afrisan toilets	• 5 toilets: For 5 individual households • Connection to a 2200 litre septic tank via simplified piping • Onsite system	Local settlement leader Biocycle organisation
Enkanini: 4449 residents Existing communal toilet blocks	• 4 toilets: Shared amongst 5 households per toilet • 1 toilet at ERC • Connection to an anaerobic digester via simplified piping • Anaerobic digester: reactor volume of 4050 litres estimated capacity; 1080 litres of effluent per day • Overflow from the digester connected to conventional municipal trunk sewer • Semi-decentralised system	Stellenbosch University researchers Enkanini co-researchers Agama Energy

Table 3.1 Cross-case synthesis of the technical configurations and social interactions in the three case studies

3.4 Technological Alternatives for Informal Settlements

3.4.1 Pour-Flush Toilet with P-Trap Design

The specific bowl used in the interventions was first piloted by Still and Louton (2012) in rural settlements in the Eastern Cape Province of South Africa with WRC funding. The bowl has a 25mm water seal within a long radius P-trap. The small volume of water in the water-seal and the gradual bend of the P-trap allow the toilet to flush on one to two litres of water (Figure 3.9). In the interventions, the users were encouraged to flush the toilet with grey domestic wastewater that would otherwise find its way into the open drains in the settlement. Because of its water seal, the pour-flush keeps away odours and flies and so it can be installed inside or close to the house (Maluti GSM, 2014). As such, the pour-flush toilet is a well-functioning 'user-interface component' in the sanitation system (Tilley et al., 2014A), because it keeps away odours and flies, and uses less water than a conventional cistern flush toilet that uses up to 7 litres (Maluti GSM, 2014).

Figure 3.8 Pour-flush pedestal and P-trap design (source: Maluti GSM, 2014)

Citing the work done by Still and Louton as well as Maluti GSM, Van Vuuren (2014) suggests that the pour-flush technology is suitable for informal urban areas in South Africa because it is preferred to a VIP latrine and is also cheaper than a conventional cistern flush toilet. Cistern toilets also require expert skills to install and maintain (Tilley et al., 2014B). The pour-flush toilet on the other hand is

easier to install especially when connected to simplified piping. Expert supervision was nevertheless required to ensure that the installations were done properly in the interventions.

3.4.2 Simplified Piping

Figure 3.9 Simplified piping with a rodding eye outlet

In all three cases, simplified piping was used as the means of conveyance for excreta from the toilets to the soak-aways, septic tank or anaerobic digester. Simplified piping is an alternative to over-designed trunk sewerage piping because it uses small diameter pipes that can meander around irregular spaces without the need for massive excavation or costly manholes. Instead, this shallower piping that has simplified inspection chambers (rodding eyes), can be installed in backyards and narrow streets (Eales, 2008; Mara, 2012). In this way, sewerage infrastructure can be constructed *in situ*, precluding the need for resettlement. In informal urban areas, resettlement is often resisted by inhabitants who want to preserve their existing economic and social networks (Govender, Barnes & Pieper, 2010; Huchzermeyer, 2009). Simplified sewerage is therefore a viable and cheaper option that has already been used extensively in South American countries as well as in Pakistan and South Africa (Mara, 2012).

3.4.3 Decentralised/Semi-Decentralised Treatment

In Klein Begin, the toilets were connected to existing soak-aways because the 39 houses are on a relatively large piece of land. It is therefore a sparsely populated settlement unlike Enkanini, where

there is no space for soak-aways. In Klipheuwel, the toilets were connected to a septic tank that partially breaks down the excreta which is then emptied into a soak-away pit. In Enkanini, the anaerobic digester breaks down the excreta and produces biogas that is used for cooking in the ERC. The excess effluent is released into the municipal trunk sewer at a drastically reduced volume and content. The fourth toilet in Klein Begin is also connected to a digester and produces biogas for cooking in the crèche.

Figure 3.10 The Biogaspro anaerobic digester at Enkanini

Both the septic tank and the anaerobic digesters provide either full or partial onsite treatment that allows the system to be either fully detached (decentralised) or partially detached (semi-decentralised) from conventional trunk sewerage. As already mentioned, centralised trunk sewerage is becoming unsustainable; hence decentralised systems such as those demonstrated in the cases, are encouraged since they can be installed faster, monitored better and failures in the system can be contained and dealt with without interfering with a large central system (George, 2008; Paterson, Mara & Curtis, 2007).

3.4.4 Resource and Cost Savings (Beneficiation)

Given the low flush volumes, the estimate is that there is a massive reduction in the amount of discharge that pour-flush toilets would add to a conventional system compared a similar number of full-flush cistern toilets. Even in the event that there was no pre-treatment through anaerobic digestion.

The biogas from the digesters is also used as energy for cooking, hence replacing the high cost and safety threats of using paraffin in informal settlements. It is also estimated that the cost of installations in all three cases is lower than installing VIP latrines, which require land space for pits with slabs on top. Simplified piping, which is cheaper than trunk sewerage also made it possible to use local labour in Enkanini and in Klipheuwel (Maluti GSM, 2014).

Beneficiation as a concept refers to the re-use of human waste to close the nutrient-cycle or to generate energy as in anaerobic digestion. Such approaches can also be referred to as ecological sanitation practices (Anand & Apul, 2014; Haq & Cambridge, 2012). The solids from the septic tank in Klipheuwel are emptied occasionally by Biocycle for use as BSF larvae feed. Waste is thus a resource that provides nutrients for the BSF larvae which in turn are used as chicken feed. Since chicken is human food, the nutrient cycle becomes a closed loop. Consequently, the Klipheuwel system provides several benefits of improving sanitation, improving food security and creating jobs for residents working in the BSF plant. In the other two systems, biogas is produced from the human waste; hence saving on energy costs.

3.4.5 Technical Hybridisation

The installation of technical components in each case took on different configurations, based on the particular requirements and resources in each of the settlements. These different ways of implementation show that it is possible to have a sanitation solution that is flexible and installed incrementally in response to growing acceptability and availability of resources in informal urban contexts. In Enkanini for example, the pour-flush toilets were later to be upgraded to automated low flush toilets referred to as the 'micro-flush'. The micro-flush is designed to have a filter and a cistern to improve the user-interface experience, by automating the flush system. The micro-flush is thus a disruptive technology that could be translated to non-poor contexts, where automated systems are favoured. This thinking is promoted by Prahalad (2012), as well as Hall, Matos and Martin (2014) who view low-income contexts as opportunities for experimentation with alternative technologies and arrangements that are hard or impossible to carry out in industrialised contexts with technological lock-ins.

3.5 Towards Service Co-Production with Informal Settlement Dwellers

In Klipheuwel and Enkanini, community members were involved in the installations. In Klipheuwel residents were hired to dig the trenches, lay the pipes and build the structures of the toilets. In Enkanini, residents were hired to assist in the construction, as well as to operate and maintain the anaerobic digester as pilot operators. The remuneration was based on average daily rates for hand labour and was paid from the WRC and NRF funds. Such participation is an income generation opportunity for residents in the short term. In the long run, participation is a chance to train local constructors and managers who can sustain informal urban sanitation systems and innovation.

Figure 3.11 Klipheuwel residents involved in the construction of the pour-flush toilets

3.6 Model for Socio-Technological Reciprocity in Informal Urban Sanitation

To better explain reciprocity, the components of the technology in the three cases can be used as an analogy for the social context of the three case studies. The pour-flush technology along with the simplified piping, are less rigid and restrictive compared to conventional trunk sewerage, and so they are more congruent and adaptive to the unplanned building processes in the informal contexts of the case studies. Tonkiss (2013) uses the term organic to describe the adaptive method of informal urbanism. Borrowing this term, simplified sewerage can be termed as organic in structure. Additionally, the hybridisation of the technical components is a metaphor for the different ways in which stakeholders were engaged in each case. Engagements were configured based on the available

financial and social resources. Such configurations may result in revolutionary innovations that cannot be realised in the locked-in, conventional systems of highly industrialised contexts.

Using the case of Enkanini, it is possible to articulate interfaces between technological components, users and providers. As researchers, we facilitated the interactions between the experts and the beneficiaries since we could dedicate more time to interacting with residents. In that regard, we organised beneficiary workshops and held frequent meetings with the Maluti GSM engineer in charge of installations. We also had to consult often with Agama Energy engineers about the digester. Table 3.2 displays how these interactions in a matrix relationship.

	Technical configurations	Social interactions	
Technology components interface	Pour-flush toilet Simplified piping Anaerobic digester Semi-decentralised system	Enkanini residents	User-Provider interface
		Enkanini co-researchers, SU researchers	
		Maluti GSM engineer Agama Energy engineers	
	Technology-people interface		

Table 3.2 Three interfaces of socio-technological reciprocity: interface between technologies; interface between people and technology; and interface between users and providers

At a more conceptual level, the three interfaces form a cyclic logic model that has theoretical significance for informal urban sanitation (Figure 3.12).
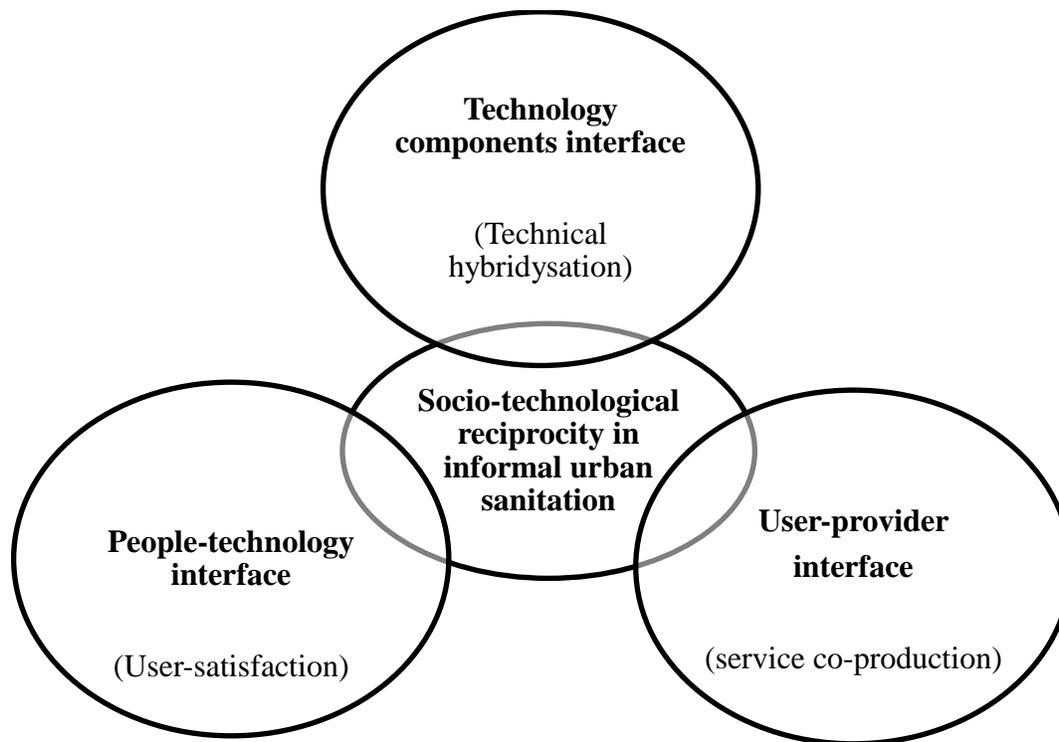
Figure 3.12 Conceptual model for socio-technological reciprocity

The articulation of reciprocity in this way enforces the metaphorical capacity of the sanitation system. It has become an artefact of engagement (Appel et al. 2015; Simone 2015) or boundary object (Pohl et al., 2010) that is constituted by the relevant social group. The individuals in the social grouping interact and engaged around the boundary object. The sanitation system therefore gives relevance to the social group, which is constituted by individual actors of diverse backgrounds with a common interest in sanitation provision. The technology itself is a complex entity with components that interact.

The variety of interactions means that conflict is likely to occur whenever there is a breakdown in communication, or there is pressure from external factors beyond the control of the group. Using the example of Klipheuwel, interactions between technological components broke down when the simplified pipe got blocked. In Klein Begin, an altercation between two beneficiaries led to the destruction of one toilet. Facilitation is therefore important to mediate the interfaces and the social sciences are best place to articulate how such facilitation takes place. Ultimately, the socio-technological reciprocity model is an integrative conceptualisation of informal urban sanitation that takes care of the nuanced interactions between technology and people.

3.7 Way Forward for Informal Urban Sanitation Discourse in South Africa

In my quest to better understand sanitation in South Africa, I attended the 'Gates sanitation technology innovation seminar' held in Pretoria, South Africa in October 2014. A variety of stakeholders including government officials, experts and community activists attended the meeting; hence their discussions highlighted the current discourse and future proposals for improving sanitation in South Africa. The findings from the three case studies are embedded within this discourse to show the practical and empirical significance of this article.

At the seminar, five of the technologies from the Gates fund were proposed for piloting in South Africa. The pilots by the five selected BMGF grantees will be carried out in the Eastern Cape under a programme known as the 'San Tech Demo Programme'. These selected technologies are expected to have low operational and maintenance requirements and to encourage beneficiation of waste streams. The South African government has committed 30 million rands to the programme, while the BMGF will provide an additional one million US dollars (Water Research Commission, 2014). These BMGF sponsored projects demonstrate the ardent search for solutions to the sanitation problem in South Africa.

According to Jayant Bhagwan of the WRC, who opened the seminar, South Africa is set to become a frontrunner in sanitation technologies by allowing the pilots of the BMGF technologies. Imraan Patel of the Department of Science and Technology (DST) of South Africa also praised the off-grid technologies of the BMGF grantees. According to him, off-grid sanitation technologies are an improvement from the large-scale sewerage technologies that have failed to serve the poor. He proposed that the triple challenge of poverty, inequality and unemployment should be an opportunity to develop alternative systems in partnerships between local providers, manufacturers and government. Cyprian Mazubane from the newly created government department of water and sanitation, South Africa, also explained the state of sanitation in South Africa. According to him, alternative technologies are needed to replace the VIP latrines in informal urban areas, as VIPs are not considered acceptable by users. Jay Bhagwan articulated the corporate strategy of the WRC which takes into account five aspects of user, institutional, environmental, technology, and financial aspects. The three case studies contribute to this type of thinking by having demonstrated the potential of the pour-flush toilet as an off-grid, cheaper alternative, which can be installed in collaboration with informal settlement dwellers.

The seminar was well attended by government officials, local experts and community activists. Community activists from informal settlements and experts from industry raised issues about the viability of the hi-tech BMGF proposals for congested settlements, where informal settlement dwellers may lack the expertise to manage hi-tech systems. Jay and Kone from BMGF defended the technologies and said they should have to be tested so as to address these concerns, hence the pilot in South Africa. The seminar was a great opportunity to understand the sanitation situation on South Africa and the opportunities that are being pursued. The government, through the new ministry of water & sanitation is clearly aware of the country's sanitation problem and promises to tackle it decisively. Jay talked about the need for non-engineers to get involved in sanitation so as to address the social issues of sanitation especially with regards to the users. He also talked about the need to understand the context in which sanitation technologies are implemented, thus confirming the role of a social science perspective in addressing sanitation problems.

Overall, the deliberations at the seminar underscored the need for a broader perspective to tackling informal urban sanitation in South Africa. The three case studies of this article have illustrated an integrative socio-technological perspective. There is a need to further investigate the political perspective in light of the current political contentions that surround the provision of sanitation in informal settlements in South Africa. A financial perspective is also necessary in understanding the viability of the co-management models proposed in participatory sanitation.

3.8 Conclusion

This article has argued that informal urban sanitation should be tackled through an integrative socio-technological approach, which takes into account the nuances between technological and social aspects of sanitation provision. Three cases studies of sanitation interventions in informal urban settlements in South Africa were used as case studies. As an observer in two of the cases and an active participant in the third case, I was able to understand the emerging socio-technological reciprocity of the sanitation interventions by adopting a constructivist paradigm. The constructivist paradigm led to the unpacking of reciprocity as: technological alternatives (pour-flush toilet, simplified piping, decentralised treatment, beneficiation and technical hybridisation), juxtaposed with demonstrations of service co-production. In other words, the technological and the social were mutually constituting.

A proposed model for socio-technological reciprocity further articulates mutuality in three interfaces between: technology components; users and providers; and people and technology. These interfaces are considerations for planning informal urban sanitation exercises. The findings from the three case studies are in line with the deliberations at the Gates sanitation technology innovation seminar in Pretoria, in which sanitation stakeholders deliberated on a multi-perspective view of sanitation provision in South Africa. The continuing work by SU researchers in informal settlements is therefore a step in the right direction that will hopefully reveal how socio-technological innovation can be leveraged to achieve long-term transformative change in informal settlements. The lessons learnt in South Africa could be theoretically significant for other Sub-Saharan Africa countries facing similar or even worse sanitation problems.

CHAPTER FOUR

4.0   CHALLENGES OF TRANSDISCIPLINARY RESEARCH IN AN INFORMAL SETTLEMENT CONTEXT

4.1 Introduction

Transdisciplinary (TD) research has gained popularity as a new mode of science that transcends disciplinary boundaries in search of scientific solutions to social problems by integrating science and society. However, the real world settings in which TD research is carried out are often volatile and incongruent to the structured processes of academia. The challenges of TD research have thus received attention in literature although few authors have used empirical examples to demonstrate these challenges. To fill in this gap, I discuss our experience of working in a TD setting in an informal settlement in South Africa. The work was carried out by the Enkanini sanitation working group that comprised of a civil engineer, university researchers and Enkanini residents. The group implemented a sanitation intervention in Section E of the settlement. As a member of the group for two years, I had an in-depth understanding of the group's dynamics and used that to analyse focus group discussions and naturally-occurring interactions within the group. From the analyses I unveil themes of knowledge co-production as key considerations in TD research. The findings are important for informing future TD work in informal contexts. The findings are also theoretically significant for establishing a more coherent TD methodology.

4.2 Method

I joined the Enkanini sanitation working group in October 2012 till July 2014. I organised three focus group discussions (FDGs) with beneficiaries and with the working group. I was also interested in naturally-occurring interactions so I gathered excerpts of Email conversations and WhatsApp group messages of the group. Using these data, I was able to capture the emergent narrative of the group. In general, I use critical discourse analysis (CDA) to unveil the power differentials of the group's narrative (Fairclough, 2005; De Melo Resende, 2012). More specifically, I use intuitive inquiry to manually code and memo the data, based on my familiarity with the case study context (Andrade,

2009). I therefore provide contextual explanations and empirical regularities (Tsang, 2013) as themes of knowledge co-production.

4.3 Transdisciplinary Research

TD research has gained popularity as a new mode of science that transcends disciplinary boundaries in order to attain a systemic and integrative perspective of knowledge. At a practical level, TD research is a method that brings together academic and non-academic actors in a collective endeavour to construct new knowledge that can solve pressing societal problems (Darbellay, 2015). The collaboration with non-academic partners in the co-production of scientific knowledge is premised on the assumption that societal problems are best solved in partnership with stakeholders by virtue of their lived experience or expertise in the problem area at stake (Pohl, 2011). These non-academic partners are in effect co-researchers, who should ideally be involved in the analysis and evaluation of data (Finlay, 2002).

Proponents of TD research stress that TD knowledge that is co-produced between science and society is more societally relevant than monodisciplinary or interdisciplinary knowledge (Hadorn et al., 2008; Lang et al., 2012; Wickson & Carew, 2014). This is because monodisciplinary knowledge separates science from society, while interdisciplinary knowledge does not require any change in working methods despite co-operation between science and society. In contrast, TD research necessitates a shift in the research approach given the complexity of working in unpredictable real world contexts that do not adhere to scholarly tenets (Regeer & Bunders, 2009).

A change in working methods is an iterative process that allows researchers to repeatedly test methods so as to adapt to the unforeseen changes in a real world TD context (Pohl and Hadorn, 2008). Self-reflexivity also allows TD researchers to be aware of their identity and positionality, so as to analyse the embodiment of values, social commitment and political views of actors in the multi-stakeholder engagements of TD settings (Haddock & Tornaghi, 2013).

As pointed out by Rickinson, Sebba and Edwards (2011), multi-stakeholder research processes are often: poorly conceptualised, difficult to manage, superficial or limited in scale, and weakly evidenced. Such processes also necessitate the blurring of boundaries between disciplines as well as between academic and non-academic constructs in the case of TD settings (Pohl et al., 2010). That blurring of boundaries can be frustrating for researchers who are still expected to fulfil the scholarly requirements of their bounded disciplines (Lingard, Schryer, Spafford & Campbell, 2007). Further, non-academic

88

partners may have interests and capabilities that are incongruent to the research process and they may therefore not contribute as much as is expected. Researchers also tend to have a higher stake in TD research processes, which results in the very power imbalances that TD researchers want to break down (Polk, 2015). As demonstrated by Buizer et al. (2015) non-academic actors may not engage actively in a collaborative research process because their personal or professional interests are not aligned with that of the research process as much as that of the researchers.

Researching in non-Western contexts may pose additional challenges to TD researchers, who may not understand the cultural nuances of their research setting and may therefore employ unsuitable mainstream methods such as using key informants who end up skewing the research process (Narag & Maxwell, 2013). Highly educated researchers working with informal settlement (slum) dwellers who may have limited formal education may also result in incongruences between the structured research methods of the researchers and the non-formal social processes in informal settlements (Brown-Luthango, 2013).

To deal with these challenges, TD researchers have to become 'knowledge brokers' who on the one hand produce a science that is credible but is also societally relevant. This means that they have to be rigorous in their research, while maintaining friendly engagements with different stakeholders (Turnhout, Stuiver, Klostermann, Harms & Leeuwis, 2013). Such knowledge brokering requires unique competencies to facilitate multi-way dialogues and to approximate perspectives from various fields. Grin, Felix, Bos and Spoelstra (2004) insist that approximation – as the congruence of common interests rather than the realisation of full consensus – is what can be realistically expected in such multi-stakeholder engagements, as opposed to the full integration of knowledge that is advocated for in TD research.

In practice therefore, the co-production of knowledge in TD settings, though aspired to, is actually very difficult to achieve in a real world context, more so in an informal settlement context such as the Enkanini case. I thus use the collective and individual subjectivities and roles in the Enkanini case to illustrate the challenges of TD research, which offer insights into how future TD research in informal settlement contexts can be improved.

4.4 Enkanini Informal Settlement as a TD Research Context

Enkanini informal settlement in Stellenbosch Municipality, South Africa, emerged when residents from the neighbouring Kayamandi Township, erected 100 'shacks' in the open space next to the township (Seeliger a& Turok, 2014). The settlement now has 4449 residents, who share 8 communal toilet blocks, at a ratio of 1 toilet for every 72 residents, according to an enumeration report carried out by the local municipality in 2012 (Stellenbosch Municipality, 2013). Other accounts claim that the population in Enkanini is much higher: between '8000 to 10000' residents (Tavener-Smith, 2012:69). The disparities in population figures demonstrate the contestations that surround the continued growth of Enkanini. I use the figures in the enumeration report since it is the only exercise of its kind so far.
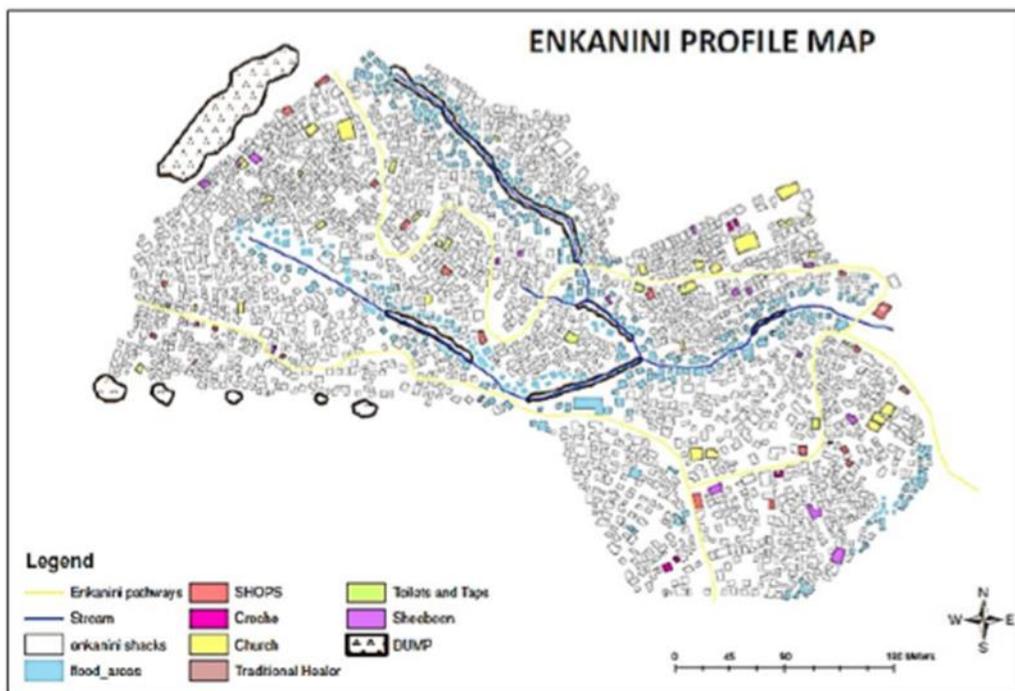
Figure 4.1 Profile Map of Enkanini (Source: Stellenbosch Municipality, 2013)

The overflowing sewers and open drains in Enkanini drain into a stream which connects to the larger Plankenbrug River that runs below it. As a result, the river has a '…very high count of Escharichia coli (E.coli) of up to 13 million per 100 millilitre' (Sebitosi, 2012:142). This means that the consequences of inadequate sanitation are not confined to the informal settlement; they also affect the wider Stellenbosch town through which the Plankenbrug River runs.

In more general terms, there are several hindrances to proper sanitation provision in informal settlements in South Africa. Some of them are: the inappropriate terrain in which informal settlements

90

typically emerge, the lack of tenure of informal settlement residents and the high population densities in such settlements (Mels et al., 2009). Sanitation for informal settlements is also a highly politicized issue in South Africa, evidenced by protests that sometimes turn violent (Robins 2014A). Sanitation experts and researchers therefore advise that the quest for sanitation provision in informal settlements in South Africa should adopt community engagement strategies that promote the participation of informal settlement dwellers in the actual implementation of sanitation interventions (Lagardien & Muanda, 2014; Taing et al., 2013).

Set against this backdrop, several Stellenbosch University (SU) researchers have made efforts to engage Enkanini residents in research projects to improve the settlement. In our case, that interest was shaped by a TD programme at SU known as the TsamaHUB that promotes a problem-centred TD research approach. TsamaHUB stands for: 'Transdisciplinary, Sustainability, Analysis, Modelling & Assessment HUB'. Two of its mission statements are:

> *'[…]to seek, encourage and facilitate Sustainable community building interventions and activities in cooperation with community-based organisations, with a view to firmly ground its knowledge-production endeavors in context and praxis; and the co-production of knowledge between the academic, government, non-governmental and private sectors so as to accept mutual responsibility for policy-making, implementation, monitoring of research findings' (TsamaHUB, 2013).*

A problem-centred TD approach in research means that a visible social problem, such as inadequate sanitation, is at the core of the research agenda whose goal is to bring about social change (Leavy 2011). The TsamaHUB uses this TD approach to bring together researchers from diverse disciplines to work on social problems, and Enkanini is a proximate context within which to explore a TD approach. This led to the formation of the 'Informal Settlement Upgrading Group' (ISUG) that undertook collaborative research with residents in Enkanini. As a doctoral student affiliated with the TsamaHUB, my own research was therefore necessarily shaped by a TD agenda.

4.4.1 Enkanini Sanitation Working Group

In November 2012, a sanitation working group was carved out of the larger ISUG. It consisted of: 1 civil engineer from Maluti GSM consulting engineers; 2 SU doctoral students (I included); and three Enkanini co-researchers. In 2013, two SU masters students joined the group, and the three initial co-researchers were replaced by four others. These first three co-researchers joined other projects such as

91

the Ishack project on energy and the food waste project that they were more familiar with. 20 residents from Section E of Enkanini became the first beneficiaries of the sanitation intervention. There was also a concerted effort to collaborate with the municipality: Meetings were held between the sanitation working group and the local councillor as well as with other municipality officials from the informal settlements department of Stellenbosch Municipality. However, these meetings remained rather casual and the municipality was never formally involved in the sanitation intervention by the working group.

Intensive interactions in the sanitation working group led to the implementation of the sanitation system in Section E of Enkanini between April and December of 2013. This became known as the phase one of the intervention. A phase two started in April of 2014 and was ongoing at the time of submitting this dissertation. The role of team leader was naturally assumed by one of the PhD researchers, whose previous research in Enkanini since 2011 formed the foundation for the intervention. In this regard, the different research backgrounds of the two PhD candidates: economics and product design, were complementary as they had strengths in quantitative and qualitative approaches respectively.

There were other interdisciplinary exchanges between the researchers themselves and also between the researchers and the engineer. For instance, there was a lot of Email and WhatsApp communication between the researchers and the engineer. As such, the two PhD researchers and the engineer formed the core of the team. The Masters students and the co-researchers formed a 'second layer' of interaction around the core team and together, the interactions in the sanitation intervention were bounded around the pour-flush pilot system. The sanitation technology was therefore a 'boundary object' around which the interactions were coagulated (Pohl et al., 2010). Having a sanitation system as a boundary object was an important way to bind the academic interests of the researchers, the technological concerns of the engineers, and the practical needs and preferences of the co-researchers and beneficiaries.

The long-term engagement of the researchers into the Enkanini context was a process of immersion into the research context. For my part, I went on 21 visits to the settlement between August 2012 and December 2013. This included spending a night at a co-researcher's house in the settlement. There were also continuous interactions amongst the members of the working group and so the relationships became less formal with time.

In 2013, the sanitation working group formed the Enkanini sanitation co-operative (ESC) to manage the upgrading of the sanitation intervention. An ESC bank account was opened and controlled by a co-researcher with the help of a researcher. By December 2013, disputes over the control of this account, together with other conflicts within the sanitation working group, led to the closure of the ESC and its account. In 2014, the Enkanini sanitation intervention continued into phase two but with a changed working group: the Masters students finished their research while the five co-researchers were dropped from the research. The pour-flush toilet system was also to be replaced by the micro-flush system. The intervention was therefore a volatile and iterative design process which changed inadvertently over time.

4.4.2 Focus Group Discussions (FDGs)

4.4.2.1 Mobilisation of Users FDG

The would-be users in the Enkanini sanitation intervention were drawn from Section E of Enkanini, where the anaerobic digester had already been installed in early 2013. The digester was installed at the ERC, which had been constructed with funds from NRF. The toilets had to be installed close to the digester so that they would drain into it by gravity. Accordingly, we the researchers and engineer invited 42 households near the ERC to several workshops to introduce the sanitation intervention and interest them in becoming beneficiaries. I had observed earlier that the would-be users were not active participants in the implementation process. For instance, in the briefing workshops, many of the would-be users were not comfortable speaking in English, and they therefore kept quiet or only gave very short answers to questions. Only a few residents, who appeared to be more articulate, were able to air their concerns about the intervention to a much greater extent. In this regard, only two residents raised several objections in two of the workshops. The conclusion therefore was that verbal communication alone was not an effective way to engage meaningfully with the residents; hence I introduced visual tools in the focus-group sessions that I organised.

With the help of an SU art postgraduate student (Susan Immelman), I later organised an FGD on grey-water use as a way of introducing the pour-flush toilet system to the would-be beneficiaries. One co-researcher invited participants from around the households around the ESC. It was common to have the co-researchers call residents to a meeting by going from house to house. Written invites proved to be ineffective. We started off the discussion with cartoon-strip drawing on how residents fetched, used and disposed of their grey water. During the session, the participants also naturally switched to Xhosa,

which was their first language so most of the discussion was in Xhosa and the translations were done for the researcher. In this sense, there was a reversal of roles as the users-participants led the discussion and I had to follow their cues as a facilitator.

4.4.2.2 Film Project FDG

I facilitated another FDG to form a shared understanding around a film project for the sanitation intervention. The film was to be used as a marketing tool to attract more funding for the Enkanini sanitation intervention. In the discussion, the narrative of the Enkanini sanitation intervention was deliberated on at length so as to formulate a storyline for the film. 59 minutes of the conversation from this focus group was video recorded, transcribed and   analytically coded. The participants in the focus group were: me as the facilitator of the session, four other SU researchers code-named R(A), R(B), R(C), R(D) and four Enkanini co-researchers code named CR1, CR2, CR3, CR4. There are also references to two other co-researchers: CR5, CR6 who were mentioned in conversation but were not present at the focus group discussion.

I set up this meeting because I sensed there was a misunderstanding about the film project for our sanitation work. The meeting started with a cartoon-strip drawing exercise, where each participant drew a cartoon strip of what they thought the film was about. From the drawings, it was clear that not everyone was on the same page as some participants dwelt on the sanitation problem in Enkanini in general and not on the film, yet the film was the agenda of the meeting. It took a long time to explain the actual purpose of the film. This discussion was critical because the history of the sanitation intervention was discussed at length since it was the storyline of the film. The researchers dominated the conversation since they were more articulate and familiar with the technical aspects of the intervention. The co-researcher's voices were marginalised and they only contributed when coaxed to do so through persistent questioning by me the facilitator. As the facilitator, I was not only concerned about the film as the agenda of the discussion; I was also going to use the discussion as part of my research. Further, I was keen to elicit responses from the co-researchers to prove that we had co-produced the film. Table 4.1 shows excerpts and subsequent coding from the discussion.

Excerpts of the conversation in the FDG	Holistic coding
R(A): … what the researchers presented, what the co-researchers presented, I think we complement one another in the story that we tell of, of these experiments, so the co-	Roles:

94

researchers really are much better positioned than the researchers to say how they use the toilets… And then the researchers have…advantage in telling the story of what this experiment means in terms of the longer term, larger scale objectives: So we are trying to scale up the experiment so that we can have the independence to grow the experiment, so that we can produce evidence to convince the government of a better way to use its subsidies. And as you said R(B), it's about growing…	Researchers and co-researchers Boundary object: Organising around toilets
R(A): And essentially, this step to get finance from the corporates, is an intermediate step … But we have already practiced that in our experiment. We have already set up our governing system.	Emphasis: intermediate step to achieve long-term goal Institutional structures: OMR, governing system
Facilitator: I would like to also ask the question about, I think several people brought out the issue of the community. And I think that is something that we have discussed before: whether we want to involve the whole community or it's just the co-researchers, researchers, showing what the project is about. Is that what you understood it to mean? (Referring to a CR1 and CR2)	Community: Enkanini Inviting participation
CR1: Yes *Facilitator: Yes? Yes to?* *CR1: To the community* *Facilitator: What about the community? Say that again?* *CR2: The community… (Giggle) probably…can you repeat that again?* *Facilitator: OK. So…* *CR3: Let me, let me, let me…explain you actually in Xhosa, cause you won't understand (Explains in Xhosa the aims of the film project and asks whether the other Enkanini residents should be involved)*	Language barrier: Need for translations into Xhosa for some of the co-researchers.
Facilitator: (Referring to CR2) So, so you would want the whole community to get involved, because, before, when we had this discussion before, the idea was that if we involve the whole community, then, people might not be very open to being part of a film, and they are not even yet part of this project, so the idea is to, just make it a film of what we are doing right now in the sanitation project. So, not necessarily to involve other people in the community. So it's not a film about Enkanini. What were you going to say? (Referring at CR4).	Framing an agenda: Dictating the purpose of the film

95

CR4: ..., if we want to include the community, we can include the people who are using the toilet, not the whole community, at least it will be better, because there are few people who are using the toilet. If we use, if we use the whole community...chaos, and people, and everyone will want to talk, it will be chaotic...	Lived experience: Chaos in Enkanini
R(C): That's how I understood community too in our last meeting, that we had, was that you wanted a meeting with the community of toilet users *R(A): So but we still, I think we should clarify. Do we want the toilet users who haven't been part of the mobilisation process, they don't know the story as well as you guys, or do we just wanna focus on the, the five of you, who already know the story that you were once the first users of the toilets plus part of the organising committee. We are just thinking in terms of making it manageable, and not causing problems for ourselves. Remember, I got an email from you that are exposing our poverty. We don't wanna go broad-based before we get a clear-cut story.*	Defining boundaries: Role/Membership into the community Sensitive topic: Exposing the problems of Enkanini residents
CR3: And, and another thing we must remember, we, we, we have a competition. We are competing ourselves with the, with the, with the municipality. So we can be in a big problem if we can involve the whole community *Facilitator: Expound on that?* *CR3: Now I am saying, you see, if we can involve the whole community, as we know that we...we are competing, we are competing with the, with the municipality, you see. So, it won't be easy. There will be a chaotic as she was saying... co-researchers...so I think, co-researchers and researchers and the, the users of the toilet, at the moment, those are enough*	Tense relationship with the Municipality (Stellenbosch Municipality)
R(B): So it doesn't have to be word for word but it has to be a basic idea of what you have to say... *R(C): Well, I think this process is helping to clarify, if everybody can agree, if everybody is represented in how the film is being made, then, then there won't be a need for script taking cause everybody will actually be participating* *Facilitator: Can I, can I ask about for example including someone like CR3, who is also, (he/she's) not a CR but...* *R(A): I am just thinking of keeping it as simple as possible...it's not, cause...then we are gonna have to have another workshop...to bring everyone onto the same page. Rather let's work with what we've got so that we can get this movie going in the next two weeks* *R(C): So, so you have five co-researchers sanitation involved?* *R(A): And now CR4 is keen to get involved, and you seem to actually already know quite a lot...* *R(C): So that makes six...*	Shared understanding: Seeking clarity and consensus The arduous effort of building consensus Time constraints Encouraging participation

96

R(A): ...and you have a strong voice, so I think, I think we've got the resources here in this room to make the film...	
Facilitator: So the film, the film is not to show people in Enkanini that these toilets are working, it is to show people who can give money so that we can actually get it going, so that it can be upscaled. So as it is we only have funding from NRF... *R(A): Two budgets from NRF... we will get more funds next year. It's a question of independence and of timing because the NRF funds, the university funds, have to go through about five different decision makers in order to make one small expenditure. If we can start getting funds into our bank account that CR1 is the steward of, then we can start doing things a lot quicker and with less bureaucracy. So thanks, that was another very good question to ask R(B)...*	Funding: source of funds frame the research Ceding control of funds to co-researchers
Facilitator: OK. Can we then proceed, and, would you want us to answer these questions in the brief? *R(C): We might as well then...* *Facilitator: Very quickly, very quickly. So what, what is the first, so that is the brief... so the brief is what is going to guide...* *R(C): See the brief is problematic though* *R(B): It's just the basics we can fill it in...* *Facilitator: let's just, let's just...* *R(C): Do you mind if I follow that thought for a second, do you mind? mhm, because it seems like we've got some frames we want in the story, like how do we use the toilets, what was here before...* *Facilitator: OK, so we go straight into that?* *R(A): I don't think this drawings are going to give us the substance. They were done in two minutes...*	Deteriorating conversation: Multiple interruptions, no proper turn-taking as in the beginning Expressing frustration
CR2: Before the people who, the toilet is...still far away to other people because is not using the toilet, is using the bush... *R(A): so maybe drainage and grey-water disposal...and....I mean, the use of buckets, and the perpetuation of buckets, even though... (Incoherent words). So the surveys that you guys collected all the information for, we see that 85% of households are still using buckets at night, for its safety reasons, and during the day about 60% of households are still using buckets for convenience reasons*	Experiential knowledge of the sanitation problem Research knowledge of the sanitation problem

Facilitator: But do you think, can I ask a question, would you want to make it very clear, to clearly demonise the municipality in the…or to just show that, that there, there obviously are problems, but not to necessarily…	Questioning the approach: opposing voice
R(A): It's not demonising to say, look the municipality's hands are bound by the fact that they don't have a partnership, therefore the best they can do is deliver at a distance, these communal blocks, which are we know to be inadequate	Negotiating meaning
R(C): I mean, if you don't put it in, if you don't put that piece in, if you are missing a piece of the story a viewer might question well why isn't the municipality there, think of the questions that it will trigger in your audience… *(many people talking)*	
Facilitator: So that is where we explain the sanitation project?	Inviting contribution
R(A): Yeah, we might just before getting into the details of the sanitation project say this is a three year transdisciplinary research project, mhm in 2011 there were three researchers and one co-researcher and it's the end of 2013 and we've got 12 researchers and eight or nine co-researchers, and that could, yeah, be the point of departure for the sanitation stuff.	Institutional memory
Facilitator: So for the project itself… *R(A): So that could maybe be the voice of a researcher…*	
Facilitator: So that is TD research	Voice
R(A): And we don't need to use the jargon we could just say we are producing knowledge that integrates everyday knowledge of residents with expert knowledge of academics	Communicating to lay audience: use simple, clear language
Facilitator: Yeah, so it's plain and simple terms… *R(C): Then he's actually got the mechanics of it, you know the grey water, he actually included (referring to a co-researcher's drawing)…* *Facilitator: Yes, so that is the next step, so now it's the project itself*	
R(C): And that's actually quite a nice tie-in because there is the demonstration in the beginning that tied into the demo at the end. That could be nice *(many people talking)*	Coherent story for film

98

R(A): So how do you guys think we should demonstrate the actual project? It's quite easy to show the toilet but there is much more to this project than just a toilet *R(C): Yeah, so what did go into it?* *R(A): CR1 and CR2? How do you think we should demonstrate this or tell people about it? The actual, the actual experiments with the toilets and with the Enkanini sanitation co-operative?* *CS2: As I think, the project can make la lot of thing for us because in Enkanini the real issue was the first issue of the toilet because we still need even the clinics here, mhm, we still need even the housing so that the project, our project can…* *R(A): So this project can have much bigger impact than just sanitation, so it can lead to longer term, larger scale upgrading in Enkanini, but before we get there, what about the details of the project itself, so just focusing narrowly on what we have done, we've got four toilets, we had 20 users, now we've got 12 households using, but again we don't need…we want to put our most positive image forward* *R(B): So how do you want to tell the story of the new toilets? How can we tell that story in the movie? (Referring to CS1 and CS2)* *R(A): Like CS1, (unclear words)…somebody walking with a bucket, I have collected, I have collected my grey-water from my cleaning of my child, my washing of my laundry..*	Defining the project: More than a technical solution Concerns beyond sanitation for Enkanini residents: health, housing Delimiting the project focus: sanitation Real achievements vs projected image Researchers framing the agenda for the co-researchers
R(C): Sorry to interrupt you, if you really are going for an overseas audience, then you might have to put some context, because they, Americans won't know about the toilet wars, they won't know about the wider context *R(A): And then those two go together, what you've both just said, and I think the context and I think that gives you the first frame for zooming into the micro reality of Enkanini. Although it could be the second frame where we have zoomed out to give context to the work…* *R(C): That is a shock and awe*	Framing the context for a specific audience
R(B): But the context is still important though, it's still important though *R(C): But then you just need a reminder* *R(A): And then in terms of context, R(C), something that you are passionate about is saying that look, Enkanini's sanitation problem is everyone in the watershed's problem…* *R(C): Yeah, and somehow demonstrating the overflow in the river (many people talking)…or literally just this overflow that is all the way down there* *R(A): And I mean it's so easy to, cause, by virtue of our height here it's so easy to show*	Sanitation problem extends beyond Enkanini

how…(many people talking)	
R(C): But he says, I'm not disparaging him, I am just showing that this is a limited brief. He says, who are we meeting, a little more about them. So we can't really, I think it might actually be more useful to him to have this storyline that we discussed and these points…	Vested interests: need to assert one's contribution
Facilitator: So can we conclude? *R(C): Are we going to the matters arising and, and conclusion?* *Facilitator: Yes, OK, so if we conclude, let us just finish with matter arising and give everyone a chance to say something in one minute concerning this meeting or some other concern that they have to do with what has been discussed today, or which can be taken to another meeting, so we will start with you this time (referring to R(B))* *R(B): I think, I think it was a very good meeting, I think it was more successful that our last one that we tried, and I think everyone understands a bit better what we are trying to do with this movie, mhm…yeah* *Facilitator: OK* *CR1: Me I'm clear….*	Satisfaction with the meeting in comparison to previous meetings of 'the collective' The co-researchers are satisfied that they now understand the purpose of the film
R(A): Mhm, but just in terms of my reflections on this session, the researchers who you guys have been working with, are trained in this technique called co-production, which means that we try and produce things as a group and what we've seen here today is a good example of how messy, and how chaotic and how difficult it is, and how it takes three hours to produce something that is, this is not simple, but we were trying to co-produce a whole big sanitation upgrading intervention… *CR3: Oh, OK. It was a very nice and successful meeting. Eeh, what I like most about it is that everyone will come out got something (unclear words) and refresh our minds and brains* *and yeah, I think this film* *Facilitator: …will be good?* *CR3: Fantastic!*	Reflexivity: admitting the limitations of co-production

Table 4.1 Excerpts and codes from the film project FGD

4.4.2.3 User-Experience FDG

At the beginning of phase two of the intervention in 2014, we the researchers and engineer agreed that a re-launch of the intervention was necessary. This was done so as to address the drawbacks that had emerged at the end of phase one in December 2013. One of those drawbacks was the dissatisfaction of users with the pour-flush. To tackle this problem, a full-flush system referred to as the micro-flush was

to replace the pour-flush toilets. Alongside this, the biogas trials were to be carried out with the aim of providing the users with alternative cooking energy, which would be cheaper and safer than the paraffin they currently use. The payments from the biogas supply would then be used to maintain the sanitation system, making the system more self-sustaining. The trials were ongoing at the time of submitting this dissertation.

Consequently, I organised a session to discuss these changes with the users as well as to collect their experiences from phase one. During the discussion, the users expressed some level of satisfaction with using the pour-flush toilets, although in earlier interactions, some users (who ended-up dropping out of the intervention all together) had expressed strong dissatisfaction with the pour-flush. The drop-out users therefore reverted to using the communal toilets provided by the municipality. Consequently, in phase two, more than half of the 20 users were now new participants who had not been part of phase one. The discussion in this session was therefore also an opportunity to engage with the new users.

In synthesis, the focus-group sessions I organised were more informative than they were participatory especially for the beneficiaries. The difficulty of forming a shared understanding through the FDGs exemplified the challenges of participatory processes. For one, I had to plan the FDGs based on the activities in the intervention and not my own research questions. In this regard, I had little control over the discussions and their outcomes. The second focus-group session in October 2013 was soon followed by a falling out between the researchers and the co-researchers in December 2013. This was a significant source of frustration, which exemplified the unpredictable and volatile nature of Enkanini itself[1].

The sessions were also difficult to convene. Finding the right time and venue for a large group to meet in Enkanini was a problem: Day meetings were attended mostly by unemployed, female residents who were not representative of the settlement's mostly male working population. Later, we tried to hold research meetings in the evening, and that too was fraught with problems such as security concerns. In the end, the most rewarding engagements were not in any of these organised sessions, but in the unplanned and naturally-occurring dialogue with Enkanini residents.

---

[1] The volatility of Enkanini can be seen in the frequent protests in Stellenbosch town by Enkanini residents. In the latest incident in 2015, there was a protest march in town by some residents, the ward councillor's house was littered with rubbish, and the Ishack project office in the settlement was destroyed (the Ishack project, 2015).

A study by Le Roux and Costandius (2013) reveals a similar challenge in an earlier art project in Enkanini, in which foreign artists intended to collaborate with residents to paint their shacks. The art project failed to negotiate sustainable social change in the settlement because the artists did not seek the express consent and active involvement of the residents. There is therefore need for a more critical consideration of the 'unquestioned optimism' and often 'romanticised prospects' that drive social projects for the disadvantaged (ibid). In a collaborative design project in South America, Hussain, Sanders and Steinert (2012) also point out the challenges of designing with marginalised users. Such projects should aim at producing empowering outcomes for the participants, beyond the tangible design outcomes. In my case, I concluded that the FDGs I organised in Enkanini may not have produced empowering outcomes but they were great learning opportunities.

4.4.3 Naturally-Occurring Interactions

I gathered excerpts of Email communication and *WhatsApp* group messages that were exchanged between members of the ISUG, as well as between members of the sanitation working group. These communications occurred naturally since they were not prompted by any specific research questions nor elicited through structured surveys or interviews. As such, they were communications loaded with covert meanings about the interrelationships within the group (Angrosino, 2007). Table 4.2 provides excerpts of these conversations. I use holistic coding to unveil the covert meanings.

EMAIL COMMUNICATIONS	
"Thanks for the opportunity to join you yesterday, it was really good to hear more of what you are doing and to get a rubber stamp from Dawie.	Collaboration:
I hope it was OK for me expand on the wider context of the pour-flush… there is a lot of nervousness around toilets and so the more proof we can give that the system is and can work the better. I look forward to seeing how well it works at Enkanini.	Follow-up after meeting with director of informal settlements department of Stellenbosch Municipality. The meeting was attended by 3 SU researchers, 3 Enkanini co-researchers and the engineer.
For your information, I had a good conversation with Dawie and Harold after our meeting regarding the pour-flush toilet and their plans for informal settlement sanitation. Pending the	

success of the Enkanini pilot Dawie wants the details of the system so that they (Natasha) can incorporate into their standard specifications. I think they can see the benefit that the system has on alleviating demand on their over stressed sewage networks… I presented the concept whereby they could collect greywater from clothes washing / tap stands and/or a new shower facility, and discharge to a pour-flush or Micro-flush toilet (Lorraine and myself will be working on the Micro-flush design over the coming year)…(Title: Sustainability Institute: Community Engagement Project research update meeting. From Maluti engineer to SU researchers and co-researchers, 31/5/13)”	Technical viability: The engineer elaborated the technical benefits of the pour-flush Design process: Suggested incremental improvements of the technical specifications
“…Lorraine I would still ike [sic] for you to come with me on the 21st if you can as you can tell the story of the non-technical processes at Enkanini. Are you free?”(From Maluti engineer to me 5/6/2013)	Roles: articulating my strength in non-technical processes e.g. facilitating participation
Users are finding that they need to dispose of their grey water at different times to when they need to use it to flush. Cultural reasons prevent them from storing grey water for any length of time, they want to discard it immediately, as its generated. Users want flush toilets, they want the automated experience, the convenience of not having to ensure you've got your flush water with you…(Title: pour--> cistern flush greywater toilets. From researcher to Maluti GSM engineer 17/9/13)	User dissatisfaction with the pour-flush
Our work to date has been to demonstrate the design developed by others, but we are now gearing up to develop our own design (the Micro-flush toilet) which will utilise the effective pour-flush pedestal design with the convenience of a	Redesign of the pour-flush to the micro-flush

103

flush. ...(From Maluti GSM engineer to researchers Title: pour cistern flush greywater toilets 17/9/13)	
As far as I am aware you are not raising funding to develop the technology, we have this covered through the WRC... please can you reword as follows... *(From engineer to SU researchers. 11/11/2013).*	Misunderstandings: SU researchers did not acknowledge the WRC fund in the film brief
"You raised important issues about power- if we change to a Trust will it reduce the power of residents to make important decisions about how sanitation upgrading happens? Will it mean that outsiders now make the strategy and decisions of the ESC? I agree that we want to keep decision making as local as possible. (Title: ERCA and ESC 'employee' contracts. From researcher to co-researchers 18/11/2013)	Power asymmetries: Control of the ESC
"...Not demanding the money back is a contradiction to the advice to close the ESC. Not sure of your and other...colleagues reasoning (to not cause further disputes and ill feelings?)..."(From researcher to other researchers 11/12/2013)	Conflict: Closure of the ESC

WHATSAPP GROUP MESSAGES	
"…*Maybe we can just add 5 small bucket a week or something. I will speak to R about it…*	Learning-by-doing:
…check the pdf instructions on the Biogaspro website- it tells you how much food waste per day…	researchers had no prior experience with the technology of the anaerobic digester
…Max 25-35kg of food waste a day. If a lot is put in the system will require pumping out…	
…hmm sherbert. i suspect that the solid to liquid ratio is going to be way out"	
"We also have a tour happening on the 3rd of December at 9am! Please can you guys be there!'"	Asserting roles:
"Hey guys just a reminder we have tours happening on the 10th and 24th of January! Helping on these tours is a good way to make hours!"	need to coax co-researchers
"co-researchers, please consider tours as necessary part of yr jobs and as J said, a good way to boost your hours"	
"Hi guys I can do 4th Dec. Guys there is going to be someone for a tour on the 26th (next tuesday 10am) please try be there! A good way to make hours!"	
"Hey man. Do you mind giving a translation?"	Language barrier: message was written in Xhosa and not translated

Table 4.2 Excerpts of Email communication and WhatsApp group messages

4.4.4 Second-Order Coding Of the Memos and Holistic Codes

The second-order coding as shown in Table 4.3 reveals some recurring themes that shaped the narrative of the sanitation working group, and provide thematic areas on the co-production process.

Memos and Holistic codes	Second- order coding
• Learning-by-doing: Conversation between researchers about the anaerobic digester	Field method
• High regard for the drawings: interpreting the images that are inconsistent with the discussion • Use of the drawings to guide the discussion • The images were more expressive that verbal communication alone. They became conversation pieces that spurred dialogue	Visual communication
• These points were all from the material that the users generated themselves and so I was merely facilitating the discussion	Facilitation
• There were lot's of inter-disciplinary exchanges amongst the researchers themselves • The engineer and two PhD students (researcher included) has a separate WhatsApp group • Researchers, supervisors and experts communicated mostly through group email	Interdisciplinarity
• The collective: Frequent use of 'we' • Ownership: 'Our collective cartoon strip' • Collaboration: help from outside the group • Partnership between researchers and co-researchers, • The collective should be a safe place for open expression and for mutual concern	Collective approach Multi-stakeholder engagement

106

• Research problem: Municipal toilets have problems • Research objectives: Long-term engagement, experiments at the small scale • Immediate goal: create film, long-term goal: social change • Emphasis: intermediate step to achieve long-term goal	Social change in TD research
• Lived experience: Chaos in Enkanini • Sanitation problems in Enkanini: communal, dirty, use of buckets • Experiential knowledge of the sanitation problem	Experiential knowledge
• So the surveys … we see that 85% of households are still using buckets at night, for its safety reasons, and during the day about 60% of households are still using buckets for convenience reasons • The civil engineer from Maluti GSM … he/she said that the technology was 'simplified sewerage system' and not 'small bore, shallow sewers' as explained in the meeting • Deliberations about the technical system	Expert/research knowledge
• Admitting failure, admitting the limitations of co-production	Challenges of co-production
• Duties were shared out amongst the researchers and co-researchers • Setting the tone for the discussion, defining the facilitator's role	Roles
• Seeking participant consent • Inviting participation, Encouraging participation • Gratitude for participation in own research • The researchers started a WhatsApp group for ease of communication with Enkanini co-researchers	Participation

• Satisfaction with meeting • Expression of enjoyment • Satisfaction • Aspirations/hope	Participant satisfaction
• The conflicts within the ERCA (Enkanini Research Centre Association) and the ESC in particular, had escalated to a point where the supervisor had to step in and resolve the disagreements. • Little regard for the drawing exercise by other researchers • Tense relationship between Enkanini residents and the Municipality (Stellenbosch Municipality) • The arduous effort of building consensus • Time constraints, Time-keeping • Expressing frustration • Questioning the approach: opposing voice • Researchers are arguing over roles and duties, which are outside of their research work	Conflict/challenges of participation
• Need for translations into Xhosa for some of the co-researchers. • Beneficiaries prefer speaking in Xhosa • Language: ease of expression in own language • Deteriorating conversation: Multiple interruptions, no proper turn-taking as in the beginning • Use of metaphors • Communicating to lay audience: use simple, clear language • Another form of communication: play acting • Concern about image in the movie: need for proper expression	Language barrier

• Sensitive topic: Exposing the problems of Enkanini residents • Sensitivity of the sanitation discussion • Concern for co-researchers comfort with the discussion • Need to be explicit about the sanitation problem	Sensitive personal topics: poverty, sanitation
• Objectivity: Inviting a non-member of the defined community of researchers and co-researchers • Need to market story vs telling an authentic story • Real achievements vs intentions • Trade-offs: telling a compelling story vs the concern for subjects	Objectivity
• The co-researchers voices were marginalised and they only contributed when coaxed to do so through persistent questioning by the facilitator • Emphasis on roles and duties/Asserting authority • Researchers dominance in the conversation: the technicalities of the film are discussed only by the researchers • Vested interests: need to assert one's contribution • Asserting roles: Need to 'push' co-researchers	Power/ marginalised voices
• Funding: source of funds frame the research • Ceding control of funds to co-researchers	Funding
• I set up this meeting because I sensed there was a misunderstanding about a film intervention for our sanitation work. • The brief of the film was written and shown to the civil engineer from Maluti GSM who was not at the meeting. He recommended that the script should not read that we were raising funds to develop the technology since that was already covered by the WRC. • Shared understanding: Seeking clarity and consensus	(Un)shared understanding

• Questioning shared understanding • Lack of shared understanding: different understanding of target audience • Dictating the understanding: researchers control/framing the agenda of the film • Negotiating meaning • Asserting/dictating meaning	
• Framing an agenda: Dictating the purpose of the film • Concerns beyond sanitation for Enkanini residents: health, housing • Delimiting the intervention focus: sanitation • Insisting that the 'you' (CR) is part of 'we' (collective) • Framing the context for a specific audience • Sanitation problem extends beyond Enkanini • Framing the aim: knowledge co-production	Framing
• Boundary object: Organising around toilets	Boundary object
• Community: Enkanini • Emphasis on the community • Defining boundaries: Role/Membership into the community • Concern for image in the community, may be perceived as having ulterior motives • Outsiders: the film maker is seen as an outsider who doesn't understand the intervention	Community
• Communication barrier between Enkanini and municipality • Discussions with Director of informal settlements at municipality. No formal arrangements were made though	Relationship with Municipality

• User-satisfaction: Users should be satisfied • Aspirations of people in Enkanini: toilet inside the house • Aspiration vs reality of sanitation provision	User-satisfaction, user aspirations
• Defining the intervention: More than a technical solution	The social of sanitation
• Technical innovation, Financial innovation • Intervention aspirations • Marketing the intervention	Innovation
• Discussion of technical specifications: Enkanini Greywater Filter design • Deliberations about the technical system	Sanitation technology
• Some residents have invested in their shacks such as adding in concrete flooring and connecting to the piped water. Such improvements are made incrementally over time as funds become available.	Incremental building

Table 4.3 Second-order coding of memos and holistic codes.

4.5 Discussion

Given the critical stance used in the analysis, each of the themes reveals the inherent conflicts and power asymmetries within the sanitation working group. The themes that emerge are therefore subjective in as far as they are shaped by my own preconceived notions and critical stance. The subjective outcomes are nevertheless valid as situated knowledge that was gained through abduction (Dorst, 2011; Letherby, Scott & Williams, 2013).

4.5.1 Framing the Co-Production Agenda

The word 'frame' was used in the conversation in the film project FGD as a technical term to refer to the different sequences that would take place in the film. It was also used figuratively by R(C) in a suggestion that the facilitator should 'frame' a question to the co-researchers differently in order to get

the appropriate response. In the holistic coding of the conversation, 'framing' is adopted as a code for the instances where the researchers sought to control the narrative of the film. This is mainly attributed to the fact that the researchers were more familiar with the research and technical aspects of the film project and of the sanitation situation in Enkanini. The co-researchers had a more nuanced understanding of the sanitation problem, which was evident in the way that they related sanitation to other social problems such as health and housing in the settlement.

For example, the researchers could quote research figures by heart and were therefore more articulate in speaking about the overall sanitation problem in Enkanini:

> R(A) '…85% of households are still using buckets at night, for its safety reasons, and during the day about 60% of households are still using buckets for convenience reasons.'

> R(B) '…there's 72 people per toilet, but that's not taking into account whether it's working, whether it's overflowing…'

On the other hand, a co-researcher seemed to veer off the track of the conversation and talk about the need for clinics and housing. CS2: *"…in Enkanini the real issue was the first issue of the toilet because we still need even the clinics here, mhm, we still need even the housing…"* In other words, the co-researchers had a more holistic view of the problems they experienced in Enkanini, while the researchers had a specific research focus on sanitation. The researchers thus framed the narrative of the film, while the co-researchers contributed very little to the actual storyline, since they expressed nuanced views that were not necessarily focused on the film.

4.5.2 Communication Barriers in the Co-Production Process

Co-researchers were not comfortable expressing themselves in English. For instance, the word 'barrier' was used repeatedly in the film project FDG to signify the poor relationship between Enkanini residents and the municipality: *'There is a barrier in service delivery…'* *'…there was a barrier between us as a community and the municipality…'* These statements were made by R(C) and CR3 respectively. After much deliberation over this point, CR1 asked: *'Can you explain me the word barrier?'* meaning that CR1 were probably lost in the whole deliberation about the poor relationship between Enkanini and the municipality.

In earlier conversations, two other Enkanini co-researchers had commented to me that they did not understand the technical terms used by the researchers. On that occasion, one co-researcher used the

word 'bombastic' to describe the words used by researchers, meaning that the researchers' language was probably too academic. As a designer with no background in sanitation, I also took a long time to familiarise myself with the technical sanitation terminology. The repeated use of the word 'barrier' in the focus group conversation therefore reflects not only the language barriers, but also the symbolic barriers within the sanitation- working group itself.

The conversation between the researchers in the FDG was also marked with disagreements and interruptions. For instance, the film project was not part of anyone's research in particular, and so there was an argument over who should write the film brief. Later, a suggestion by R(D) to include a beneficiary in the film who was not a co-researcher was also argued over. R(D) defended this suggestion by claiming that a co-researcher would be biased, to mean that they will not represent an objective view in the film. The beneficiaries in the other two FDGs were also more comfortable expressing themselves in Xhosa; hence the use of visual tools to enhance dialogue.

Another communication barrier was apparent between the researchers and the engineer. In speaking about the available funding for the intervention, the researchers only mentioned the university funding (NRF) and not the WRC funding. Later, the engineer who was not at the focus group discussion, asked via email communication that the written film brief should be changed to reflect the role of the WRC fund. In this regard, the engineer asserted that the technological innovations were already covered by the WRC fund and should be stated as such in the film brief.

4.5.3 The Role of Funding in Co-Production

In the film project FDG, the university funding provided by the National Research Foundation (NRF) of South Africa was mentioned severally, while the WRC funding used for the technical system was not mentioned and was therefore not included in the film brief. In a later email communication, the Maluti GSM engineer, who was not at the discussion, asked that the support of the WRC be made clear in the film. The film was eventually produced on the 14th of November 2013 and was used to secure further funding Wilhelm Frank Trust.

The control of funding resulted in power differences in the sanitation working group. The NRF budget was obviously controlled by the university and by extension, the researchers, whose research was pegged on that funding. The engineer controlled the WRC budget and so was able to dictate the

specific technical outcomes of the installations. In this regard, the WRC had provided funding for the pour-flush toilet specifically.

An attempt to share control of funds with the co-researchers prompted the opening of the ESC account, in which some of the university funding was transferred into. One co-researcher was nominated to control the account as the treasurer of the ESC. Disputes over the use of ESC funds were the main reasons for the dissolution of the ESC in December 2013. The co-researchers wanted full control over the account yet the researchers were the ones accountable for the use of those funds to the university. Allowing co-researchers to continue controlling the funds was incompatible with university regulations.

Additionally, the remuneration of co-researchers also had ethical implications. One co-researcher was concerned that their neighbours perceived them to be liars who were only interested in the success of the sanitation intervention because they were being remunerated. This is exemplified in a comment by CR2 during the film project FGD, who felt that contractual agreements with the research group tarnished their image in the settlement since they were representing the interests of the researchers.

> '…*you don't think if we gonna, for the video we can use the co-researcher, those is using the toilet, it's gonna like, we are liars because we are co-researcher. Mhm I think me I'm agree for this that is say, its better one person who is not a co-researcher, he gonna explain the one us we have to know it is…unclear word) to keep the money is gonna say something, say I am happy for to use the toilet, because if we gonna use the co-researcher, us now we looking we just lying cause we need the project to go up.'*

The remuneration was however necessary because the co-researchers were engaged full time in the sanitation intervention.

4.5.4 Participation and Voice in Co-Production

The co-researchers spoke very little in the film project FDG and they mostly contributed when coaxed to do so through persistent questioning by me. At some point, R(B) sought to reassure the co-researchers that they should feel comfortable to express themselves because they were in a 'safe place'. '…*this is a safe place, no one is gonna get angry…if you are worried about something you must say it'*. In the entire 59 minutes of the FDG researchers did most of the talking.

The imbalance in the FDG conversation was indicative of the difference in participation in the sanitation working group. The researchers put in the most time and effort into the intervention. This was because they were fully funded to participate in the intervention. The engineer was more interested in the technology itself and was also involved in other interventions in Klipheuwel and Klein Begin. He was therefore not as involved in the interactions in Enkanini as the researchers were. The co-researchers were remunerated for their time in the intervention, yet they had to be nudged to perform their duties.

Having to coax the co-researchers into taking part in site visits revealed their growing reluctance to participate in the research. By the end of 2013, the involvement of these four co-researchers CR1, CR2, CR3, CR4 was untenable due to the irresolvable conflicts between them and the researchers. As earlier mentioned, this sanitation working group was dissolved in December 2013. In 2014, CR6 was the only co-researcher working with the SU researchers in the sanitation intervention. Another Enkanini resident was also contracted and trained to carry out the operations, maintenance and repair duties of the sanitation system.

4.5.4.1 Positionality in TD teams

Our conflicts in Enkanini were hard to come to terms with given the initial idealistic TD approach that we had nurtured at the TsamaHUB. In this idealist approach, we as researchers intended to co-produce egalitarian knowledge with Enkanini residents in what was supposed to be a joint quest to improve the sanitation situation in Enkanini. We therefore regarded the Enkanini residents we worked with as co-researchers and not research assistants, with whom we set out to form a shared problem statement and a shared solution to the obvious problem of inadequate sanitation. That problem turned out to be far more socially complex than we had anticipated, as we were unable to bring together all the stakeholders we had intended to work with, or to implement the ecological sanitation system that was initially proposed by the ISUG. We had to make do with a much less ambitious technological system. The group that we were able to constitute did not work smoothly either, as the power differentials between the researchers and co-researchers remained contentious.

The differences in race complicated the interrelationships in the working group further as most of the researchers were white, except me, while all the co-researchers were black. Racial identities in South Africa complicate community engagement in cross-cultural settings given the Apartheid history of the country. As the only black researcher in the sanitation working group, I experienced personal conflicts

115

because of the intersectional identities that I embodied (Maxwell, Abrams, Zungu & Mosavel, 2015). Being black led me to believe that I would readily identify with Enkanini residents and thus become an 'insider'. I was however seen as a privileged researcher and I did not speak the local language and so maintained the position of an 'outsider'. My initial optimism was thus met with some disappointment because I did not imagine that my status as a researcher would overshadow my racial similarity with Enkanini residents. In one instant, a co-researcher told me in an informal conversation that all researchers are the same, to mean that we were merely interested in our research outcomes and not in bringing about real social change in Enkanini. Acknowledging our positionality through self-reflexivity is therefore an important step in learning from our mistakes and misconceptions.

In conclusion, the analyses of the challenges of knowledge co-production using a real world case, exposes the empirical limits of TD research, which have been articulated in theoretical discussions, but have not been adequately demonstrated using real world examples. From the analysis of these challenges I recommend that TD researchers should employ creative methods such as the cartoon-strip drawing exercises in working with informal settlement dwellers who often have limited formal education. I also found that naturally-occurring conversations yielded deep insights about the sanitation intervention.

4.6 Measuring our TD Research Achievements

Wickson, Carew, and Russell (2006) theorise that TD research should have six characteristics: responsive goals, broad preparation, evolving methodology, significant outcome, effective communication and communal reflection. In our field experience, these six characteristics were difficult if not impossible to achieve.

i) Our goals were indeed responsive to the urgent problem of sanitation in the settlement

ii) We did prepare broadly by engaging a wide pool of possible stakeholders in the beginning. In this regard we had several meetings with municipality officials although the municipality was never officially involved in the intervention as we would have wished.

iii) Our methodology did evolve as we learned by doing.

iv) We achieved a fairly significant outcome in implementing a working sanitation system, but we were unable to sustain our intended social outcome i.e. the Enkanini Sanitation co-operative failed.

v) Communication between researchers and co-researchers was not effective.

116

vi) We did not engage in meaningful communal reflection with the co-researchers and experts. At best, we had many disparate interactions with all the stakeholders.

In our own reflection as researchers we turned our challenges into great learning opportunities as exemplified by the comments of one researcher during the film project FDG:

> '...we try and produce things as a group and what we've seen here today is a good example of how messy, and how chaotic and how difficult it is, and how it takes three hours to produce something that is, this is not simple, but we were trying to co-produce a whole big sanitation upgrading intervention, so I think this is really good practice. Start small, start with something focused, like producing a small three minute film and from that we can really see what co-production is really all about…'

The findings of this article are significant because challenges of TD research have been written about but have not been demonstrated empirically to a large extent. More so in the context of working with marginalised, non-academic partners such as informal settlement dwellers (Brown-Luthango 2013). There is therefore need for institutional transformation in universities if they are to facilitate mutually beneficial and sustainable community engagement (ibid). The TsamaHUB at SU is well placed to continue driving such a TD process.

4.7 Conclusion

Co-producing knowledge through TD research with informal settlement dwellers is a challenging process that is nevertheless necessary for the realisation of social change in informal settlements. TD researchers should therefore be aware of these challenges and should be self-reflexive in their dealings with various stakeholders in the co-production process. My own reflection on the narrative in the Enkanini sanitation working group has revealed themes of knowledge co-production, through the analyses of FDGs and naturally-occurring interactions in the group. These themes are important for strengthening the weak methodological base of TD research and for informing future field work in informal settlement contexts.

CHAPTER FIVE

5.0   DESIGN FACILITATION FOR INFORMAL CONTEXTS

5.1 Introduction

This article articulates the widening social agenda of design, in which the focus of design is shifting from object to process, and designers are giving greater attention to the philosophical underpinnings of design practice (Ceschin, 2013; Manzini, 2014; Papanek & Fuller, 1972). This means that designers are getting more involved in multi-actor engagements that aim to implement processes of change, as opposed to simply offering technological product solutions (Ceschin, 2014; Cross 2011). In transdisciplinary (TD) research contexts, designers can become 'researcher-designers' (Sanders & Stapper, 2008) and 'design ethnographers' (Gunn & Donovan, 2012) who explore diverse processes, while employing both traditional and emerging design methods.

Informal urban sanitation is an apt context for researching the expanding social role of design and innovation, given that purely technocratic approaches have failed to meet the complex needs of providing sanitation in informal contexts (McFarlane, Desai and Graham, 2014). In general, the complexity of informal contexts emanates from their deviance with conventional methods that have been successful in mainstream urbanisation trajectories in the Global North, but are incongruent to the emerging urbanisation waves in the Global South (Swilling, 2013). In Sub-Saharan Africa for example, informal settlements are fast becoming the dominant urban reality, and governments are unable to provide adequate infrastructure and services to the burgeoning populations in such settlements (UN-Habitat, 2014). Informality is therefore a complex urban trajectory that holds both opportunities and challenges for the next urbanisation wave that will take place in Africa and Asia.

As such, designers need to focus greater attention on informality if they are to contribute solutions and take advantage of the alternative pathways for innovation. In architectural design, informal settlement practices are used in design studios through simulation games (Owen, Dovey & Raharjo, 2013). Informality has also been used to articulate the significance informal place-making as a narrative in

118

architectural design (Dovey, 2013; Kellet, 2005). In this article, my involvement as a designer with an industrial design background in a sanitation intervention in Enkanini informal settlement was a chance to expound on the role of the researcher-designer as a design facilitator in an informal settlement context. As a researcher-designer, I took advantage of the analytical skills of research and the generative skills of design (Sanders & Stapper, 2008).

5.2 Method

I present an auto-ethnographic account of my journey in the Enkanini case study through a narrative analysis (Wattsjonson, 2009) of my research journal entries and field photographs during my participation between 2012 and 2014. The auto-ethnographic approach allows me to embed my story within the story of the case, thereby rounding off the meta-narrative of findings in this dissertation. It is an intentional and systematic inquiry of my own practice to reveal knowledge about design practice (Hamilton, Smith & Worthington, 2009). In that quest, I articulate the role of design ethnography in TD research by mapping my participation in a time series analysis (Yin, 2009). I also articulate core design competencies based on the work that other actors produced in the intervention, but did not necessarily refer to as design products. In this way, I balance out my researcher-designer role in acknowledging that I was not the only designer in the group, but I was the only one who used a design lens to systematise the outcomes of the intervention.

5.3 My Journey as a Researcher-Designer in the Enkanini Case

From October 2012 to July 2014 I participated in the Enkanini sanitation intervention, in which the pour-flush toilet system was to be piloted. Over the two years I engage in the intervention and collected data through journal entries and photographs. I also participated in workshops with beneficiaries and organised focus group discussions (FDGs). Overall, I gained a rich understanding of Enkanini and of the sanitation problem. In retrospect, I systematised my experiences and that of others in order to articulate the role of design and its methods in the growing field of TD research.

5.3.1 Journal Entries

I kept a personal research journal throughout my participation in the Enkanini case. In the frequent entries, I wrote down my thoughts on what occurred in the field and was therefore able to capture my internal emotions, which were shaped and were shaping the outward context of the research process (Wattsjonson, 2009). In that way, I created my own personal narrative that was influenced by other

actors and by the sanitation technology. In turn, my agency helped to co-craft the narrative of the interventions. Excerpts of key journal entries below show emerging themes from my records. Below each excerpt is a memo of my reflections on my journal entry.

Meeting at Church with research group: 26th November 2012

> *'C explained the toilet design in detail through drawings by hand and computer. I asked many questions about how design will work and tried to include the group in the discussion. 1st co-researcher has done some building work for the I-shack so he commented on the use of tyres for the foundation. He thinks it will work. 2nd co-researcher had no comments about the entire project. C is very taken up with his design and does not seek the meaningful contribution of the group. He is however concerned about his ideas not being embraced by the project leader. Meeting set for Thursday to install filter. 1st and 2nd co-researcher will come.'*

Memo: I started questioning our co-production approach early on in my research. In this instance, I felt that a designer we had contracted to design the myco-filter was too controlling. I therefore developed uneasiness about our work, which later cemented my critical stance towards co-production. I however stack with the process because I thought we would with time learn to work better together.

Reflections (30th November 2012)

> *'So far we are yet to install the filter so L is worried that things are moving a bit too slow. C is maybe not delivering as fast as we would expect and so there is need to nudge him (me). I also need to be up to speed with what's happening by reading e.g. all the materials that project leader sends through and following up on targets. We need to look at our timetable and see how far along we've come. (I should send in an abstract to the Nairobi conference sent by civil engineer). Today we are all meeting civil engineer to select a site. He is averse to the idea of selecting a site all by himself (co-producer?). We all need to meet the councillor soon after to select one site. Before then maybe we should meet co-researchers and agree on how we'll approach the meeting. My suggestion is that one …co-researcher should also speak. So far the process seems to be developing very organically. Contributions are coming from multiple sources esp. on L's side which could be useful but also confusing and slow us down. E.g. yesterday at SI- the engineer plus other two guys who were engineers? All contributed conflicting information but the civil engineer seems most credible and he is also formally on board so maybe we should listen to him more. The Cos are still as is expected learning their*

120

way through all the complicated terminology. S commented that the words being used esp. by L are not understandable. W called them 'bombastic'. Maybe there is need to simplify the information so as to make it more inclusive. Even I am still coming to terms with what's happening and learning to contribute more and more in the conversation'

Memo: The first co-researchers were involved in the sanitation work from late 2012 till early 2013. Afterwards, new co-researchers had to be recruited because these first ones were more involved in other research projects. We researchers therefore spent a considerable amount of time recruiting co-researchers. This was time taken away from our own research and from carrying out other duties in the intervention. The meeting with councillor that I refer to only happened on the 29th of April 2013. She was concerned that she was not informed or involved earlier in the Enkanini projects. She also warned us that Enkanini is a sensitive area that has to be approached with caution. We did not have any further meetings with her.

Enkanini San-Coop meeting notes held at ERC (17th September 2013)

- *Introduction by R(A)*
- *Advisory board document to be drafted by R(C)*
- *New researchers have well defined roots to enter into Enkanini for research*
- *Co-business of co-op to upgrade the sanitation project*
- *Me to follow-up with Agama Energy on bio digester- installation to happen within a week (CR3 R(B) CR5) 3500*
- *R(B) to co-ordinate the film- the documenting*
- *Sanitation story- R(C) to write the brief for the film*
- *R(C): Distel interested in how Enkanini is brought into the project. Inquiry into the process – story telling using photography*
- *Convince corporates to invest by doing film*
- *5th October- Workshop for 20 households*

Memo: The Enkanini sanitation cooperative (ESC) was now up and running. Duties were shared out amongst the researchers and co-researchers. In this meeting, R(C) was assigned the duty to write the film brief but in the FDG on the film project it was re-assigned to me which I was not too happy about. Most of the talking was done by the researchers in this meeting. The 5th October workshop with the households did not materialise as the conflicts within the ESC had escalated.

Visit by Councillor to Enkanini projects (5th December 2013)

'We met at the bottom of the circle of Enkanini (former PG glass) to wait for councillor at around 9.30am. Present: R(A), R(B), R(C), R(F), CR1, CR2, CR3, CR4, CR5, CR6, CR7, Me. Before the co-researchers arrived, R(A) told me of her altercation with CR1 over the control of the co-op account. They had exchanged WhatsApp messages earlier in the morning and now R(A) was worried that things were going awfully wrong- She said the ERCA should be dissolved- She doesn't want to be part of it anymore. She also mentioned when CR5, CR7, CR4, CR6 had arrived that Supervisor wants to meet co-researchers to find out what's going on. CR5 said they should meet supervisor without us the researchers. R(A) said she wants to be there to defend herself! I said we don't need to be there- Supervisor needs to know directly from the Co's what's happening…'

Memo: The conflicts within the ERCA and the ESC in particular, had escalated to a point where the research supervisor had to step in and resolve the disagreements. One major disagreement was about the control of the ESC account, which had thus far been controlled by CR1 with the help of a researcher R(A). Later in the month, the ESC had to be disbanded.

Reflection on Social innovation seminar held at UCT (6th January 2014)

'What if the project fails? – we were challenged to also think about co-failure and not think of it necessarily as a bad thing. When projects fail, the tendency is to wind them up and forget about them – but then another project fails and its wound up and we do not learn… We need to know why things fail just as much as why they succeed. Only a meticulous following – reflexive following allows us to understand how social innovation takes place or doesn't take place…'

Memo: After the failure of the ESC, I was concerned that the whole Enkanini sanitation intervention was going to fail and that my own research would be adversely affected. I worried that I will in fact have nothing to write about in my dissertation. The co-researchers we had recruited specifically for the intervention (CR1, 2, 3, 4, and 5) left the project. In 2014, we had to work with new and fewer co-researchers as well as an additional research assistant so that we the researchers could focus more on our own research. The concept of co-failure discussed at the UCT conference helped me to see that there were many lessons to be learnt from our failures and our efforts were therefore not in vein. If anything, we had achieved some successes as well and so I reworked my data so as to juxtapose the successes and the failures, while highlighting the lessons.

WRC visit to 3 sites (8th August 2013)

122

'We met in Stellenbosch and drove to Klein begin the Klipheuwel settlement and finished with Enkanini… Jay asked if I know how to do the maximum performance test that is done using soya paste in condoms to test the amount of human waste a toilet can flush. … I laughed because I had never heard of the test.

Memo: Jay is an engineer with years of experience in sanitation. His technical question made me question my own role as a designer in the sanitation intervention. During this meeting he and another engineer engaged in discussions which I contributed little to. I felt out of place.

Table 5.1 summarises other key journal entries which display the extent of my participation.

Dates	Memos of key Journal entries	Codes
27/8/2012	Talk with Scelo (SU researcher): Scelo is researching on 'becoming an urban citizen'. He explains that Enkanini politics is complicated by the wrangles in the street committees.	My immersion into Enkanini
28/8/2012	1st visit to Enkanini with Vanessa (SU researcher): Vanessa wants to implement a food waste management project in Enkanini	
6/9/2012	2nd visit with Scelo to Enkanini: We met Linda who is one of the leaders. The enumeration process by CORC and municipality is ongoing. We talk to some of the enumerators who are local residents.	
-/9/2012	Meeting at church in Enkanini: SU researchers & Enkanini co-researchers	
17/9/2012	Sleep over at Sylvia's house (Enkanini co-researcher). I experienced first-hand the inaccessibility of the toilets at night. They are not safe since they are far from the shack.	
25/9/2012	Met Saliem (Director of Waste management at Stellenbosch Municipality) at SI with Lauren (researcher). Saliem proposed that his department would pay for the digester.	Meeting with various stakeholders from municipality, university and professionals
3/10/2012	Met Prof. Kobus du Plessis from engineering to discuss technical specifications of the Enkanini sanitation intervention. He suggested that his students would be able to design the hydraulic system.	
-/10/2012	Met Charles (free-lance designer) with Lauren (researcher) and Jonny (Maluti engineer). We discussed the technical design based on the initial proposal to have a myco-filter.	
7/11/2012	Met Charles, Lauren. We discussed the technical design with myco-filter	
13/11/2012	Met Charles, Lauren, Jonny at SI: formation of a working-group	Sanitation working-group in Enkanini
15/11/2012	Met Charles, Lauren and Enkanini co-researchers- Sylvia, Yondela, Victor: viewing of the myco-filter at SI. A date set for installation in Enkanini as 1st March 2013	
11/4/2013	1st workshop with potential beneficiaries in Enkanini	Follow-up FGD: mobilisation of users

12/4/2013	Site visit to Klipheuwel installation with Enkanini co-researchers: Sylvia, Yondela, Sindi	
20/4/2013	Walk-about by the working-group in Enkanini to see possible sites for the installations	
23/4/2013	Brainstorming about user-payments in Enkanini	
29/4/2013	Met Kayamandi/Enkanini councillor at *Corridor* (her office). We briefed her on the installations. She insisted that her office should be consulted more on such projects.	Talks with municipality officials
6/5/2013	Plan with Yondela for co-design workshop	FDG: mobilisation of users
11/5/2013	I organised a co-design workshop in Enkanini. Attendance: 8 residents from section E. Assisted by Yondela and Susan (SU researcher).	
17/5/2013	I did translations of notes from FDG participants of the 11th with Sylvia. We used the information to do the generative workbook.	Creating a generative workbook to elicit further participation
30/5/2013	Meeting with Dawie (Director of informal settlements, Stellenbosch Municipality)	Talks with Stellenbosch municipality officials
9/6/2013	We had a workshop which was the official launch of the intervention in Enkanini	Beneficiary workshop
9/7/2013	I had a skype call with Lauren to discuss the Enkanini intervention.	Interdisciplinary exchanges
8/7/2013	WRC site visits. I explained about the ESC in Enkanini (non-technical processes)	Reporting the successes of the Enkanini projects
16/7/2013	Meeting at ERC with Lauren and Survey team (Enkanini residents) for Lauren's quantitative survey	
31/7/2013	Visit by parliamentary committee on energy to IShack project. I explained the sanitation work and the TD approach.	
10/10/2013	Co-design workshop on film. Attendance: 5 SU researchers-including me, 4 Enkanini co-researchers.	FGD: film project

125

5/12/2013	Visit to Enkanini by councillor David Botha of Stellenbosch Municipality. All SU researchers (PhD and Masters) and the sanitation co-researchers attended. Before the councillor arrived we discussed the conflicts in the ESC.	Conflicts in the sanitation working group
23/7/2014	Workshop with new users in phase two. Attended by 20 users form section E. Assisted by Yondela and Mphumlani.	FDG: user experience

Table 5.1 Memos from key journal entries

From August to October 2012 I interacted with various SU researchers not necessarily involved in the sanitation intervention. For instance, I initially had several talks with Scelo Zibagwe who was carrying out his own PhD research in Enkanini. As a Xhosa speaker, he had deep insights about Enkanini that helped shape my own critical stance about our work in the intervention. He was able to attend street committee meetings that were held at night in Enkanini. During those meetings, residents often expressed their frustrations with the Municipality and their local leaders such as the councillor. According to Scelo, residents were also suspicious of the research engagements in the settlement especially those that seemed to contravene their own plans for improving their situation. A case in point is the Ishack research project which was to provide solar powered electricity in the settlement. Some residents viewed this as an avenue for denying them their right to conventional grid electricity. Scelo also introduced me to a few de facto leaders in the settlement who I could use as 'references' in case I got into trouble in the settlement. Luckily, I never did get into trouble but there was another researcher who was robbed of her phone. After that incident, we were advised to only go to the settlement in groups.

The number of site visits and meetings took their toll on me because I still had to write my own research. The frequent interactions with other researchers and experts were also confusing because I tried to include the varying perspectives in my own research. The engineers for example emphasised the technical aspects and I had to learn the sanitation terminology that they used. It therefore took a lot of reflection to articulate design as a significant perspective equally deserving of consideration in the informal urban sanitation discourse.

5.3.2 Field Photographs

I took many photographs on my visits to Enkanini. I use some of those photographs here to reflect on my experience. The photographs are therefore visual explanations, which I layer with verbal descriptions of my experience.

Figure 5.1 From top-left to bottom-right: Gardening exercise in Enkanini; Enkanini sanitation group meeting; Myco-filter test; Enkanini site visit with the sanitation working group (Author, 2012-2013)

In my early involvement in Enkanini, I participated in various research projects such as the urban gardening exercise by another researcher, Vanessa Von der Heyde. This broad interest was beneficial because it served as an entry point into Enkanini. When the sanitation working group was formed, I was already well placed to work with the group because of my earlier immersion into the context. In November 2012, Maluti GSM engineers got WRC funding to trial the pour-flush in Enkanini and so we collectively went on several site visits to Enkanini. We the researchers already had NRF funding for community engagement and so the collective approach was a way to maximise on the available resources. Since I had no previous expertise in sanitation, the site visits were very important for me to learn about the sanitation problem.

Figure 5.2 Researchers and co-researchers meeting at Enkanini research centre (Author, 2013)

The collective group of SU researchers and Enkanini co-researchers working in Enkanini met often at the ERC to discuss all the ongoing projects on energy, food waste and sanitation. According to Lauren Tavener-Smith, one of the early members of the group, the group started in 2011 with three researchers and one co-researcher and by the end of 2013, there were 12 researchers and 8 to 9 co-researchers. The membership was however highly varied as some researchers were not focusing only on Enkanini and some co-researchers left the group. As such, the transdisciplinary process took place over an extended period as the engagements changed and progressed. The conflicts in the group were an opportunity for drastic changes, such as the need for co-researchers to sign new, clearer contracts. It was also an opportunity to reflect on our work and critique the approaches we had adopted so far as researchers.

Figure 5.3 From left to right: A burnt down shack and painted shacks in Enkanini (Author, 2013)

My design interests also led me to see the creative ways in which residents of Enkanini make their settlement more liveable. So, while investigating the sanitation problem in Enkanini, I developed a strong appreciation for the creative ways in which Enkanini residents make their space, despite the inadequacies of the informal settlement. For example, a fire in 2013 gutted down over 40 shacks. In two days, the residents helped each other to rebuild their shacks using mostly salvaged material. Fires are often caused by candles or stoves that are used to light or warm up shacks at night. Some residents have illegal connections into the electricity grid via neighbouring Kayamandi households.
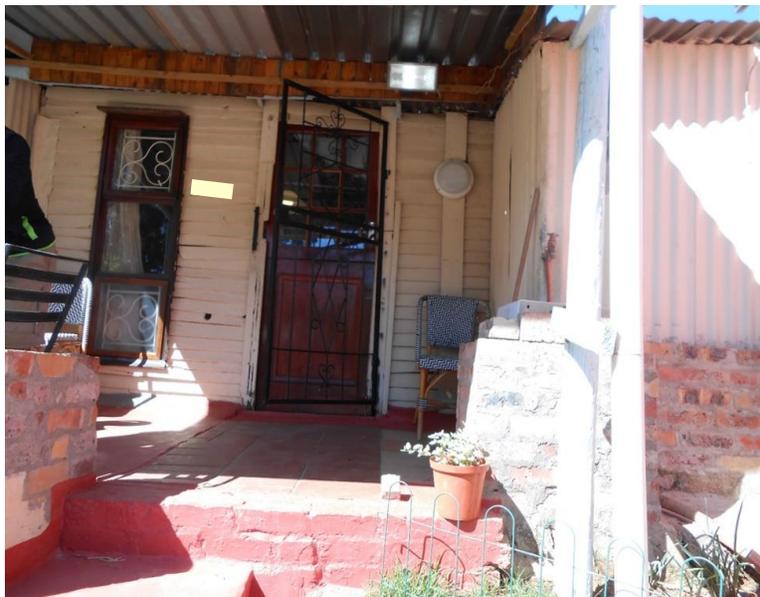
Figure 5.4 A serviced shack in Enkanini (Author, 2014)

129

One resident told me that he pays a household owner about 500 rand a month for the connection, alongside other residents, which means that the household owner supplying the electricity makes a considerable profit from these illegal connections.

It is inadequacies such as sanitation and electricity in Enkanini that prompt an impetus for creative ways of place-making. Place-making in such a context reveals 'alternative forms', which may 'manifest different values and sensibilities' opposed to mainstream place-making (Walker, 2011:2). In Enkanini, the alternative forms and sensibilities are identifiable in the design processes that are being instigated by Enkanini residents themselves, as opposed to the processes instigated by us the researchers. The significance of unearthing an informal design narrative in this way lies in the potential for creating linkages and mediating the tensions between the formal (professional design) and the informal (slum living). In particular, the informal design narrative in Enkanini is observable in several ways: i) the incremental approach to building homes, ii) the use of recycled building materials, iii) the engagement in informal entrepreneurial activities, and iii) the formation of social support groups. These examples are a challenge for the professional designer as they display inherent sensibilities that inform a vibrant informal design process.

5.3.3 My Role as a Researcher-Designer

As a trained designer, I was generally interested in the technological aspects of the sanitation intervention from the beginning. This interest led to the close collaboration with the Maluti GSM civil engineer who was in charge of installations in the Enkanini case. Unfortunately, I was not as involved in the actual technical design of the system as I had hoped to be. This was because the design process was controlled to a large extent by the engineer, whose mandate was to prototype the pour-flush and micro-flush toilets specifically. I therefore found more opportunity in what the engineer referred to as the 'non-technical processes': *"...I would still ike [sic] for you to come with me on the 21st if you can as you can tell the story of the non-technical processes at Enkanini. Are you free?"* (Harris, Email communication, June 5, 2013).

Upon reflection, these non-technical processes articulated the expanding social role of design that is beyond technological product design. Nonetheless, I still accorded great significance to the technology as demonstrated in the in-depth analysis of the sanitation technology in chapter three. The less active role in the actual prototyping of the technology was thus supplemented by a thorough understanding of

the technology, in an effort to gain an integrated and holistic view of the design process in the Enkanini intervention.

In other words, my focus as a researcher-designer was not just on the design object (i.e. sanitation technology), but also on the design team (i.e. engineer and SU researchers), the design users (i.e. Enkanini residents) and the design context (i.e. Enkanini informal settlement). These were the components of the design process, and the interplay between them required facilitation. As such, I wrote this article in order to articulate design ethnography as field research tool that is useful for TD research.

5.4 Methodological Concerns in Design: Design ethnography

Current thinking in design provides a closer connection between theory and practice, which means that design thinkers are concerned with the methodological and philosophical underpinnings of design (Von Thienen et al., 2011). Additionally, the concept of 'infrastructuring' is used to explain how collaborative design exercises can be sustained to achieve long-term social change (Hillgren, Seravalli & Emilson, 2011). In infrastructuring, the design process is an open-ended network that allows participants to visualise social and technical arrangements that can be tested and improved collaboratively over time. For infrastucturing to work, it has to be supported by a community of collaborators (ibid). Infrastructuring can thus be related to the TD method, in which collaborations are geared towards social change. In the Enkanini case, the collaboration between researchers, the engineer and Enkanini residents is conceptualised here as an initial attempt at infrastructuring, in which I participated as a researcher-designer.

To conceptualise on design ethnography, I map my participation in the Enkanini case (Figure 5.5). The mapping shows that the design process was distributed and asynchronous[2] in the beginning, meaning that it happened at different places and different times. For instance, the researchers met with several stakeholders separately. The researchers therefore fully led the design process in the initial pre-pilot phase. When the installation of the system started in Enkanini, the co-designing was more localised in section E of Enkanini but it was still asynchronous: most interactions took place in Section E although they did not involve everyone at the same time. This is exemplified in the way that

---

[2] O'Sullivan and Dooley (2009:289-90) discuss 'distributed asynchronous collaboration' and 'asynchronous collaboration' as methods of innovation in organisations.

researchers often met or communicated separately either with the engineer or with the co-researchers. It is hoped that past 2015, the co-designing can become a lot more synchronised if collaborative activities can be better coordinated and more inclusive. Such collaboration can take place both as localised and as distributed and flexible activities i.e. infrastructuring.

Whilst participation in the pre-pilot phase of the intervention, I observed that the design team composed of SU researchers and engineering expert maintained relative control over the intervention, whereas the would-be users and co-researchers from Enkanini played a less active role. For instance, the technical aspects of the sanitation system were largely dictated by the engineer who had funding specifically to experiment with the pour-flush and micro-flush toilets. The SU researchers on the other hand, controlled the funding from the university, as well as the general running of the intervention.

Additionally, I observed during the workshops with the would-be users, that they were not contributing meaningfully to the dialogue on the sanitation intervention. I therefore identified the need to facilitate exercises that would empower the would-be users to contribute more to the dialogue and the design process of the intervention by articulating their needs and interacting better with the researchers and expert. Subsequently, I set out to achieve what I regarded as empowering outcomes by enhancing the participation of the would-be users. To achieve this aims in the field, I organised focus-group discussions (FDGs analysed in Chapter Four) around design aspects of: mobilisation, interaction and user-experience. In retrospect, I systematise the objectives of the focus-group sessions as:

- the need to enhance participation by mobilising would-be users at the beginning of phase one

- the need to improve the interactions between co-researchers and the researchers towards the end of phase one

- the need to understand the user-experience from phase one, to inform phase two of the intervention

It was possible for me to organise these FDGs because I was already an active member of the Enkanini sanitation working group. This means that my prolonged participation in the group (ethnography) was necessary for me to understand the needs of the group and align my research interests and objectives (design) to the reality in the field.

Mapping Design ethnography in Enkanini

My entry into research context
Researcher-designer role

User
Mobilisation

Enhancing
Interaction

Understanding
User-experience

Exit from
Case study context

Immersion
Site visits
Stakeholder meetings

Installation
5 pour-flush toilets
Anaerobic digester

Research workshops
Failed innovation:
Closure of ESC

Re-design
Biogas trials,
Micro-flush toilets

August
2012

May
2013

Oct
2013

July
2014

2015

Pre-pilot

Phase 1

Phase 2

**Distributed asynchronous
Design**
*Separate meetings with potential
stakeholders and partners*

**Localised asynchronous
Design**
*Regular but separate meetings at the
site of installation*

**Synchronous
Co-design?**
*Regular, well-coordinated meetings
and interactions between
stakeholders; both localised and
distributed*

Figure 5.5 Mapping my participation as a Researcher-designer in the Enkanini case

5.5 Core Design Competencies

Design facilitation is premised on the idea that designers already possess the skills needed to support co-design activities with non-designers. These skills are the analytic and creative methods of traditional design, which are: visualising, experimenting, prototyping, gathering feedback, and re-designing (Razzouk & Shute, 2012). Such design skills can be applied through collaborative exercises to augment other professional competencies (Bjögvinsson, Ehn & Hillgren, 2012). In this section, I analyse design aspects in the work of others in the case and reveal three core competencies of design. These are: iteration, prototyping and visualisation.

5.5.1 Iteration

The Informal Settlement Upgrading Group in Enkanini (ISUG) was made of masters and doctoral researchers from SU who started working in Enkanini in January of 2011 (Tavener-Smith, 2012). From the research done since then, there have been Masters' theses focusing on energy-poverty (Keller, 2012; Radmore, 2015) and food waste management (Mollatt, 2014; Von der Heyde, 2014) and the co-production process (Wessels, 2015). I joined the group in late 2012 and became part of a smaller team within the ISUG, known as the 'sanitation working group' that was specifically focused on implementing a sanitation intervention in Enkanini.

The initial sanitation intervention plan presented by the ISUG in 2012 was clear and well laid out. The plan was to constitute a working group made up of Enkanini residents, Stellenbosch Municipality officials, NGOs, experts and researchers:

> *'The Working Group is constituted of residents (knowledge of the everyday reality in inadequate sanitation), SM officials and tech staff (knowledge of policy, regulations, bylaws and planning), CORC and ISN (mobilisation partners) and sanitation technology experts (academics and practitioners with specialised knowledge). The Decision Group is comprised by SM directors, and signatories to the Gates MoU (CORC/ ISN and SI), the local Ward Councillor, Enkanini resident/ leaders (issues of representation at present' (ISUG PowerPoint presentation, 2012)*
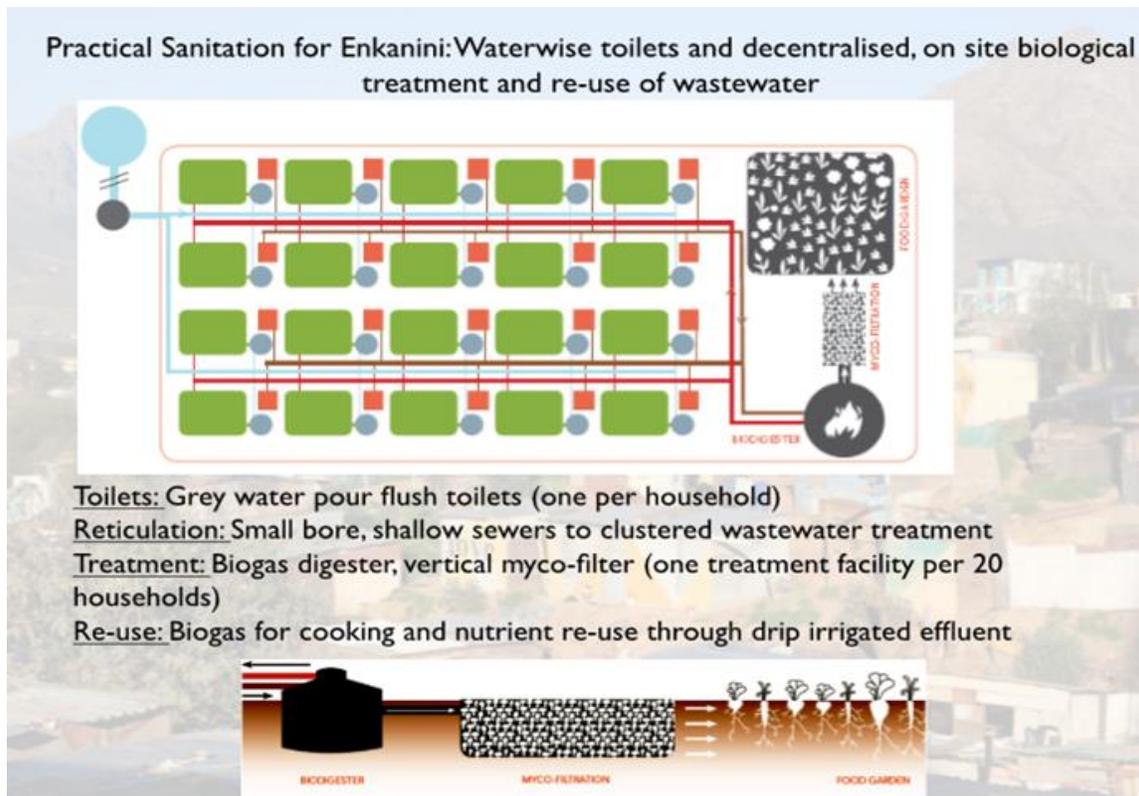
Figure 5.6 Proposed technical design for the Enkanini intervention (Source: ISUG, 2012)

The technical design for the sanitation system was also proposed as 'waterwise' toilets with onsite biological treatment of black water using a myco-filter (Figure 5.5). Later, the constraints of time, budget and expertise necessitated many changes to the technical design (Figure 5.6): The grey water flush toilets in the proposal were replaced by the cheaper pour-flush toilet design of Maluti GSM. Earlier tests of the myco-filter proved that it was unviable since it was a revolutionary filtration technology that has not been tested on a large scale or in informal settlements such as Enkanini. In its place, the biogas digester was installed but it did not have the optimal chemical conditions to produce enough biogas for the households as intended. The re-use of effluent for irrigation was also not implemented because of the lack of a filtration system. By the end of phase one of the installation in December 2013, only five shared toilets had been installed as opposed to the 20 individual toilets proposed in 2012. The design of the system was therefore iterative and in response to the limited funding, expertise and time.
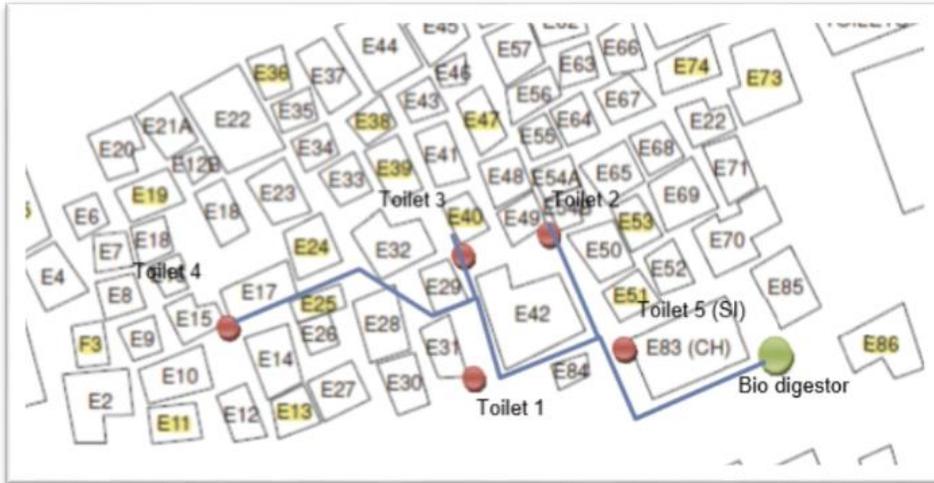
Figure 5.7 Implemented plan in phase one of the Enkanini sanitation intervention (Source: Maluti GSM, 2014)

The pour-flush toilet was installed in phase one of the Enkanini intervention in April 2013. By April 2014, users expressed dissatisfaction with the pour-flush toilet. This dissatisfaction was attributed to: i) the need to pour water into the toilet bowl by hand, and ii) the need to store grey-water for flushing the toilet, a practice that was against Xhosa cultural beliefs. This dissatisfaction was reported by one of the researchers to the engineer as shown in the email excerpt below by:

> *…We've had some feedback from users re the pour-flush being a bit of a pain. Users are finding that they need to dispose of their grey water at different times to when they need to use it to flush. Cultural reasons prevent them from storing grey water for any length of time, they want to discard it immediately, as its generated. Users want flush toilets, they want the automated experience, the convenience of not having to ensure you've got your flush water with you (eg someone had to use toilet urgently as she had diarrhoea and was unable to flush as there was no water)…* (Tavener-Smith, Email communication, September 17, 2013).

The engineer responded to this feedback by pointing out that the pour-flush toilet bowl, which was developed by Still and Louton (2012), would be developed further into the micro-flush by Maluti GSM engineers:

> *…Our work to date has been to demonstrate the design developed by others, but we are now gearing up to develop our own design (the Micro-flush toilet) which will utilise the effective*

pour-flush pedestal design with the convenience of a flush… (Harris, Email communication, September 17, 2013)

I was to be involved in the design of the micro-flush by facilitating a co-design process with the users. This role was implied in the communications between the engineer and the researchers "*…Lorraine and myself will be working on the Micro-flush design over the coming year…*" (Harris, Email communication, May 31, 2013).

I therefore got involved in the initial design process of the micro-flush and discussed the micro-flush design with users in a focus-group. At the time of submitting this article, the micro-flush was still in the design phase. The design phase of micro-flush toilet illustrates an iterative process that was informed by user-needs.

5.5.2 Prototyping

The concept design of the micro-flush was inspired by the vortex shape of the arum lily as explained by the engineer. According to the design, the micro-flush is expected to offer the same convenience as a full-flush cistern toilet, but with a significant water saving. This is due to the spiral flush of water that should clear the pan (Figure 5.7). Currently, the micro-flush is being designed by 'Isidima design and development' firm. The engineer responsible for the design moved from Maluti GSM to Isidima, and was able to continue working on the micro-flush. The funding for this work is provided by the WRC and is expected to take two years to develop and prototype, starting from 2014.
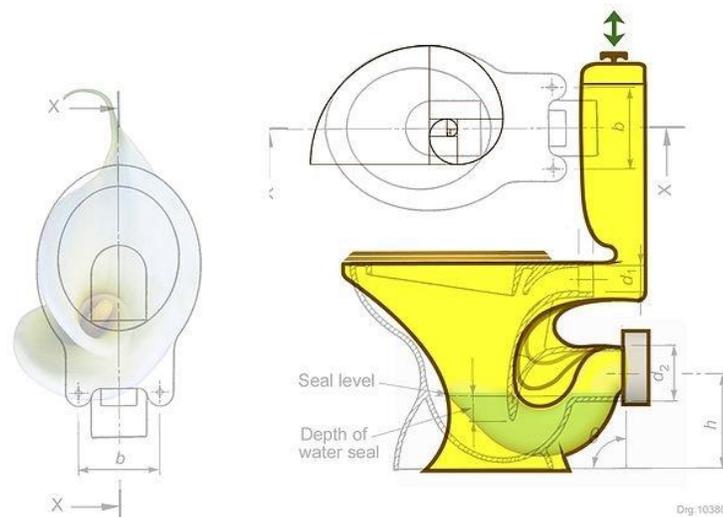
Figure 5.8 Concept design for the micro-flush inspired by the arum lily flower (Source: Isidima, 2016)

The P-trap of the micro-flush is borrowed from the pour-flush toilet. *'The sloped entry and long radius bend enables waste to be flushed with minimum effort. The inverted egg profile of the P-Trap reduces the water seal volume to 0.6 litres without compromising conveyance capacity.'* (Isidima, 2016)
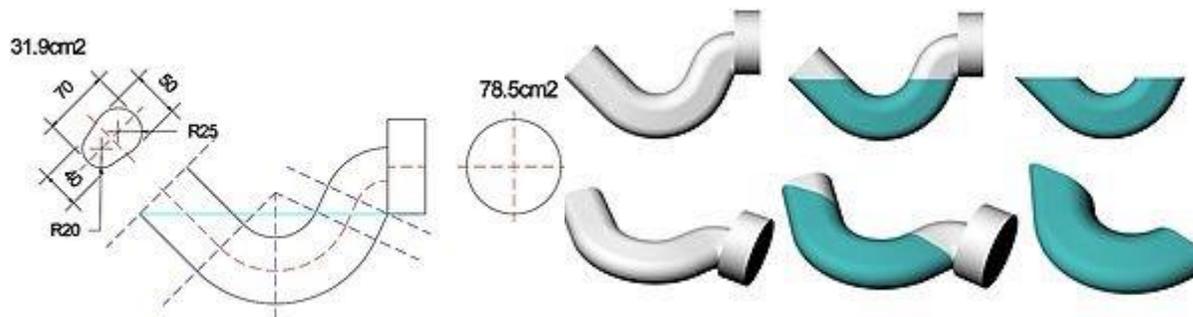
Figure 5.9 The P-trap design (Source: Isidima, 2016).

5.5.3 Visualisation

During the sanitation intervention, there was a challenge in collaborating effectively with the users. As explained by Anderson, Curtis and Wittig (2014), users do not always have the capacity to engage meaningfully in collaborative design processes. Participatory design processes should therefore not only seek to involve users in design but to also empower them. In the Enkanini case, there was a need to enhance user-participation, which I sought to do using visual tools. Enhanced user-participation is considered here as a path towards empowerment.

In research on participation, verbal communication, which is often expressed in the form of rational arguments, limits the participation of stakeholders. It is therefore recommended that other communicative genres should be used to create more representative spaces (Cumming & Norwood, 2012). 'Text' is a specific barrier to effective participation of vulnerable communities and so 'beyond text' tools are advocated for as a way to democratise knowledge by enhancing participation (Beebeejaun, Durose, Rees, Richardson & Richardson, 2014).

User-generated images: I introduced cartoon-strip drawing exercises as visual tools to enhance dialogue for the participants in the focus-groups. These cartoon-strips were humorous and served as ice-breakers for the dialogue in the sessions, while they also represented metaphorical forms of

expression, given the sensitivity of the topic (Costandius, 2012). The inadequacy of sanitation in Enkanini is a particularly sensitive topic that required the discussion of personal habits. Drawing cartoons was therefore a way to ease into the discussion as the conversation was often directed at the drawings and not at individuals. Figure 5.9 shows some of the cartoon-strips drawn by participants in a focus-group session on grey-water use. The participants were eight Enkanini residents: two were male, six were female.
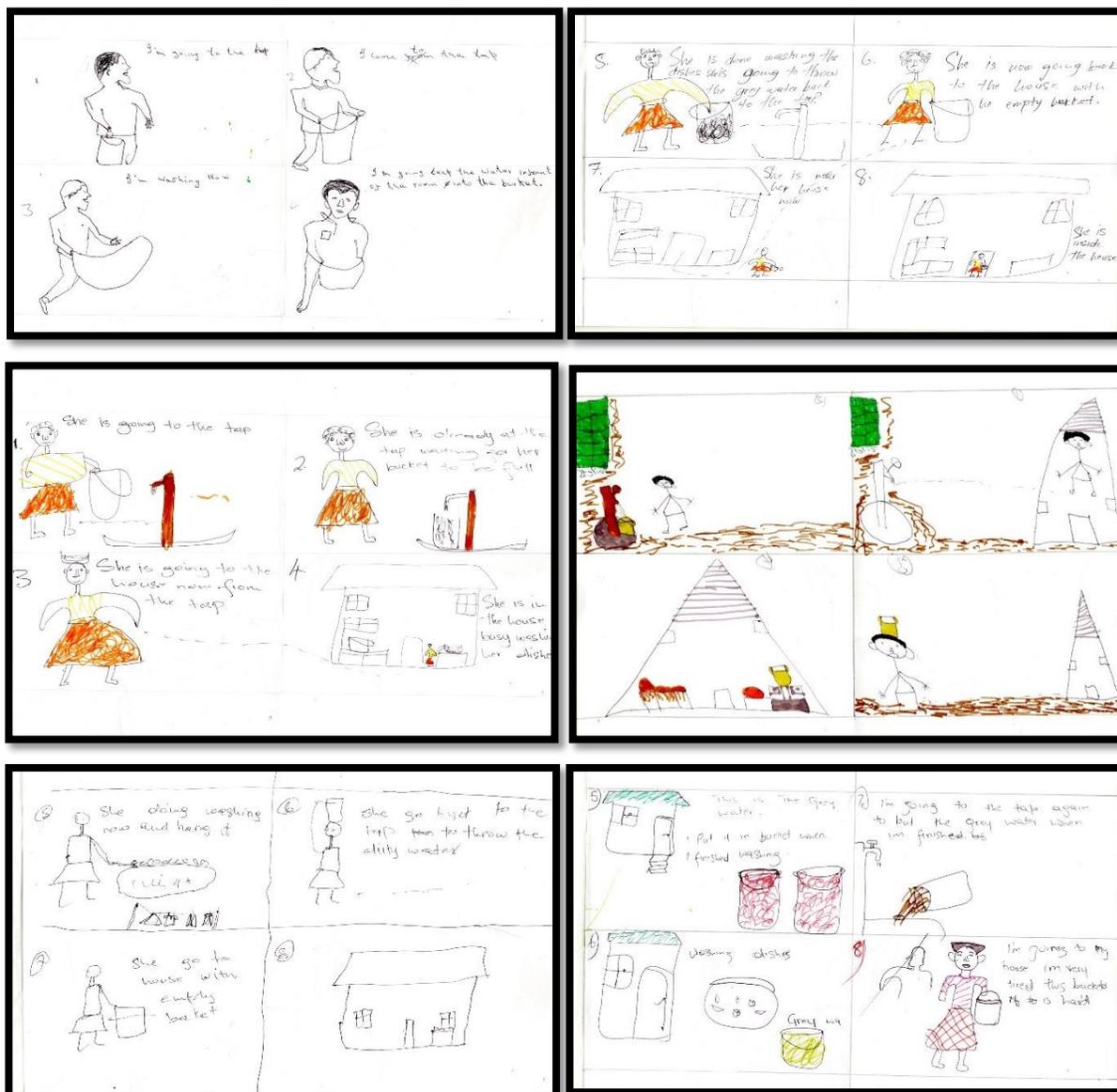
Figure 5.10 Cartoon-strip drawings by participants in Enkanini (Source: FDG participants)

Figure 5.11 Compiled drawings from individual participants to tell the agreed-upon grey-water story (Source: FDG participants)

After discussing each participant's drawings in the group, we selected individual strips from six participants, which we used to tell the desired grey-water story that we had agreed upon (Figure 5.10).

In my analysis, I classified the drawings into visual prototypes, which I corroborated with verbal sources to describe their social, cultural and political context of the visual material. More specifically, iconography was used to measure the occurrence of specific signs and symbols in an image while iconology was used to expound on the contextual meaning of the drawings exercise as a whole (Muller, 2011). In assigning meaning, it was necessary to adopt intuitive inquiry based on my experience and understanding of Enkanini (Saldaña, 2013). Table shows how iconography was employed by generating holistic codes from the drawings. Iconology was then used to assign intuitive inquiry to the codes.

140

Holistic codes from analysis of drawings	Intuitive inquiry	Thematic analysis
Use of bucket	Residents do not have piped water in their homes so they have to fetch water using buckets which they carry back to their homes on their heads. It's an activity that consumes a lot of time and physical energy. Stellenbosch municipality has provided and maintains 32 shared water taps in the settlements.	Difficulty in accessing water for daily use
Water point	Every morning residents meet at the water points to fetch water. The water points are therefore a meeting place since some women actually do their washing there.	Communal role of shared facilities
More women than male characters	Fetching water and washing is a gendered activity. According to the enumeration report by the Municipality, more men than women in the settlement have some form of employment, hence the women remain in the home to carry out chores	Gendered perspective of water access
English vs Xhosa	The participants are comfortable writing in English although the conversations were in Xhosa. Mixing the two languages in writing and in conversation was confusing for me but was a comfortable means of communication in Enkanini	Language
Keeping used water in the house	Keeping used bath water is frowned upon as bath water is believed to have spirits that need to be disposed of immediately	Belief systems governing water disposal
Disposal of used water in the toilet vs in the open drain	The shared toilets are far from some homes and so residents often pour water into the open drains which may lead to poor health outcomes especially for children who play in the open drains. In the discussion after the drawing sessions, a majority of participants agreed that water should be disposed in the toilet.	Health and environmental consequences of poor water disposal

Figure 5.12 Analysis of the cartoon-strips using iconography and iconology

The emerging themes from the thematic analysis of the cartoon strips by Enkanini participants are useful for planning grey-water systems such as the pour-flush toilet design. The gendered dimension of water use is a particularly important consideration that is in line with the global SDG agenda for water and sanitation (Sustainable Development Knowledge Platform, 2015).

Designer-generated images: One of the participant's drawings was used in a concept design by an MA student with an art background. The concept design was to be used in branding the pour-flush toilets in a collaborative exercise with the participants.

Figure 5.13 Concept design for painting pour-flush toilets using participants' drawings (Source: Meyer, 2013)

In another instance of employing visualisation, I compiled the deliberations from a discussion with Enkanini participants, with the help of an Enkanini co-researcher, into a generative workbook that was to be used in groups to elicit further suggestions for the planning of phase one of the intervention (Figure 5.14). The generative workbook addressed issues of: care and cleaning, membership, pilot operator, payments, defaulting, group meeting and security. It ended with a motto which had been generated during the focus-group session: "*Please let us take good care of the toilets because they will improve our health and our lives. Working hand in hand, we can go far*".

142

User-group Agreement

Care and Cleaning

- The group should have a duty rooster for the entire week showing who will clean each day

- The group should jointly buy cleaning agent, hand soap, sanitizer, air freshener and tissue paper once a month (These items will not be provided by the research)

- The group will also need to provide a bucket to collect water from the hand basin and a place mat for the floor

- If a user has visitors using the toilet, they must clean the toilet again on that day, even if it is not their day for cleaning

- Users should not throw food or plastics down the toilet which may cause a blockage

- Each user should flush the toilet after use, and grey water can be used for this purpose

- The toilet should not be used for commercial purposes such as by shebeen customers

- The group will paint the walls and door of the toilet (The paint will be provided by the research. The painting will also be facilitated by one of the researchers)

Figure 5.14 A page from the generative workbook from participants' deliberations (Author's design)

As far as membership was concerned, the participants were supposed to form four groups of toilet users, who would share four of the five pour-flush toilets. The participants were expected to work on the generative workbooks within these groups. In this regard, the generative workbooks failed to elicit the kind of extended participation that was hoped for. The failure was due to the fact that the participants did not make much effort to meet outside of the organised focus-group sessions; hence the workbooks were never used. Nevertheless the workbooks still served the purpose of articulating the deliberations from the focus-group; hence they were less generative but were informative. In a third session with users, I used a leaflet to clearly display what will occur in phase two of the intervention (Figure 5.15).

Figure 5.15 A leaflet explaining phase two of the intervention (Author's design)

In synthesis, visualisation was a facilitatory tool to:

- Prompt dialogue: in speaking about their drawings and about the images in the leaflets, participants expressed their opinions about personal topics such as bathing and using the toilet. This was in contrast to other workshops that were purely verbal and dominated by researchers.

- Reveal nuanced user-experiences: Enkanini residents approached the sanitation problem with a more nuanced view, as opposed to the focused approach of the researchers and engineer. Visualisation was therefore an effective way to understand their nuanced approach. Researchers had the clear advantage in rational argumentation, but the users had the tacit knowledge based on their experiences in using the system and in living in Enkanini. Their views and opinions were therefore necessary for the development of the system and visualisation was an effective way to elicit those nuanced views and opinions. Literature supports the use of a visual methodology in TD settings: tangible objects can be used as conversation pieces (Pink, 2012, Raijmakers, Van Dijk, Lee & Williams, 2009).

The drawing sessions were however time-consuming and more involving for the participants, especially for those who were participating in other research sessions. It was therefore not possible to have a consistent group that could participate in a quasi-experiment. The quasi-experiment would have been an opportunity to test the causal impact of the drawing sessions on a specific target group.

5.6 Design ethnography in TD research

By first analysing my participation as a researcher-designer, then analysing the design aspects of other actors in the Enkanini case, I have highlighted the significance of design as a research method i.e. design ethnography, and as an analytical lens i.e. core design competencies (Figure 5.16). The wish was not to romanticise design as the solution to the challenges we faced in the Enkanini case, but to strongly suggest that design offers an approach for facilitating generative learning, especially in complex, multi-actor processes such as informal urban sanitation exercises.
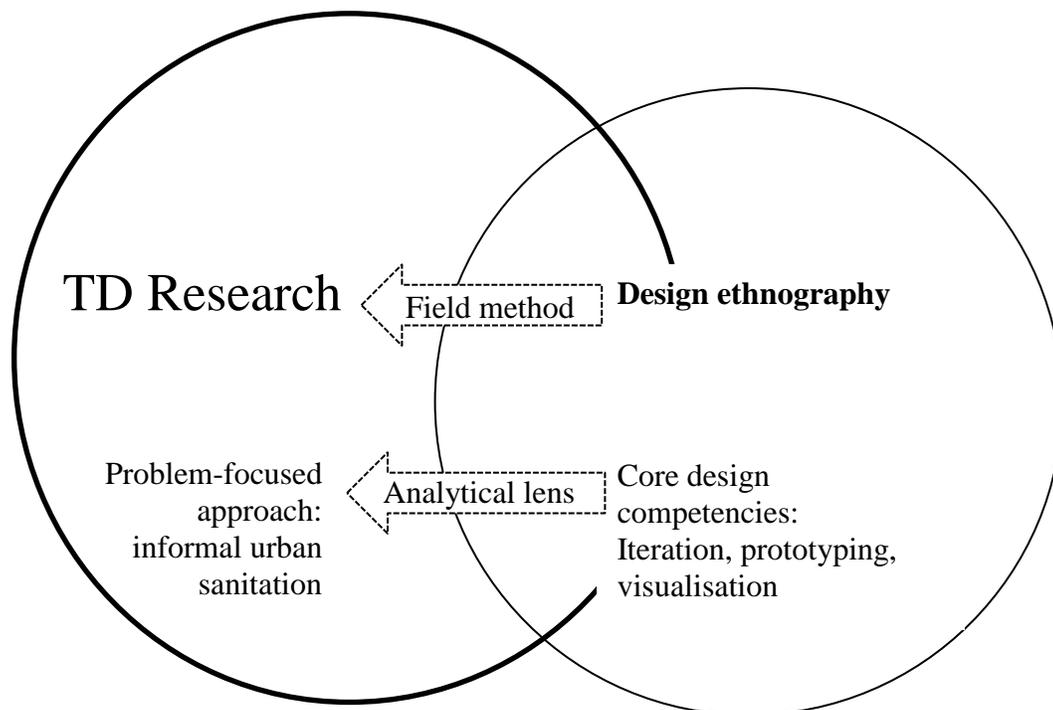
Figure 5.16 Design ethnography in TD research

The displayed relationship between design ethnography and TD research is an important step towards developing a toolbox for design ethnographers working in informal contexts.

5.7 Conclusion

I set out to better understand design practice for under-served contexts by articulating my journey as a researcher-designer in the Enkanini case. I used my journal entries and field photographs to provide an auto-ethnographic account that embeds my story in the meta-narrative of the case. I then use this to expound on design ethnography as a facilitatory method in the meta-narrative of TD research. I analysed the work of other participants in the case to articulate the core competencies of design as: iteration, prototyping and visualisation. In this regard I analyse the difference between the planned

sanitation system and the implemented sanitation system in iteration; the re-design of the pour-flush to the micro-flush toilet in prototyping; and the cartoon-strip drawings by participants in visualisation. These core competencies make up a toolbox for design ethnography. My articulation of design ethnography is therefore theoretically significant for the expanding social responsibility and sustainability discourses in in design practice.

CHAPTER SIX

6.0 CONCLUSION OF THE DISSERTATION

6.1 Summary of Findings

I have argued in this dissertation that informal urban sanitation is a complex problem that calls for a TD approach. This is because transdisciplinarity provides the multi-actor and multi-perspective approach that is required to investigate and tackle the complexity of informal urban sanitation. A multi-dimensional approach is however challenging, more so in cases where researchers have to work with marginalised or disempowered groups such as informal settlement dwellers. It is therefore necessary to engage disciplines such as design which can provide facilitatory techniques for TD processes. I thus propose design ethnography as a generative method for facilitating relationships in TD processes that aim to tackle informal urban sanitation.

The backdrop to this argument is traced back to the *Future Earth's* global initiative that strongly advocates for co-design and co-production between science and society. The *Future Earth* proposals also brings to the fore the significant role of the social sciences in realising sustainable change in the face of todays' global environmental changes. Vulnerable communities in Sub-Saharan Africa bear the brunt of these global changes because their countries lack the intellectual and institutional infrastructures to support coping mechanisms.

One of the visible rapid changes in Sub-Saharan Africa is accelerated urban growth, which is incongruent to the urban forms that were long-drawn-out over the industrial revolution of the Global North region. This means that the urban design narrative developed in the Global North fails to capture the current urban realities in Sub-Saharan Africa, in which informality is the dominant paradigm. Urban planners and researchers in Sub-Saharan Africa have thus expounded on informality as an alternative urban pattern, while also focusing on the practices and processes that can ameliorate the deficiencies of urban informality. One of those deficiencies is inadequate sanitation.

I therefore set out to understand how the global co-production agenda translates in the real-world context of informal urban sanitation. I studied three cases of informal settlements, in which sanitation interventions were implemented by multi-stakeholder groups. The guiding research questions were:

- How are social and technological considerations configured in the sanitation interventions in the three informal settlements?

- What are the challenges of co-producing knowledge in an informal settlement context?

- How can design facilitation enhance participation in contexts such as informal settlements that have traditionally been under-served by professional design?

The three research questions framed three journal type articles that were supported by a synthesis of literature on informal urban sanitation and knowledge co-production. The synthesised literature revealed that informal urban sanitation is a complex problem that is shaped not just by technological concerns, but also by social, institutional and political concerns. Technological concerns have however been the most prominent considerations in informal urban sanitation, leading to failed sanitation interventions across Sub-Saharan Africa. In light of these failures, social scientists have been more vocal about the relevance of social, institutional and political perspectives in tackling informal urban sanitation. These different perspectives are underscored by the concept of service co-production. The concept of service co-production in informal urban sanitation is premised on the argument that the participation of informal settlement dwellers can improve the implementation of sanitation services in their settlements. Informal settlement dwellers should therefore be engaged in different phases of the implementation process based on their capacities and resources.

In practice however, participatory processes and user-involvement in informal urban sanitation exercises are hard to realise because they are time consuming and require broad and extensive consultations with stakeholders. This is opposed to expert-led sanitation interventions, in which decision making is quicker and resources can be maximised. The push for participation of users may also thwart individual agency in favour of collective engagement. The benefits of service co-production are nevertheless visible in successful exemplars where alternative solutions were made possible through co-installations, co-management or co-financing. In this regard, innovative technologies that are cheaper than conventional trunk systems have been successfully piloted in various informal settlements in the Global South region.

I then discuss the particular situation of informal urban sanitation in South Africa in order to provide the specific context of the case studies under investigation. It that discussion, I reveal that the provision of sanitation in informal urban settlements in South Africa is a highly contentious issue despite the fact that South Africa is one of the few Sub-Saharan countries that was on track to meet the 2015 MDG goal for improving sanitation. The complexity of providing sanitation in informal urban settlements has thus led to calls for greater user involvement and participation in sanitation interventions in South Africa, as in elsewhere in the Global South region.

The need for service co-production is echoed in the TD research approach, in which non-academic partners are invited to co-produce both knowledge and services that have social relevance, in the acknowledgement that non-academic partners can contribute to solutions given their expertise or experience of the social problem at hand. However, power asymmetries abound between partners who engage in TD research as they attempt to transcend disciplinary boundaries and academic confines. Non-academic partners such as informal settlement dwellers may be further disadvantaged because of their limited formal education and resources. To overcome these challenges, reflexivity is necessary to expose positionalities in the co-production process. Acknowledging positionality offers avenues for resolving conflicts or in the very least, an opportunity for learning from past conflicts and failures. Mainstream research methods that are often text-based also inhibit participation because they perpetuate the power of the researcher over the researched. Creative participatory methods such as those used in design can therefore be meaningfully employed to enhance the contribution of non-academic partners. In this regard, researcher-designers can facilitate and enhance TD processes with non-academic actors.

The emergent theoretical frame from the reviewed literature is then used to support the empirical material in three journal articles. The first journal article has articulated an integrative socio-technological approach for tackling informal urban sanitation. This approach was informed by the cross-case synthesis of the technical configurations of the sanitation installations in the three settlements, vis-à-vis the social interactions between the stakeholders who enabled the sanitation interventions. The synthesis leads to the articulation of socio-technological reciprocity in informal urban sanitation. The findings from Enkanini further illustrate a conceptual model of socio-technological reciprocity that has three interfaces of: technological components interface; user-provider interface and people-technology interface. To highlight the theoretical significance of the case study findings, I use notes from a sanitation seminar that took place in Pretoria, to embed my findings within

the wider sanitation discourse in South Africa. This article sets the empirical overview for the dissertation by providing a more nuanced understanding on informal urban sanitation.

The second article unveiled the challenges of carrying out TD research in an informal settlement context by unpacking the interrelationships between researchers, expert and co-researchers in the sanitation working group. As an active participant in the Enkanini sanitation working-group, I was able to capture the emergent narrative of the group through FDGs and the naturally-occurring interactions of its members. In the analysis, the critical stance of CDA highlighted the conflicts and power asymmetries within the sanitation working group, which I then used to systematise themes of knowledge co-production. In this way, I engaged my own conflicting insider-outsider position in the group through a self-reflexive approach.

The third article extended my insider-outsider role by demarcating my specific role as a researcher-designer, whose wide realm of interest in transdisciplinarity is shaped by a specific design interest in technology. The article therefore emphasises the facilitatory role of design ethnography in TD research through an auto-ethnographic account of my participation in the Enkanini case. I do this by analysing my research journal entries and field photographs. I also unveil design aspects from the work of other actors in the case through a thematic analysis of participants' drawings and the technical design of the sanitation system. From these, I articulate core design competencies that form part of the toolbox of design ethnography. Table 6.1 summarises the specific findings of each article, which have contributed to a finer understanding of the TD co-production processes for improving informal urban sanitation.

Overall, TD research was both a practical field approach i.e. a multi-stakeholder engagement between researchers, experts and informal settlement dwellers to tackle inadequate sanitation; as well as a methodological approach for organising this dissertation i.e. presentation of multiple perspectives in the literature review and journal articles.

Understanding co-production through sanitation intervention case studies in South Africa			
Cases	Articles	Data Analysis	Discussion
Klein Begin Klipheuwel Enkanini	Socio-technological reciprocity innovation in informal urban sanitation	Technical configurations of piloted systems Social interactions that enabled implementation	Socio-technological reciprocity and innovation for sanitation in informal settlements • Technological alternatives for informal settlements • Service co-production • Model of socio-technological reciprocity in informal urban sanitation Way forward for informal urban sanitation in South Africa • Notes from 'Gates sanitation technology innovation seminar' Pretoria
	Challenges of TD research in an informal settlement context	Focus group discussions Naturally occurring interactions: Emails and WhatsApp group messages	Themes in TD research • Framing the co-production agenda • Communication barriers in the co-production process • The role of funding in co-production • Participation in co-production • Positionality, voice and self-reflexivity in TD research • Measuring our TD research achievements
	Design facilitation for TD research	Auto-ethnographic account: journal entries and field photographs Participants' drawings and technical designs	Design ethnography • Mobilisation of users through design facilitation • Enhancing dialogue in group discussions • Understanding user-experience Core design competencies for design ethnography: • Iteration- changes in the sanitation intervention plan • Prototyping- concept design of the micro-flush • Visualisation- cartoon-strip drawings by participants

Table 6.1 Summary of findings

The three articles relate to each other as follows:

Empirical base:
Socio-technological reciprocity and
innovation in informal urban
sanitation

Overarching Methodology:
Challenges of TD research in an informal
settlement context

Applied method:
Design facilitation for TD research
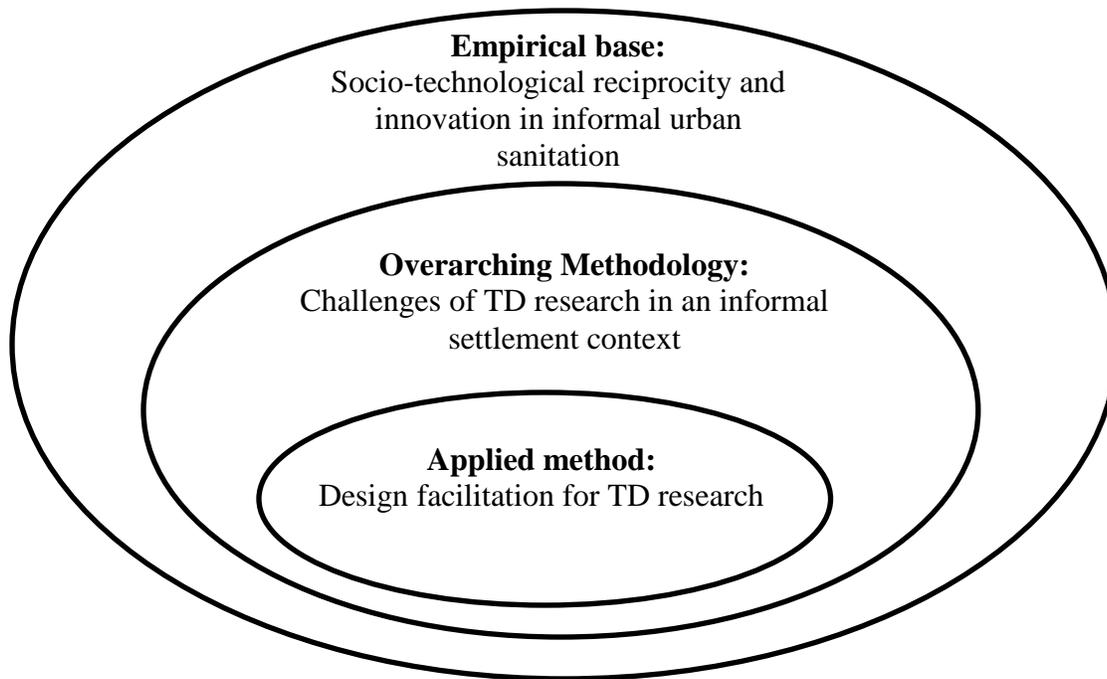
Figure 6.1 The empirical and theoretical relationship of the three journal articles

The first article set the empirical base using the three case studies while the other two delved into the Enkanini case. In this way, the three articles build on each other but also suffice as stand-alone articles. Formatting the dissertation as journal articles made it possible to deal sufficiently with separate discussions that are nevertheless overlapping. The challenge is in ensuring that the overlaps do not result in unnecessary repetitions. However, one theoretically significant overlap in the different literatures of the review and in the empirical discussions of the articles is the recurring theme of facilitation. As such, the third article on design facilitation brings the dissertation full circle by emphasising the need for facilitating TD research processes in informal urban sanitation provision.

6.2 Linking Findings to Broader Theories of Change

The findings of this dissertation are extended to broader theories of change to open up further opportunities for research. Informality has served usefully as a heuristic model yet it remains a contested and limiting concept because it fails to capture the multiplicity of urban configurations in African cities (Jaglin, 2014; Malaquais, 2011). Incremental urbanism on the other hand is a new form of urbanism that is opposed to the large-scale urbanisation planning methods of the industrial era

(Erfurt IV, 2015; Mehrotra & Rose, 2014); while celebrating the incremental processes of self-organisation and assemblage that are carried out by informal settlement dwellers in the Global South (Dovey, 2014; Ernstson, Lawhon and Duminy 2014). Incremental urbanism is therefore proposed as a more encompassing and inclusive urban paradigm that can stretch beyond the contextual limits of informality, and therefore offers better prospects for the heterogeneous nature of urbanisation in Sub-Saharan Africa. In incremental urbanism the co-production of services with the poor to improve their immediate material needs is intertwined with the normative approach of co-producing academic knowledge to support knowledge infrastructures that can sustain innovations.

In more specific terms, two TD processes are congruent to the short and long terms aims of incremental urbanism: In the TD work by the Enkanini sanitation working group: there was: i) the social-technological process -that was geared towards practical outcomes, and was informed by relational and experiential knowledge, and ii) the research process -that was geared towards academic and epistemological outcomes and was informed by rational forms of knowledge. These two processes are important in the TD setting, in keeping with the academic and extra-academic concerns of TD research. Unpacking the processes also affords a better theoretical understanding of TD action in informal settlements, where the main objective is to ameliorate the immediate social situation through innovation, while also contributing to the knowledge infrastructures that are required for long-term transformative change in incremental urbanism.

The social-technological process of TD research, resonates with that of social innovation (SI), in which innovation aims to primarily improve a social situation beyond the economic and technological concerns of traditional innovation (Moore & Westley, 2011). The socio-technological approach of this dissertation has however emphasised that technology is key to improving the social situation and so innovation for informality is socio-technological. Further, an intersection between TD methodology and SI is cemented in the argument that '…reflexivity in social innovation is necessarily transdisciplinary' (Jessop, Moulaert, Lars & Hamdouch, 2013:127). In other words, transformative SI can be achieved by adopting a TD methodology that provides the epistemological tools to engage with a diverse group of actors in complex settings, whose common interest is in realising sustained social change.

In the cases of this dissertation, it was first necessary to realise an immediate practical outcome through sanitation interventions. This approach promotes the view that immediate and incremental practical

outcomes are drivers towards transformative, systemic social change; a view that is condensed in the notion of 'radical incremental change' (Ernstson, Lawhon & Duminy, 2014). In plain terms, radical incrementalism is an oxymoron that brings together seemingly binary concepts of radical change (big, transformative) and incremental change (small, step-wise). In this dissertation, an incremental approach has been described with the aim of crafting a path towards transformative change.

Transformative, long-term change can be realised through knowledge co-production in communities of practice. Communities of practice are more dynamic than the communities of place of the three case studies of this dissertation. A community of practice further guarantees that agency is held within the institutional memory of the collective, and not in any one individual. This would mean that the lessons learnt through a reflexive approach can be ploughed back into a dynamic community of practice.

6.3 Conceptual Models of Knowledge Co-Production in Incremental Urbanism

The *Future Earth's* model proposes that different stakeholders need to develop a common vision, integrate available knowledge and implement action together. It also proposes that lessons from experience should be ploughed back into the knowledge base. The findings of this dissertation have demonstrated how challenging it is to develop a common vision amongst stakeholders with varying capacities, resources and knowledge backgrounds, more so in complex informal settlement contexts. The challenges have nevertheless resulted in theoretically significant findings as shown in the journal articles. The findings can be extrapolated within the broader context of incremental urbanism by proposing conceptual models of knowledge co-production. The conceptual models proposed here are informed by my intuitive insights from the field, which are supported by my extensive review of literature.

6.3.1 A Framework for Informal Urban Sanitation

Innovations in informal urban sanitation need to be scaled up. In this regard, small scale sanitation systems such as those piloted in the cases of this dissertation, need to be expanded and perhaps reconfigured if they are to catch up with rapid urbanisation. That proposal is in line with the thinking of Oosterveer and Spaargaren (2010) who argue that small scale decentralised sanitations systems cannot of themselves solve the massive sanitation challenge of informal areas in Sub-Saharan Africa. They thus advocate for a 'modernised mixtures approach' which leads to hybrid solutions that fit different local contexts. In this mixtures approach, emphasis is placed on management and governance aspects

that are needed to sustain such hybrid systems. Pieterse (2011B) also points out that local actions in low-income contexts should be linked to large-scale systemic transformations in the global context.

Large-scale systemic transformation in informal urban sanitation can best be realised through a socio-technological framework of innovation that is supported by TD research. According to Mara (2012), the lack of such frameworks is in fact the main cause of poor sanitation in developing economies. Sanitation is a public good that must be supported by a framework of customer services, public services and infrastructure development at the local and the national level (Hawkins, Blackett & Heymans, 2013). Customer services are the front-end services involving users hence they have a large private goods component. Public services are more downstream and have a public goods component. Infrastructure development is also a public good component that is often provided at the national or provincial level (ibid). Sanitation provision as a framework also consists of 'software' and 'hardware' issues, which are relatable to the services and infrastructure components (Okurut et al., 2015).

According to McFarlane, Desai and Graham (2014), addressing the software of sanitation may require a re-conceptualisation of sanitation as a socio-spatially differentiated concept that is affected by a complex set of social processes. As such, sanitation for the urban poor is governed by 'informal sanitation processes' such as patronage, solidarity, exclusion and self-management. It is these processes that result in different urban sanitation geographies for different settlements. Understanding the sanitation geographies of settlements is necessary for the provision of flexible and localised interventions (ibid). The three case studies in this article offer such localised sanitation geographies.

The challenges of community-based approaches in informal urban sanitation can be dealt with by targeting both the front-end and the back-end users of sanitation services. The front-end users are the informal settlement dwellers themselves, while the back-end users are service providers who can market the products of sanitation recycling such as compost and biogas (Murray & Ray, 2010). Non-poor residents can also be motivated to contribute to the improvement of sanitation in informal areas that are close to their neighbourhoods (Kobel & Del Mistro, 2012; 2015). The role of local governments in sanitation provision is also of significance, especially in South Africa, where local governments are mandated to oversee infrastructure development in informal settlements. As observed by Taing et al. (2013) municipalities play a crucial role in the management of sanitation partnerships in the South African context. To synthesise this thinking, informal urban sanitation can be categorised into a framework with three levels of micro, meso and macro. The functions at the three levels are

spread across a complex socio-spatial framework of sanitation that is localised in informal areas but not limited to them, since sanitation is a public good. The three levels may also overlap considerably but they have been separated here for a better theoretical understanding (Table 6.2).

LEVELS AND COMPONENTS OF INFORMAL URBAN SANITATION PROVISION			
	Micro	**Meso**	**Macro**
Actors	Informal settlement dwellers	Small-scale service providers Non-poor residents NGOs, CBOs Research institutions, Local government	Development agencies Provincial, national government
Services	Customer services: Front-end users provide internal components: user-interfaces, conveyance outside their homes	Customer and public services: Infrastructure development of external components: conveyance at the settlement level	Public services Managing informal settlements, coordinating sanitation projects, providing centralised services
Software	User-grouping, agreements, saving clubs, local entrepreneurs	Sanitation marketing, research & innovation, financing	Enabling policy, urban governance
Hardware	Simple O&M functions e.g. cleaning, unblocking simplified piping, collecting biogas, using compost in community gardens	Prototyping innovative technologies: simplified sewers, anaerobic digesters, dry technologies Back-end services: desludging, composting, irrigation, biogas production	Constructing and financing large-scale components e.g. trunk sewerage, treatment plants

Table 6.2 Levels and components in informal urban sanitation provision

6.3.2 TD Methods for Informal Urban Contexts

To meet the challenges of working in informal urban contexts, TD researchers should engage in joint proposal writing exercises, extend their TD research programmes; share their findings and attribute knowledge to their non-academic partners; maintain professionalism in their TD engagements and also support the creation of boundary organisations.

Joint proposal writing: Finding the resources to carry out sustained engagements in informal settlements is a challenge that calls for creative proposal writing. In the Enkanini case, the funding came from both the NRF and WRC in phase 1. In phase two, more funding was provided by the Wilhelm Frank Trust, which enabled the intervention to continue into 2014. Managing these different funds requires transparency. Chilisa (2012) advises that community members should be involved in the proposal writing process to ensure that the proposal addresses issues of concern to the community from the very beginning.

Extended TD research programmes: Engaging in a complex setting means that more time is needed to try out different methods, and so mastery of specific methods is harder to achieve. Huge amounts of time are also taken up in meetings and in maintaining relationships with a large pool of people, some of who are only remotely connected to the actual work. TD research may therefore require more intensive or lengthier programmes than mono-disciplinary work. Researchers should be prepared for this kind of intensity from the outset. In the Enkanini case, a lot of time was taken up in immersion and in forging relationships prior to data collection.

Knowledge attribution: Researchers and experts have the resources and capacity to publish findings. As such, it is important to consider how co-researchers, beneficiaries, and users who do not have the same resources, can also be acknowledgement in full for their contribution. Joint publications should thus be pursued avidly by TD teams so that knowledge is attributed to everyone who participated in the TD process. In the Enkanini case, a website was set up, where co-researchers could also upload posts. The website is currently non-functional but there are proposals to revamp it. However, it is imperative to find other low-tech methods of getting everyone in the team to tell their own story in their own voice. Facilitatory methods in design practice may be useful in this regard. Chilisa (2012) recommends a range of methods that can explore community constructed ideologies. The methods include: story-

telling, songs and use of metaphors. In one focus-group conversation, the metaphor of a wall was used to explain the practical barriers of sanitation service provision in Enkanini.

Professionalism: Prolonged interactions in an informal setting means that social relations between members can also become too informal: either too familiar or acrimonious. In the Enkanini case, working together for long resulted in frustrations that were often expressed in inappropriate ways such as through rude Emails or incessant phone calls to other members during odd hours of the night. At such times, it was necessary to have outside mediation from supervisors. Frequent mediation within TD groups is therefore recommended.

Boundary organisations: Polk (2014) advises that TD research should be institutionalised in boundary organisations that can resolve the challenges of participation and problem ownership. Such boundary organisations would ensure that communities of practice are sustained. In this way, co-researchers can retained over a considerable period and empowered to drive research processes. In the Enkanini case, the ERCA was formed to serve as a boundary organisation between the university researchers and the Enkanini co-researchers. If well supported, the ERCA could preserve the institutional memory of the collaborative work in Enkanini and serve as a repository for future research.

More specifically, the following are proposed as TD methods that are useful for collective and individual research processes in a complex informal settlement setting:

- **Critical observation and deep listening-** TD researchers need to observe and re-observe the complex interrelationships and outcomes in informal interactions. This requires deep listening skills that go beyond the mere search for answers to specific research questions. Deep listening unveils the underlying political/ideological character of language and also empowers research subjects to narrate their own stories. In this dissertation, critical discourse analysis has been used as a lens for critical reflection.

- **Social dialogue-** informal but consistent interactions are a useful way to understand actors' worldviews in naturally-occurring settings as opposed to creating artificial spaces such as structured interviews that precondition actors' responses. This dissertation has used naturally-occurring communications in the sanitation working-group and ISUG.

- **Active participation and instigation-** active participation means that researchers have to exercise their own agency and influence the context in concrete ways. Inspiring and instigating

158

certain actions towards a specific outcome is a requirement in TD research if it is to result in transformative change. However, instigation carries heavier ethical demands and responsibilities, which TD researcher have to constantly address.

- **Facilitation-** the need to integrate diverse knowledge, worldviews and backgrounds requires the researcher to have or to develop facilitation skills. In this regard, I undertook a course on facilitation (Facilitation for sustainable futures course) that was offered at SU through the Sustainability Institute, Lynedoch.

These methods are offered here as tools for TD researchers because they are considered to be well suited to exploring, analysing and understanding complex problems. They contribute to TD research as an emerging methodology, while also contributing to the practical outcomes of the Enkanini sanitation intervention.

6.3.3 Design Facilitation in Under-served Contexts

Design ethnography has been proposed as a method that can be used by designers in dealing with complex design contexts. However, designers may not have the time for long-term engagements with under-served users and so 'researcher-designers' can bridge that gap by engaging in long-term TD research processes.

Additionally, researcher-designers have to develop empathy for the fragile, unpredictable and fragmented situations in under-served contexts. In this way, they will be able to work flexibly and adapt to contingencies. The challenges faced in the Enkanini case point to a need for more inclusive and flexible engagements. According to Allenby and Sarewitz (2011), open-ended engagements give room for option spaces where changes can be absorbed in real time and continual learning is ensured if it is accompanied by a high frequency of decision making. In industrial and engineering design, such option spaces are referred to as 'probes' for social organisation (Sengers, Boehner, David & Kaye, 2005). In an emerging capacity, design facilitation can create option spaces and technological probes for social organisation. From the Enkanini case, the sanitation system could be conceptualised as a probe that can draw in more participation and allow for a better understanding of the social practices in the settlement. In this way, technology can mediate the relationship between humans and their social world (Verbeek, 2012), while creating option spaces for innovation.

For Norman and Verganti (2012), design research can bring about radical innovation if it can address the fundamental questions of new meanings and interpretations in technology. This article has argued that the role of the researcher-designer is to facilitate processes of change towards radical socio-technological innovation. In that role, it must be acknowledged that radical change in under-served contexts may happen at a much slower pace than expected or hoped (Hussain, Sanders & Steinert, 2012). A slow design process is nevertheless desirable in the sense that there is more time for reflexive community deliberations. Figure 6.2 illustrates how a dynamic community of practise can engage in a reflexive, transdisciplinary process of socio-technological innovation, by turning opportunities (option spaces) into tangible but flexible solutions (probes).
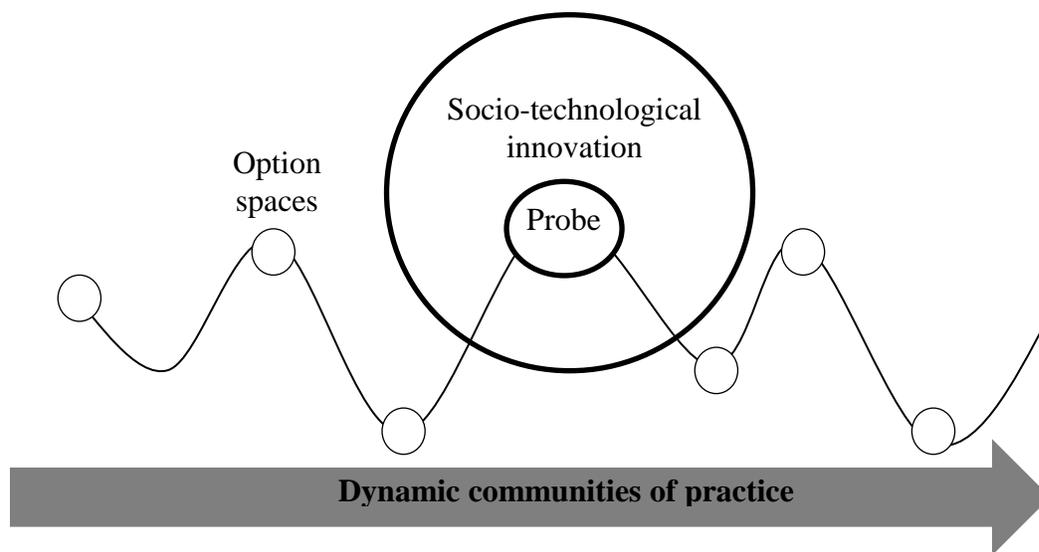
Figure 6.2 Conceptual model for design facilitation in under-served contexts

Ultimately, researcher-designers should adopt a broadened view of the design process and pay attention to design aspects such as the three Ps of: the design object (product), the designers and design users (people), the design (process). The interplay between these different components requires facilitation in order to enhance participation. Further, the design context (place) should be taken into account (Figure 6.3). In the Enkanini case, the product was the sanitation system; the people were the researchers, engineer and Enkanini residents; the process was the intervention; the place was the informal settlement and participation was the interplay between all these components.
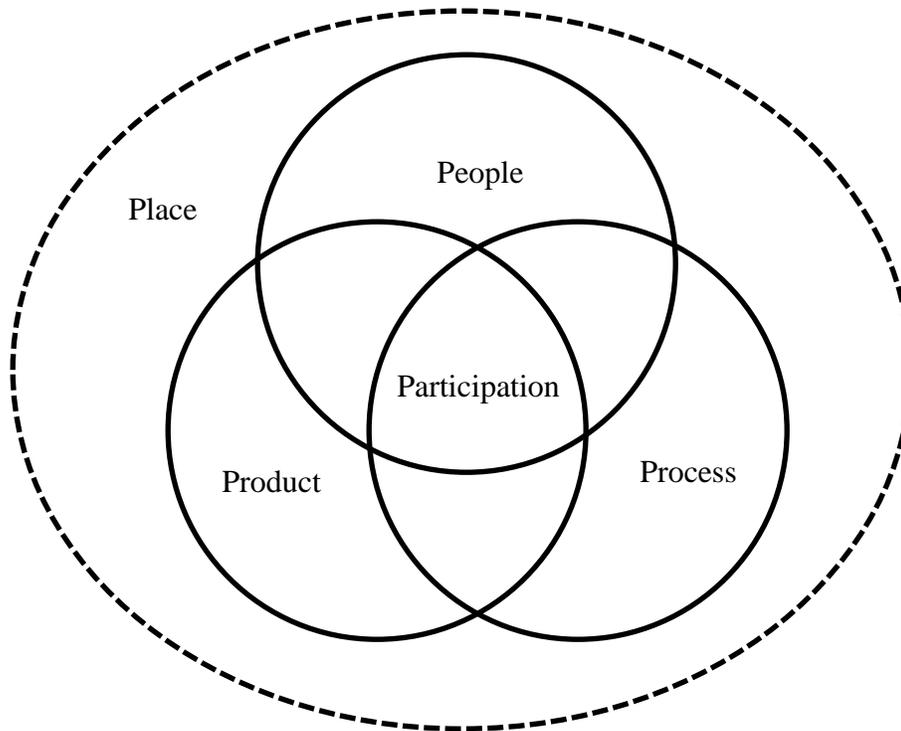
Figure 6.3 Considerations for design ethnography in informal contexts

6.3.4 Transformative Urbanism in Sub-Saharan Africa

To realise long-term transformative change, it is necessary to propose comprehensive approaches for improving urban areas in Sub-Saharan Africa. In the proposed approach of this dissertation (Figure 6.4), the first sphere is that of incubation where local and expert knowledge can be supported and integrated through research and innovation. Here, inclusive and disruptive technologies can be prototyped as alternatives to meet the unique needs of informal settlement dwellers. The idea is to promote hybridisation, so that different types of technological configurations, social arrangements and financial models can be considered. The second sphere is that of socialisation, where actors can build capacity and empower marginalised users to have a say in the improvement of their own environment. Such empowerment needs to go beyond sanitation provision for example, so as to tackle other challenging issues such as tenure, employment, among other social issues. The technical and managerial capacity of local operators is also considered in this sphere, so that they are built into the system from the outset to ensure sustainability beyond implementation. At the macro-level, national governments have to support these two spheres by enacting enabling programmes, policies and

161

coordination activities to guarantee sustainability, fairness and equity. Local governments can then oversee the enactment of policy and programmes at the local level.

The interrelationships between these three spheres can be complex and problematic and so they need to be facilitated. Such facilitation roles can be taken on by 'social intermediaries' who have to forge connections amidst difficult circumstances (Nitti & Dahiya, 2004). The three spheres can also be conceptualised as related sub-systems, in which change needs to occur simultaneously and on a sufficient scale, if the change is to be transformative.
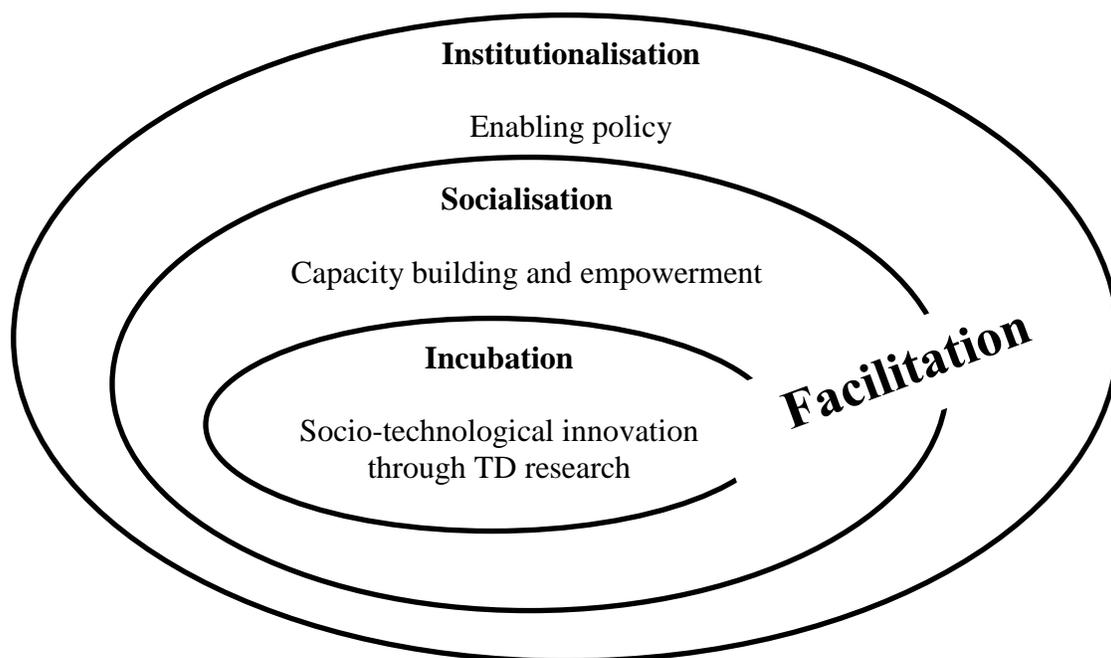
Figure 6.4 Conceptual model for transformative urbanism in Sub-Saharan Africa

6.4 Practical and Theoretical contribution

The TD approach of this dissertation was geared towards the production of three types of knowledge, (Gaziulusoy & Boyle, 2013; Pohl, 2011) namely:

i) *Systems Knowledge* of the current status of the social problem under investigation i.e. the state of informal urban sanitation in South Africa

ii) *Target Knowledge* of the desired status of the system that is to be attained i.e. alternative technologies and service co-production with informal settlement dwellers

iii)   *Transformation knowledge* about the means to change the social issue or problem i.e. Knowledge co-production for improving informal urban sanitation.

More specifically, the first article provided systems knowledge by giving an overview of the current status of informal urban sanitation in the three case studies. The emergent interfaces of the socio-technological reciprocity model are useful for the practical planning of informal urban sanitation exercises. The way forward for informal urban sanitation in the conclusion of the article provides target knowledge of the desired status for sanitation provision in South Africa.

The second article provided systems knowledge about the current status of TD practice using the experiences from the Enkanini case. The emerging themes of knowledge co-production from the Enkanini TD experience offer practical lessons for other TD researchers while also advancing TD research as a methodology for investigating complex problems. It therefore provides target knowledge for TD research methodology.

The third article provided target and transformation knowledge by proposing design ethnography as a facilitatory approach that can improve TD research in informal urban contexts. This is a significant theoretical contribution for mainstream professional design practice, which has so far failed to adequately meet the needs of under-served consumers such as informal settlement dwellers.

Further, the different types of knowledge produced in the articles have been extended in this chapter by proposing conceptual models of knowledge co-production. Those conceptual models provide target and transformation knowledge as follows:

- The framework of informal urban sanitation articulates the components (actors, services, software, and hardware) and levels (micro, meso and macro) of providing informal urban sanitation. These components and levels extend beyond the informal settlement to suggest a comprehensive framework for planning sanitation systems in informal urban areas.

- The proposed TD methods build on TD methodology by providing specific methods that can be applied in the field. These methods can also be used as analytical lenses to systematise TD research results.

- The proposed conceptual model for design facilitation in informal contexts has theoretical implications for design pedagogy and theory. In design pedagogy, this conceptual model can be useful, especially in Sub-Saharan Africa, where design students and researchers use mainstream methods that are incongruent to the continent's urban reality. In theory, the model can be applicable to other under-served design contexts that are not necessarily informal settlements.

- The considerations of design ethnography articulated as the five 'Ps' of people, product, process, participation, and place can inform and enhance the toolbox for designer ethnographers working in informal contexts.

- The proposed system for transformative urbanism has three spheres of incubation, socialisation and institutionalisation, which can be applied to comprehensive approaches of transformative innovation and change in Sub-Saharan Africa.

6.5 Further Recommendations for Future Research

The inadequacies of the TD approach need to be researched further so that a more coherent methodology is developed in line with the need for transformative social change. One way to do this is to explore the divergence and convergence between TD research and other social research paradigms such as transformative social innovation, critical theory or sen's capability approach. TD researchers may also do well to borrow methods from established disciplines such as sociology, anthropology and linguistics, which are disciplines with a long history of studying societies and human interaction. The interdisciplinary field of science and technology studies (SST) may also provide theoretical lenses for organising a TD dissertation.

There is also a need to better understand how long-term, transformative change is actually achieved. This would be possible through longitudinal and comparative case studies, as well as impact assessments that collect evidence of how knowledge co-production processes are carried out over a considerable length of time in the same cases. Such studies require more time and resources, which can be accommodated in boundary organisations that empower and support non-academic participation. Boundary organisations need to be open to experimentation, hence they can be modelled as design and social innovation labs, in which new urban narratives and configurations are prototyped. In such labs,

researchers, informal settlement residents, experts and local municipalities can work more closely, and as flexible communities of practice.

In the case of South Africa, it has been recommended that local municipalities need to manage such collaborations with informal settlement dwellers. In other Sub-Saharan Africa countries, it would be necessary to explore options of how communities of practice in informal contexts are managed in the quest to co-produce contextualised knowledge and innovative solutions. Further, different African urban contexts require their own TD studies that will unveil a variety of socio-technological configurations that pay attention to the heterogeneous realities of Africa's emerging urbanism.

In design, the role of the researcher-designer in TD research and in informal urban contexts needs to be researched further, so as to develop a flexible toolbox of techniques that are congruent to the heterogeneous urban forms in Sub-Saharan Africa. There is also a need for change in design curricular, so that designers can prepare to work in more interdisciplinary and transdisciplinary settings that aim to solve the intractable changes facing Africa's burgeoning population.

7.0   REFERENCE LIST

ACOSTA, G., MORALES, K., LAGOS, D. and ORTIZ, M., 2011. Addressing Human Factors and Ergonomics in Design Process, Product Life Cycle, and Innovation: Trends in Consumer Product Design. *Human Factors and Ergonomics in Consumer Product Design: Methods and Techniques,* pp. 133-154.

ADUBOFOUR, K., OBIRI-DANSO, K. and QUANSAH, C., 2013. Sanitation survey of two urban slum Muslim communities in the Kumasi metropolis, Ghana. *Environment and Urbanisation,* 25(1), pp. 189-207.

AIYAR, S.A, 2014A. In: *The Informal City Reader: South Africa Edition*. Johannesburg: South African Cities Network.

ALLENBY, B.R. and SAREWITZ, D., 2011. *The Techno-Human Condition.* US: MIT Press.

ALTBACH, P.G., 2013. Advancing the national and global knowledge economy: the role of research universities in developing countries. *Studies in higher education,* 38(3), pp. 316-330.

ANAND, C.K. and APUL, D.S., 2014. Composting toilets as a sustainable alternative to urban sanitation–A review. *Waste Management,* **34**(2), pp. 329-343.

ANDERSON, T., CURTIS, A. and WITTIG, C., 2014. *Definition and Theory in Social Innovation.* Krems: Danube University.

ANDERSSON, J.C., ZEHNDER, A.J., WEHRLI, B., JEWITT, G.P., ABBASPOUR, K.C. and YANG, H., 2013. Improving crop yield and water productivity by ecological sanitation and water harvesting in South Africa. *Environmental science & technology,* 47(9), pp. 4341-4348.

ANDRADE, A.D., 2009. Interpretive research aiming at theory building: Adopting and adapting the case study design. *The Qualitative Report,* 14(1), pp. 42-60.

ANGROSINO, M., 2007. *Doing ethnographic and observational research.* London: Sage.

APPEL, H., ANAND, N. and GUPTA, A. 2015. *"The Infrastructure Toolbox." Theorising the Contemporary,* Cultural Anthropology website, [ONLINE] Available at: http://www.culanth.org/fieldsights/725-the-infrastructure-toolbox [Accessed 2 February 2016]

ARCHAMBAULT, C.S., DE LAAT, J. and ZULU, E.M., 2012. Urban Services and Child Migration to the Slums of Nairobi. *World Development,* 40(9), pp. 1854-1869.

ARKU, F.S., ANGMOR, E.N. and SEDDOH, J., 2013. Toilet is not a dirty word: close to meeting the MDGs for sanitation? *Development in Practice,* 23(2), pp. 184-195.

BÆRENHOLDT, J.O., BÜSCHER, M., SCHEUER, J.D. and SIMONSEN, J., 2010. Perspectives on design research. In: J. SIMONSEN, J.O. BÆRENHOLDT, M. BÜSCHER and J.D. SCHEUER, eds, *Design Research: Synergies from interdisciplinary perspectives.* Routledge, pp. 1-15.

BANANA, E., CHIKOTI, P., HARAWA, C., MCGRANAHAN, G., MITLIN, D., STEPHEN, S., SCHERMBRUCKER, N., SHUMBA, F. and WALNYCKI, A., 2015. Sharing reflections on inclusive sanitation. *Environment and Urbanisation,* 0956247815569702.

BAPTIST, C. and BOLNICK, J., 2012. Participatory enumerations, in situ upgrading and mega events: the 2009 survey in Joe Slovo, Cape Town. *Environment and Urbanisation,* 24(1), pp. 59-66.

BARTRAM, J., CHARLES, K., EVANS, B., O'HANLON, L. and PEDLEY, S., 2012. Commentary on community-led total sanitation and human rights: should the right to community-wide health be won at the cost of individual rights? *Journal of water and health,* 10(4), pp. 499-503.

BAŠKARADA, S., 2014. Qualitative Case Study Guidelines. *The Qualitative Report,* 19(40), pp. 1-18.

BAXTER, G., 2012. Human factors and ergonomics in consumer product design: methods and techniques. *Ergonomics,* 55(9), pp. 1124-1125.

BAXTER, P. and JACK, S., 2008. Qualitative case study methodology: Study design and implementation for novice researchers. *The qualitative report,* 13(4), pp. 544-559.

BEEBEEJAUN, Y., DUROSE, C., REES, J., RICHARDSON, J. and RICHARDSON, L., 2013. 'Beyond text': exploring ethos and method in co-producing research with communities. *Community Development Journal.*

BEVERIDGE, R. and GUY, S., 2011. Innovation to intermediaries: translating the EU urban wastewater directive. In: S. GUY, S. MARVIN, W. MEDD and T. MOSS, eds, *Shaping urban infrastructures: intermediaries and the governance of socio-technical networks.* London: Earthscan. Pp. 92-107.

BHAGWAN, J., STILL, D., BUCKLEY, C. and FOXON, K., 2008. Challenges with up-scaling dry sanitation technologies. *Water Science and Technology,* 58(1), pp. 21.

BHATTI, Y.A. and VENTRESCA, M., 2012. *The Emerging Market for Frugal Innovation: Fad, Fashion, or Fit?* Available at SSRN: http://ssrn.com/abstract=2005983

BIJKER, W.E., HUGHES, T.P., PINCH, T., and DOUGLAS, D.G. 2012. *The social construction of technological systems: New directions in the sociology and history of technology*. MIT press.

BILL AND MELINDA GATES FOUNDATION, 2014. *Reinvent the toilet challenge*. [ONLINE] Available at: http://www.gatesfoundation.org/What-We-Do/Global-Development/Reinvent-the-Toilet-Challenge [Accessed 15 November 2014]

BIOCYCLE. THE n.d [ONLINE] Available at: http://www.theBiocycle.com/ [Accessed 20 April 2015]

BIOGASPRO AGAMA ENERGY, 2014. [ONLINE] Available at: http://www.Biogaspro.com/products/biogas-digesters/product-information-downloads.html [Accessed 20 April 2015]

BJÖGVINSSON, E., EHN, P. and HILLGREN, P., 2012. Design things and design thinking: contemporary participatory design challenges. *Design Issues,* 28(3), pp. 101-116.

BLOOR, M. and BLOOR, T., 2013. *The practice of critical discourse analysis: An introduction.* New York: Routledge.

BOLAANE, B. and IKGOPOLENG, H., 2011. Towards improved sanitation: Constraints and opportunities in accessing waterborne sewerage in major villages of Botswana. *Habitat International,* 35(3), pp. 486-493.

BRACKEN, L., BULKELEY, H. and WHITMAN, G., 2014. Transdisciplinary research: understanding the stakeholder perspective. *Journal of Environmental Planning and Management,* (ahead-of-print), pp. 1-18.

BRANDT, P., ERNST, A., GRALLA, F., LUEDERITZ, C., LANG, D.J., NEWIG, J., REINERT, F., ABSON, D.J. and VON WEHRDEN, H., 2013. A review of transdisciplinary research in sustainability science. *Ecological Economics,* 92, pp. 1-15.

BROWN, T. 2014 *Change by design*. HarperCollins e-books.

BROWN, T. and WYATT, J., 2010. Design thinking for social innovation. *Stanford Social Innovation Review,* 8(1), pp. 30-35.

BROWN-LUTHANGO, M., 2013. Community-university engagement: the Philippi CityLab in Cape Town and the challenge of collaboration across boundaries. *Higher Education,* 65(3), pp. 309-324.

BRUNDIERS, K., WIEK, A. and REDMAN, C.L., 2010. Real-world learning opportunities in sustainability: from classroom into the real world. *International Journal of Sustainability in Higher Education,* 11(4), pp. 308-324.

BUIZER, M., RUTHROF, K., MOORE, S.A., VENEKLAAS, E.J., HARDY, G. and BAUDAINS, C., 2015. A Critical Evaluation of Interventions to Progress Transdisciplinary Research. *Society & Natural Resources,* (ahead-of-print), pp. 1-12.

BULAYA, C., MWAPE, K.E., MICHELO, C., SIKASUNGE, C.S., MAKUNGU, C., GABRIEL, S., DORNY, P. and PHIRI, I.K., 2015. Preliminary evaluation of Community-Led Total Sanitation for the control of Taenia solium cysticercosis in Katete District of Zambia. *Veterinary parasitology,* 207(3–4), pp. 241-248.

CALLON, M. 2012. Society in the Making: The study of technology as a tool for sociological analysis. In W. E. BIJKER, T.P. HUGHES, T. PINCH, and D.G. DOUGLAS, eds, *The social construction of technological systems: New directions in the sociology and history of technology.* MIT press. pp 77-98.

CARMEL-GILFILEN, C. and PORTILLO, M., 2012. Where what's in common mediates disciplinary diversity in design students: A shared pathway of intellectual development. *Design Studies,* 33(3), pp. 237-261.

CESCHIN, F., 2014. How the design of socio-technical experiments can enable radical changes for sustainability. *International Journal of Design,* 8(3), pp. 1 – 21.

CESCHIN, F., 2013. Critical factors for implementing and diffusing sustainable product-Service systems: insights from innovation studies and companies' experiences. *Journal of Cleaner Production,* 45, pp. 74-88.

CHAI, K. and XIAO, X., 2012. Understanding design research: A bibliometric analysis of Design Studies (1996–2010). *Design Studies,* 33(1), pp. 24-43.

CHAMBERS, R., 2012. Sharing and Co-generating Knowledges: Reflections on Experiences with PRA1 and CLTS2. *IDS Bulletin,* 43(3), pp. 71-87.

CHANCE, K. R., 2012. Living Politics: Practices and Protests of 'the Poor 'in Democratic South Africa. *Journal of Pan African Studies,* 5(1), pp. 284.

CHATAWAY, J., HANLIN, R. and KAPLINSKY, R., 2014. Inclusive innovation: an architecture for policy development. *Innovation and Development,* 4(1), pp. 33-54.

CHEN, C., ZHU, J., YU, J. and NOORI, H., 2012. A new methodology for evaluating sustainable product design perfor5mance with two-stage network data envelopment analysis. *European Journal of Operational Research,* 221(2), pp. 348-359.

CHILISA, B., 2012. *Indigenous research methodologies*. US: Sage.

CHINYAMA, A., CHIPATO, P. and MANGORE, E., 2012. Sustainable sanitation systems for low income urban areas–A case of the city of Bulawayo, Zimbabwe. *Physics and Chemistry of the Earth, Parts A/B/C,* 50, pp. 233-238.

CIPOLLA, C. and BARTHOLO, R., 2014. Empathy or inclusion: A dialogical approach to socially responsible design. *International Journal of Design,* 8(2), pp. 87-100.

CITY OF CAPE TOWN, 2015. *Informal settlements*. [ONLINE] Available at: https://www.capetown.gov.za/en/Water/Pages/Informal-settlements.aspx. [Accessed 24 February 2015]

CITY OF CAPE TOWN, 2008. *Water and sanitation service standard*. Preliminary draft 2.

COHRE, WATERAID, SDC and UN-HABITAT, 2008. *Sanitation, A Human Rights Imperative.* Geneva: Centre on Housing Rights and Evictions.

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH (CSIR), 2007. Sanitation technology demonstration centre. [ONLINE] Available at: http://www.csir.co.za/Built_environment/santechcentre/ [Accessed 3 November 2014]

COSTANDIUS, E., 2010. Using Art as a Medium to Enhance Social Responsibility and Citizenship. *Discourse and Communication for Sustainable Education,* 1(2), pp. 74-81.

CROSS, N., 2011. *Design thinking: understanding how designers think and work.* Oxford: Berg.

CROUS, P., HAARHOFF, J. and BUCKLEY, C., 2013. Water demand characteristics of shared water and sanitation facilities: Experiences from community ablution blocks in eThekwini Municipality, South Africa. *Water SA,* 39(3), pp. 211-220.

CUMMING, G. and NORWOOD, C., 2012. The Community Voice Method: Using participatory research and filmmaking to foster dialog about changing landscapes. *Landscape and Urban Planning,* 105(4), pp. 434-444.

CUMULUS JOHANNESBURG, 2014. Design with the other 90%: changing the world by design. [ONLINE] Available at: http://www.cumulusjohannesburg.co.za/ [Accessed 5 December 2014]

DACE, E., BAZBAUERS, G., BERZINA, A. and DAVIDSEN, P.I., 2014. System dynamics model for analysing effects of eco-design policy on packaging waste management system. *Resources, Conservation and Recycling,* 87, pp. 175-190.

DAHLMAN, C. and KUZNETSOV, Y., 2014. Innovation for the" base of the pyramid": Developing a framework for policy experimentation. Making Innovation Policy Work, , pp. 71-122.

DAKA, E. and TOIVANEN, H., 2014. Innovation, the informal economy and development: The case of Zambia. *African Journal of Science, Technology, Innovation and Development,* (ahead-of-print), pp. 1-9.

DARBELLAY, F., 2015. Rethinking inter- and transdisciplinarity: Undisciplined knowledge and the emergence of a new thought style. *Futures,* 65(0), pp. 163-174.

DAVIDSON, K., 2008. When CSR meets BOP: Ethical concerns at the base of the pyramid. In: P. KANDACHAR and M. HALME, eds, *Sustainability challenges and solutions at the base of the pyramid: Businesss, technology and the poor.* Greenleaf Pub., pp. 462-474.

DAVIS, M., 2006. Planet of slums. *New Perspectives Quarterly,* 23(2), pp. 6-11.

DAWSON, H.J., 2014. Patronage from below: Political unrest in an informal settlement in South Africa. *African Affairs,* 113(453), pp. 518-539.

DE MELO RESENDE, V., 2012. Critical discourse analysis and ethnography: the crisis in the national street children's movement in Brazil. *Qualitative Research*, p.1468794112451040.

DIK, S.J., 2014. Urbanisation, Racism and the Environment: Identifying the Effect of Racism-Driven Uneven Development on Environmental Injustice in Cape Town, South Africa.

DONALDSON, K., 2008. Why to be Wary of "Design for Developing Countries". *Ambidextrous* 9 (2008), 35, 37.

DONALDSON, K.M., 2006. Product design in less industrialised economies: constraints and opportunities in Kenya. *Research in Engineering Design,* 17(3), pp. 135-155.

DORST, K., 2011. The core of 'design thinking' and its application. *Design Studies,* 32(6), pp. 521-532.

DOVEY, K., 2014. Incremental Urbanism: the Emergence of informal settlements. *Emergent Urbanism: Urban Planning & Design in Times of Structural and Systemic Change,* pp. 45.

DOVEY, K., 2013. Informalising Architecture: The Challenge of Informal Settlements. *Architectural Design,* 83(6), pp. 82-89.

DOVEY, K. and KING, R., 2012. Informal urbanism and the taste for slums. *Tourism Geographies,* 14(2), pp. 275-293.

EALES, K., 2008. Partnerships for sanitation for the urban poor: Is it time to shift paradigm? *Essay for Symposium on Urban Sanitation. IRC International Water and Sanitation Centre. Delft, The Netherlands* 2008.

ECHANOVE, M. and SRIVASTAVA, M., 2014A. In: The Informal City Reader: South Africa Edition. Johannesburg: South African Cities Network.

ERFURT IV, E. 2015. *Tactical urbanism*. [ONLINE] Available at: http://restlessurbanist.com/2015/03/18/tactical-urbanism/ [Accessed 05 April 15].

ERNSTSON, H., LAWHON, M. and DUMINY, J., 2014. Conceptual vectors of African urbanism:'engaged theory-making'and 'platforms of engagement'. Regional Studies, 48(9), pp. 1563-1577.

FAIRCLOUGH, N., 2005. Critical discourse analysis in transdisciplinary research. *A new agenda in (Critical) Discourse Analysis: theory, methodology and interdisciplinarity. Amsterdam,* pp. 53-70.

FARIAS, I., 2010. Introduction: decentring the object of urban studies. In: I. FARIAS and T. BENDER, eds, *Urban assemblages: how actor-network theory changes urban studies.* Oxfordshire: Routledge, pp. 1-24.

FINLAY, L., 2002. Negotiating the swamp: the opportunity and challenge of reflexivity in research practice. Qualitative research, 2(2), pp.209-230.

FLORES, A., BUCKLEY, C. and FENNER, R., 2009. Selecting sanitation systems for sustainability in developing countries. IWA.

FOX, S., 2014. The political economy of slums: theory and evidence from sub-Saharan Africa. *World Development,* 54, pp. 191-203.

FUENTES, M., 2012. *A new sanitation system for slums in urban dense areas*. Delft University of Technology.

FUJII, L.A., 2014. Five stories of accidental ethnography: turning unplanned moments in the field into data. *Qualitative Research*, 1468794114548945.

FUTURE EARTH. 2015. *Future earth, research for global sustainability*. [ONLINE] Available at: http://www.futureearth.org/. [Accessed 07 May 15].

GARCIA, R.R., GONZÁLEZ, S.M. and GARCÍA, L.M., 2013. Eco-design workshop: Delivering new concepts for future designs, *New Concepts in Smart Cities: Fostering Public and Private Alliances (SmartMILE), 2013 International Conference on* 2013, IEEE, pp. 1-3.

GAZIULUSOY, A.I. and BOYLE, C., 2013. Proposing a heuristic reflective tool for reviewing literature in transdisciplinary research for sustainability. *Journal of Cleaner Production,* 48, pp. 139-147.

GEORGE, G., MCGAHAN, A.M. and PRABHU, J., 2012. Innovation for inclusive growth: towards a theoretical framework and a research agenda. *Journal of Management Studies,* 49(4), pp. 661-683.

GEORGE, R., 2008. *The big necessity: Adventures in the world of human waste.* London: Portobello Books.

GOLDSCHMIDT, G. and RODGERS, P.A., 2013. The design thinking approaches of three different groups of designers based on self-reports. Design Studies, 34(4), pp. 454-471.

GONÇALVES, M., CARDOSO, C. and BADKE-SCHAUB, P., 2014. What inspires designers? Preferences on inspirational approaches during idea generation. *Design Studies,* 35(1), pp. 29-53.

GOOGLE MAPS 2015A. Western Cape Province, South Africa, 34° 0′ 0″ S, 20° 0′ 0″ E. [ONLINE] Available: https://www.google.co.ke/maps/place/Western+Cape,+South+Africa/@-32.6316328,20.9899868,7z/data=!3m1!4b1!4m2!3m1!1s0x1dcc5d887a698df3:0xe98e798f2136a28b?hl=en&hl=en [Accessed 7 July 2015]

GOOGLE EARTH 2015B. Grabouw, South Africa, 34° 9′ 0″ S, 19° 1′ 0″ E [ONLINE] Available: https://www.google.co.ke/maps/place/Grabouw,+South+Africa/@-

34.1558455,19.0152269,14z/data=!3m1!4b1!4m2!3m1!1s0x1dcdc5e4522f8fdd:0x70ff7e2a4d35e2e6?h
l=en&hl=en [Accessed 7 July 2015]

GOOGLE EARTH 2015C. Klipheuwel, South Africa, 33° 43′ 26.4″ S, 18° 42′ 25.2″ E [ONLINE]
Available: https://www.google.co.ke/maps/place/Klipheuwel,+Cape+Town,+South+Africa/@-
33.7209679,18.7074929,15z/data=!3m1!4b1!4m2!3m1!1s0x1dccf92dd6b557e7:0x398a1cc417c5987e?
hl=en&hl=en [Accessed 7 July 2015]

GOOGLE EARTH 2015D. Stellenbosch, South Africa, 33° 55′ 12″ S, 18° 51′ 36″ E [ONLINE]
Available: https://www.google.co.ke/maps/place/Stellenbosch,+South+Africa/@-
33.9466914,18.8445859,12z/data=!3m1!4b1!4m2!3m1!1s0x1dcdb2f75188e2a5:0x7009aa00dee36be2?
hl=en&hl=en [Accessed 7 July 2015]

GOUNDEN, T., PFAFF, B., MACLEOD, N. and BUCKLEY, C., 2006. Provision of free sustainable
basic sanitation: the Durban experience. *Conference proceedings: 32nd WEDC International
Conference, Sustainable Development of Water Resources, Water Supply and Environmental
Sanitation,* Colombo 2006.

GOVENDER, T., BARNES, J.M. and PIEPER, C.H., 2010. Living in low-cost housing settlements in
Cape Town, South Africa—the epidemiological characteristics associated with increased health
vulnerability. *Journal of Urban Health,* 87(6), pp. 899-911.

GRANT, R., 2014. Sustainable African Urban Futures Stocktaking and Critical Reflection on Proposed
Urban Projects. *American Behavioural Scientist,* 0002764214550301.

GREIF, M.J., 2012. Housing, medical, and food deprivation in poor urban contexts: implications for
multiple sexual partnerships and transactional sex in Nairobi's slums. *Health & place,* 18(2), pp. 400-
407.

GREYLING, M., 2013. An Undivided Landscape: Dissolving Apartheid buffer zones in Johannesburg,
South Africa, University of Waterloo.

GRIN, J., FELIX, F., BOS, B. and SPOELSTRA, S., 2004. Practices for reflexive design: lessons from
a Dutch programme on sustainable agriculture. International Journal of Foresight and Innovation
Policy, 1(1), pp. 126-149.

GROENEWALD, L., HUCHZERMEYER, M., KORNIENKO, K., TREDOUX, M.J., RUBIN, M. and
RAPOSO, I., 2013. Breaking down the binary: meanings of informal settlement in southern African
cities. In: S. BEKKER L. FOURCHARD eds. *Governing cities in Africa- Politics and policies*, pp 93-
115

GROSSE-HERING, B., MASON, J., ALIAKSEYEU, D., BAKKER, C. and DESMET, P., 2013. Slow
design for meaningful interactions, *Proceedings of the SIGCHI Conference on Human Factors in
Computing Systems* 2013, ACM, pp. 3431-3440.

GRUNDLINGH, A. and SCOTT, D., 2012. Heritage- contextualising heritage production. In: M. SWILLING, B. SEBITOSI and R. LOOTS, eds, *Sustainable Stellenbosch: Opening dialogues.* AFRICAN SUN MeDIA, pp. 236-243.

GUEVARA, N.K.A., 2014. Informality and Formalization of Informal Settlements at the Turn of the Third Millennium: Practices and Challenges in Urban Planning. *Journal of Studies in Social Sciences,* 9(2).

GULYANI, S., BASSETT, E.M. and TALUKDAR, D., 2014. A tale of two cities: A multi-dimensional portrait of poverty and living conditions in the slums of Dakar and Nairobi. *Habitat International,* 43, pp. 98-107.

GULYANI, S. and TALUKDAR, D., 2010. Inside informality: The links between poverty, microenterprises, and living conditions in Nairobi's slums. *World Development,* 38(12), pp. 1710-1726.

GUNN, W. and DONOVAN, J., 2012. Design anthropology: an introduction. In: W. GUNN and J. DONOVAN, eds, *Design and Anthropology.* Ashgate Publishing Ltd, pp. 1-16.

GÜNTHER, I., NIWAGABA, C.B., LÜTHI, C., HORST, A., MOSLER, H. and TUMWEBAZE, I.K., 2012. When is shared sanitation improved sanitation?-The correlation between number of users and toilet hygiene.

HADDOCK, S.V. and TORNAGHI, C., 2013. A transversal reading of social innovation in European cities. In: F. MOULAERT, D. MACCALLUM, A. MEHMOOD and A. HAMDOUCH, eds, The International Handbook on Social Innovation: Collective Action, Social Learning and Transdisciplinary Research. Edward Elgar Publishing, pp. 264-273.

HADORN, G.H., HOFFMANN-RIEM, H., BIBER-KLEMM, S., GROSSENBACHER-MANSUY, W., JOYE, D., POHL, C., WIESMANN, U. and ZEMP, E., 2008. *Handbook of transdisciplinary research*. Springer.

HAGEN, P. and ROBERTSON, T., 2012. Social Technologies: The Changing Nature of Participation in Design. *Design Issues,* 28(3), pp. 77-88.

HAHN, R., 2008. Sustainable development at the BoP: On integrated approaches beyond trade-off thinking. In: P. KANDACHAR and M. HALME, eds, *Sustainability challenges and solutions at the base of the pyramid: Businesss, technology and the poor.* Greenleaf Pub., pp. 446-461.

HALL, J., 2014. Innovation and entrepreneurial dynamics in the Base of the Pyramid. *Technovation,* 34(5), pp. 265-269.

HALL, J., MATOS, S.V. and MARTIN, M.J., 2014. Innovation pathways at the Base of the Pyramid: Establishing technological legitimacy through social attributes. *Technovation,* 34(5), pp. 284-294.

HALSE, J., 2008. Design Anthropology: Borderland Experiments with Participation. *IT University of Copenhagen.*

HAMILTON, M.L., SMITH, L. and WORTHINGTON, K., 2008. Fitting the methodology with the research: An exploration of narrative, self-study and auto-ethnography. *Studying Teacher Education,* 4(1), pp.17-28.

HAQ, G. and CAMBRIDGE, H., 2012. Exploiting the co-benefits of ecological sanitation. *Current Opinion in Environmental Sustainability,* 4(4), pp. 431-435.

HARRIS, J.C., 2014. The confounding influence of urban informality on innovation and production specialisation in production clusters: evidence from Nairobi. *African Journal of Science, Technology, Innovation and Development,* 6(6), pp. 529-539.

HASAN, A., 2008. Financing the sanitation programme of the Orangi Pilot Project—Research and Training Institute in Pakistan. *Environment and Urbanisation,* 20(1), pp. 109-119.

HASAN, A., 2006. Orangi Pilot Project: the expansion of work beyond Orangi and the mapping of informal settlements and infrastructure. *Environment and Urbanisation,* 18(2), pp. 451-480.

HAWKINS, P., BLACKETT, I. and HEYMANS, C., 2013. Poor-Inclusive Urban Sanitation: An Overview. World Bank.

HEGGER, D.L., VAN VLIET, J. and VAN VLIET, B.J., 2007. Niche management and its contribution to regime change: the case of innovation in sanitation. *Technology Analysis & Strategic Management,* 19(6), pp. 729-746.

HENDRIKSEN, A., TUKAHIRWA, J., OOSTERVEER, P.J. and MOL, A.P., 2012. Participatory decision making for sanitation improvements in unplanned urban settlements in East Africa. *The Journal of Environment & Development,* 21(1), pp. 98-119.

HICKEL, J., 2014. "Xenophobia" in South Africa: Order, Chaos, and the Moral Economy of Witchcraft. *Cultural Anthropology,* 29(1), pp. 103-127.

HILLGREN, P., 2013. Participatory design for social and public innovation: Living Labs as spaces for agonistic experiments and friendly hacking. *Public and collaborative: Exploring the intersection of design, social innovation and public policy,* pp. 75-88.

HILLGREN, P., SERAVALLI, A. and EMILSON, A., 2011. Prototyping and infrastructuring in design for social innovation. *CoDesign,* 7(3-4), pp. 169-183.

HILLIGAN, J., SPIEGEL, A. and ARMITAGE, N., 2012. Cape Town study confirms that toilets count, people matter: sanitation. *Water Wheel,* 11(4), pp. 28-31.

175

HOLDERNESS, T., KENNEDY-WALKER, R., ALDERSON, D. and EVANS, B., 2013. *An Evaluation of Spatial Network Modeling To Aid Sanitation Planning In Informal Settlements Using Crowd-Sourced Data.* University of Wollongong.

HOLM, J., SØNDERGÅRD, B. and HANSEN, O.E., 2010. Perspectives on design reseach. In: J. SIMONSEN, J.O. BÆRENHOLDT, M. BÜSCHER and J.D. SCHEUER, eds, Design Research: Synergies from interdisciplinary perspectives. Routledge, pp. 123-137.

HOSSAIN, M.S.J. and AHMAD, N., 2011. Green design principles and trends of using them among Bangladeshi consumer goods manufacturers, Industrial Engineering and Engineering Management (IEEM), *Conference proceedings: 2011 IEEE International Conference*, IEEE, pp. 467-471.

HUBBARD, B., SARISKY, J., GELTING, R., BAFFIGO, V., SEMINARIO, R. and CENTURION, C., 2011. A community demand-driven approach toward sustainable water and sanitation infrastructure development. *International journal of hygiene and environmental health,* 214(4), pp. 326-334.

HUCHZERMEYER, M., 2014A. In: *The Informal City Reader: South Africa Edition*. Johannesburg: South African Cities Network.

HUCHZERMEYER, M., 2014B. Invoking Lefebvre's 'right to the city' in South Africa today: A response to Walsh. City, 18(1), pp. 41-49.

HUCHZERMEYER, M., 2009. The struggle for in situ upgrading of informal settlements: a reflection on cases in Gauteng. *Development Southern Africa,* 26(1), pp. 59-73.

HUCHZERMEYER, M., 2008. Slum Upgrading in Nairobi within the Housing and Basic Services Market A Housing Rights Concern. *Journal of Asian and African Studies,* 43(1), pp. 19-39.

HUNTER, M. and POSEL, D., 2012. Here to work: the socioeconomic characteristics of informal dwellers in post-apartheid South Africa. *Environment and Urbanisation,* 24(1), pp. 285-304.

HURN, K., 2014. *Reinventing the toilet: academic research meets design practice in the pursuit of an effective sanitation solution for all.* Loughborough University.

HUSSAIN, S., SANDERS, E.B. and STEINERT, M., 2012. Participatory design with marginalised people in developing countries: Challenges and opportunities experienced in a field study in Cambodia. *International Journal of Design,* 6(2), pp. 91-109.

ISHACK PROJECT, THE 2015. [ONLINE] Available at: https://www.facebook.com/iShackproject.org?fref=ts. [Accessed 16 July 2015].

JAGLIN, S., 2014. Regulating service delivery in southern cities: rethinking urban heterogeneity. In: S. PARNELL and S. OLDFIELD, eds, The Routledge handbook on cities of the global south. Routledge, pp. 434-447.

JAGTAP, S., LARSSON, A., HIORT, V., OLANDER, E., WARELL, A. and KHADILKAR, P., 2014. How design process for the Base of the Pyramid differs from that for the Top of the Pyramid. *Design Studies,* 35(5), pp. 527–558.

JESSOP, B., MOULAERT, F., LARS, H. and HAMDOUCH, A., 2013. Social Innovation Research: A New Stage in Innovation Analysis? In: F. MOULAERT, D. MACCALLUM, A. MEHMOOD and A. HAMDOUCH, eds, *The International Handbook on Social Innovation: Collective Action, Social Learning and Transdisciplinary Research.* Edward Elgar Publishing, pp. 110-127.

JONES, B.G., 2012. 'Bankable Slums': the global politics of slum upgrading. *Third World Quarterly,* 33(5), pp. 769-789.

JOSHI, D., FAWCETT, B. and MANNAN, F., 2011. Health, hygiene and appropriate sanitation: experiences and perceptions of the urban poor. *Environment and Urbanization,* **23**(1), pp. 91-111.

JØRGENSEN, M.S., JØRGENSEN, U. and CLAUSEN, C., 2009. The social shaping approach to technology foresight. Futures, 41(2), pp. 80-86.

JÜRGENS, U., DONALDSON, R., RULE, S. and BÄHR, J., 2013. Townships in South African cities– Literature review and research perspectives. *Habitat International,* 39, pp. 256-260.

KABIRU, C.W., BEGUY, D., NDUGWA, R.P., ZULU, E.M. and JESSOR, R., 2012. "Making It": Understanding Adolescent Resilience in Two Informal Settlements (Slums) in Nairobi, Kenya. *Child & Youth Services,* 33(1), pp. 12-32.

KANDACHAR, P. and HALME, M., 2008. Introduction: Farewell to pyramids, how can business and technology help eradicate poverty? In: P. KANDACHAR and M. HALME, eds, *Sustainability challenges and solutions at the base of the pyramid: Business, technology and the poor.* UK: Greenleaf publishing, pp. 1-27.

KAR, K., 2012. Why not Basics for All? Scopes and Challenges of Community-led Total Sanitation. *IDS Bulletin,* 43(2), pp. 93-96.

KAR, K. and CHAMBERS, R., 2008. Handbook on community-led total sanitation. London: Plan UK and Brighton: IDS.

KARNANI, A., 2012. Markets of the Poor: Opportunities and Limits. *International Journal of Rural Management,* 8(1-2), pp. 7-17.

KARWOWSKI, W., SOARES, M.M. and STANTON, N.A., 2011. *Human Factors and Ergonomics in Consumer Product Design: Uses and Applications.* CRC Press.

KELLER, A., 2012. *Conceptualising a sustainable energy solution for in situ informal settlement upgrading*, Stellenbosch: Stellenbosch University.

KIM, B., 2001. Social constructivism. *Emerging perspectives on learning, teaching, and technology,* 1(1), pp. 16

KLEIN, J.T., 2015. Reprint of "Discourses of transdisciplinarity: Looking back to the future". *Futures,* 65(0), pp. 10-16.

KOBEL, D. and DEL MISTRO, R., 2012. Evaluation of non-user benefits towards improvement of water and sanitation services in informal settlements. *Urban Water Journal,* 9(5), pp. 347-359.

KOBEL, D. and DEL MISTRO, R., 2015. Valuing the non-user benefits of improving water and sanitation in informal settlements: a study of Cape Town. *Urban Water Journal,* 12(3), pp. 248-261.

KOOLA, J. and ZWANE, A.P., 2014. Water Supply and Sanitation. In: A.J. CULYER, ed, *Encyclopedia of Health Economics.* San Diego: Elsevier, pp. 477-482.

KORIA, R., BARTELS, F., ANDRIANO, L. and KOESZEGI, S., 2014. Effectiveness and Efficiency of National Systems of Innovation: the importance of ICT, the Cases of Ghana and Kenya, *IST-Africa Conference Proceedings, 2014* 2014, IEEE, pp. 1-18.

KUIJER, L. and DE JONG, A.M., 2011. Practice theory and human-centered design: A sustainable bathing example. *Nordes,* (4).

KVARNSTROM, E., MCCONVILLE, J., BRACKEN, P., JOHANSSON, M. and FOGDE, M., 2011. The sanitation ladder-a need for a revamp? *Journal of Water, Sanitation and Hygiene for Development,* 1(1), pp. 3-12.

LAGARDIEN, A., MUANDA C. and BENJAMIN A., 2012. User acceptance and functioning of mobile communal sanitation facilities for informal settlements of South Africa. WRC report No. 2017\1\12. Gezina: WRC.

LANG, D.J., WIEK, A., BERGMANN, M., STAUFFACHER, M., MARTENS, P., MOLL, P., SWILLING, M. and THOMAS, C.J., 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustainability science, 7(1), pp. 25-43.

LATOUR, B., 2005. *Reassembling the social-an introduction to actor-network-theory. Reassembling the Social-An Introduction to Actor-Network-Theory*. Oxford University press.

LARSEN, T.A., GEBAUER, H., GRÜNDL, H., KÜNZLE, R., LÜTHI, C., MESSMER, U., MORGENROTH, E., NIWAGABA, C.B. and RANNER, B., 2014. Blue Diversion: a new approach to sanitation in informal settlements. IWA.

LE ROUX, K. and COSTANDIUS, E., 2013. The viability of social design as an agent for positive change in a South African context: mural painting in Enkanini, Western Cape. *Image & Text: a Journal for Design,* 21, pp. 106-120.

LEAVY, P., 2011. *Essentials of transdisciplinary research: Using problem-centered methodologies.* CA: Left Coast Press.

LENSKJOLD, T.U., 2011. Accounts of a Critical Artefacts Approach to Design Anthropology. *Nordes,* (4).

LIGHTHOUSE MISSION, n.d. [ONLINE] Available at: http://www.lighthouse-mission.com/about-us.php. [Accessed 13 May 2015]

LINGARD, L., SCHRYER, C.F., SPAFFORD, M.M. and CAMPBELL, S.L., 2007. Negotiating the politics of identity in an interdisciplinary research team. Qualitative Research, 7(4), pp.501-519.

LOPES, A.M., FAM, D. and WILLIAMS, J., 2012. Designing sustainable sanitation: Involving design in innovative, transdisciplinary research. *Design Studies,* 33(3), pp. 298-317.

LUNDIN, S., 2013. Dry Toilets as a Sanitation Solution in Makana Municipality, South Africa. Novia University of Applied sciences.

LURY, C. and WAKEFORD, N., 2012. Introduction: a perpetual inventory. In: C. LURY and N. WAKEFORD, eds, *Inventive methods: The happening of the social.* London: Routledge, pp. 1-24.

LÜTHI, C., MCCONVILLE, J. and KVARNSTRÖM, E., 2010. Community-based approaches for addressing the urban sanitation challenges. *International Journal of Urban Sustainable Development,* 1(1-2), pp. 49-63.

MAATHAI, W., 2009. *The challenge for Africa.* London: Arrow books.

MALAQUAIS, D., 2011. Anti-teolology. In: N. EDJABE and E. PIETERSE, eds, *African Cities Reader II: Mobilities and Fixtures.* Chimurenga and African Centre for Cities, pp. 7-23.

MALUTI GSM CONSULTING ENGINEERS. 2014. Pour-flush Trials in the Western Cape. WRC Report No. KV 332/13. Gezina, WRC.

MANGENA, S., 2012. Anger at Zille disrupts SAHRC Water and Sanitation Hearing in Western Cape. [ONLINE] Available at: http://www.sahrc.org.za/home/index.php?ipkArticleID=156 [Accessed 2 December 2014]

MANZINI, E., 2014. Making Things Happen: Social Innovation and Design. *Design Issues,* 30(1), pp. 57-66.

MANZINI, E., 2010. Small, local, open, and connected: design for social innovation and sustainability. *The journal of Design strategies, Change Design,* 4(1), pp. 8-11.

MANZINI, E. and RIZZO, F., 2011. Small projects/large changes: Participatory design as an open participated process. *CoDesign,* 7(3-4), pp. 199-215.

MARA, D., 2012. Sanitation: What's the Real Problem? *IDS Bulletin,* 43(2), pp. 86-92.

MARA, D. and BROOME, J., 2008. Sewerage: a return to basics to benefit the poor. *Municipal Engineer,* 161(4), pp. 231-237.

MAZEAU, A., REED, B., SANSOM, K. and SCOTT, R., 2014. Emerging categories of urban shared sanitation. *Water and Environment Journal,* 28(4), pp. 592-608.

MCCOMB, C., CAGAN, J. and KOTOVSKY, K., 2015. Rolling with the punches: An examination of team performance in a design task subject to drastic changes. *Design Studies.* 36, pp. 99–121

MCFARLANE, C., DESAI, R. and GRAHAM, S., 2014. Informal urban sanitation: Everyday life, poverty, and comparison. *Annals of the Association of American Geographers,* 104(5), pp. 989-1011.

MCGRANAHAN, G., 2013. Community-driven sanitation improvement in deprived urban neighbourhoods. *Pubs.iied.org.*

MCGRANAHAN, G., 2015. Realising the Right to Sanitation in Deprived Urban Communities: Meeting the Challenges of Collective Action, Co-production, Affordability, and Housing Tenure. *World Development,* 68(0), pp. 242-253.

MEHROTRA, R. and ROSE, P., 2014. Incremental Urbanism from Montreal. *Harvard Design Magazine: architecture, landscape architecture, urban design and planning,* (37), pp. 48.

MELLES, G., KUYS, B., KAPOOR, A., RAJANAYAGAM, J., THOMAS, J. and MAHALINGAM, A., 2015. Designing Technology, Services and Systems for Social Impact in the Developing World: Strong Sustainability Required. *ICoRD'15–Research into Design Across Boundaries Volume 2.* Springer, pp. 89-97.

MELO, J.C., 2005. The experience of condominial water and sewerage systems in Brazil. *Case studies from Brasılia, Salvador and Parauapebas.* Lima: Water and Sanitation Program Latin America.

MELS, A., CASTELLANO, D., BRAADBAART, O., VEENSTRA, S., DIJKSTRA, I., MEULMAN, B., SINGELS, A. and WILSENACH, J., 2009. Sanitation services for the informal settlements of Cape Town, South Africa. *Desalination,* 248(1), pp. 330-337.

METH, P., 2013. 'I Don't Like My Children to grow up in this Bad Area': Parental Anxieties about Living in Informal Settlements. *International Journal of Urban and Regional Research,* 37(2), pp. 537-555.

MILES, I. and RIGBY, J., 2013. Demand-led innovation. In: D. COX and J. RIGBY, eds, *Innovation Policy Challenges for the 21st Century.* Routledge, pp. 36-63.

MITCHELL, C., 2011. *Doing visual research.* London: Sage.

MIT PRESS, 2015. Design issues. [ONLINE] Available at: http://www.mitpressjournals.org/loi/desi [Accessed 7 May 2015]

MITLIN, D., 2008. With and beyond the state- co-production as a route to political influence, power and transformation for grassroots organisations. *Environment and Urbanisation,* 20(2), pp. 339-360.

MJOLI, N. and BHAGWAN, J., 2012. Turning sanitation policy into practice. *Water Research Commission.* [ONLINE].Available: http://www.ewisa.co.za/literature/files/68_19% 20Mjoli.pdf. [Accessed 29 April 2015]

MOLLATT, M.C., 2014. *Ecological Food Sense: Connections between food waste flows and food production in Enkanini Informal Settlement.* Stellenbosch University.

MOORE, M.L. and WESTLEY, F., 2011. Surmountable chasms: networks and social innovation for resilient systems. *Ecology and Society,* 16(1), pp. 5.

MORALES, M.D.C., HARRIS, L. and ÖBERG, G., 2014. Citizenshit: the right to flush and the urban sanitation imaginary. *Environment and Planning,* 46(12), pp. 2816-2833.

MOREAU, C.P., 2011. Inviting the amateurs into the studio: understanding how consumer engagement in product design creates value. *Journal of Product Innovation Management,* 28(3), pp. 409-410.

MOVIK, S. and MEHTA, L., 2009. Going with the flow? Directions of Innovation in the Water and Sanitation Domain.

MPE, R. and OGRA, A., 2014. Making great places in slums/informal settlements, *Conference Proceedings: Planning Africa.*

MUHAR, A., VISSER, J. and VAN BREDA, J., 2013. Experiences from establishing structured inter- and transdisciplinary doctoral programs in sustainability: a comparison of two cases in South Africa and Austria. *Journal of Cleaner Production,* 61, pp. 122-129.

MUHULA, S.O., MEMIAH, P., SIBHATU, B, NDIRANGU, M. and KYOMUHANGI, L., 2015. Effects of highly active antiretroviral therapy on the survival of hiv-infected adult patients in urban slums of Kenya. *Pan African Medical Journal,* 20(63).

MULLER, M., 2011. Iconography and iconology as a visual method and approach. In: E. MARGOLIS and L. PAUWELS, eds, *The Sage handbook of visual research methods*. London: Sage, pp. 281-297.

MUNYAI, K. and M'RITHAA, M., 2010. Local indigenous cultures and modern design innovations: a South African perspective. *Conference proceedings Cumulus 2010 ShangHai conference, Young Creators For Better City & Better Life 2010*, ShangHai, pp. 347-352.

MURPHY, H.M., MCBEAN, E.A. and FARAHBAKHSH, K., 2009. Appropriate technology–A comprehensive approach for water and sanitation in the developing world. *Technology in Society,* 31(2), pp. 158-167.

MURPHY, J., 2008. Transforming innovation and development practice in the Global South? Myths, realities and the prospects for base of the pyramid approaches. In: P. KANDACHAR and M. HALME, eds, *Sustainability challenges and solutions at the base of the pyramid: Businesss, technology and the poor.* Greenleaf Pub., pp. 412-429.

MURRAY, R., CAULIER-GRICE, J. and MULGAN, G., 2010. *The open book of social innovation.* The Young foundation, Nesta.

MURRAY, A. and RAY, I., 2010. Commentary: Back-End Users: The Unrecognised Stakeholders in Demand-Driven Sanitation. *Journal of Planning Education and Research,* 30(1), pp. 94-102.

MURUNGI, C. and VAN DIJK, M.P., 2014. Emptying, Transportation and Disposal of feacal sludge in informal settlements of Kampala Uganda: the economics of sanitation. *Habitat International,* 42, pp. 69-75.

MUSEMWA, M., 2010. From 'Sunshine City'to a Landscape of Disaster The Politics of Water, Sanitation and Disease in Harare, Zimbabwe, 1980–2009. *Journal of Developing Societies,* 26(2), pp. 165-206.

NANCE, E., 2013. Engineers and Communities: Transforming Sanitation in Contemporary Brazil. Plymouth: Rowman & Littlefield.

NANCE, E. and ORTOLANO, L., 2007. Community Participation in Urban Sanitation Experiences in Northeastern Brazil. *Journal of Planning Education and Research,* 26(3), pp. 284-300.

NARAG, R. and MAXWELL, S.R., 2013. Understanding cultural context when collecting field data: lessons learned from field research in a slum area in the Philippines. Qualitative Research, p.1468794112473496.

NEWELL, A.F., GREGOR, P., MORGAN, M., PULLIN, G. and MACAULAY, C., 2011. User-sensitive inclusive design. *Universal Access in the Information Society,* 10(3), pp. 235-243.

NILSSON, D., 2006. A heritage of unsustainability? Reviewing the origin of the large-scale water and sanitation system in Kampala, Uganda. Environment and Urbanization, 18(2), pp. 369-385.

NILSSON, B., PETERSON, B., HOLDEN, G. and ECKERT, C., 2011. Design Med Omtanke: Participation and sustainability in the design of public sector buildings. Design Studies, 32(3), pp. 235-254.

NITTI, R. and DAHIYA, B., 2004. Community Driven Development in Urban Upgrading. Washington DC: World Bank.

NJOH, A.J., 2015. An OLS analysis of the impact of colonialism on inter-country differentials in slum incidence in Africa. *Cities,* 44, pp. 104-111.

NORMAN, D.A. and VERGANTI, R., 2014. Incremental and Radical Innovation: Design Research vs. Technology and Meaning Change. *Design Issues,* 30(1), pp. 78-96.

NYENJE, P., HAVIK, J., FOPPEN, J., MUWANGA, A. and KULABAKO, R., 2014. Understanding the fate of sanitation-related nutrients in a shallow sandy aquifer below an urban slum area. *Journal of contaminant hydrology,* 164, pp. 259-274.

O'REILLY, K. and LOUIS, E., 2014. The toilet tripod: Understanding successful sanitation in rural India. *Health & place,* 29, pp. 43-51.

OBENG-ODOOM, F., 2014. The State of African Cities 2014. *Journal of Asian and African Studies,* 0021909614547604.

ODOM, W., SELBY, M., SELLEN, A., KIRK, D., BANKS, R. and REGAN, T., 2012. Photobox: on the design of a slow technology, *Proceedings of the Designing Interactive Systems Conference* 2012, ACM, pp. 665-668.

OKURUT, K., KULABAKO, R., ABBOTT, P., ADOGO, J., CHENOWETH, J., PEDLEY, S., TSINDA, A. and CHARLES, K., 2014. Access to improved sanitation facilities in low-income informal settlements of East African cities. IWA.

OKURUT, K., KULABAKO, R.N., CHENOWETH, J. and CHARLES, K., 2015. Assessing demand for improved sustainable sanitation in low-income informal settlements of urban areas: a critical review. *International journal of environmental health research,* 25(1), pp. 81-95.

OLDFIELD, S. and PARNELL, S., 2014. From the South. In: S. PARNELL and S. OLDFIELD, eds, *The Routledge handbook on cities of the global south.* Routledge, pp. 1-4.

O'NEILL, M., 2015. Ecological Sanitation-A Logical Choice? The Development of the Sanitation Institution in a World Society. *Tampereen teknillinen yliopisto.Julkaisu-Tampere University of Technology. Publication; 1284.*

OOSTERVEER, P. and SPAARGAREN, G., 2010. Meeting social challenges in developing sustainable environmental infrastructures in East African cities. Social perspectives on the sanitation challenge. Springer, pp. 11-30.

OPP-RTI (ORANGI PILOT PROJECT RESEARCH AND TRAINING INSTITUTE) 2012. [ONLINE] Available at: http://www.oppinstitutions.org/. [Accessed 2 December 2014]

OSTROM, E., 1996. Crossing the great divide: co-production, synergy, and development. *World Development,* 24(6), pp. 1073-1087.

O'SULLIVAN, D., and DOOLEY, L., 2009. Applying innovation. CA: Sage.

OTI, S.O., VAN DE VIJVER, S. and KYOBUTUNGI, C., 2014. Trends in non-communicable disease mortality among adult residents in Nairobi's slums, 2003-2011: applying InterVA-4 to verbal autopsy data. *Global health action,* 7, pp. 25533.

OTSUKI, K., GERA, W. and MUNGAI, D., 2013. Multi-Actor Approaches to Total Sanitation in Africa. *Policy Brief,* (8). United Nations University Press.

OWEN, C., DOVEY, K. and RAHARJO, W., 2013. Teaching Informal Urbanism: Simulating Informal Settlement Practices in the Design Studio. *Journal of Architectural Education,* 67(2), pp. 214-223.

OWEN, R., MACNAGHTEN, P. and STILGOE, J., 2012. Responsible research and innovation: From science in society to science for society, with society. *Science and Public Policy,* 39(6), pp. 751-760.

PANSERA, M. and OWEN, R., 2014. Framing resource-constrained innovation at the 'bottom of the pyramid': Insights from an ethnographic case study in rural Bangladesh. *Technological Forecasting and Social Change. 92, pp. 300–311*

PAPAIOANNOU, T., 2014. How inclusive can innovation and development be in the twenty-first century? *Innovation and Development,* 4(2), pp. 187-202.

PAPANEK, V. and FULLER, R.B., 1972. *Design for the real world.* London: Thames and Hudson.

PARNELL, S. and WALAWEGE, R., 2011. Sub-Saharan African urbanisation and global environmental change. *Global Environmental Change,* 21, pp. S12-S20.

PARNELL, S. and ROBINSON, J., 2012. (Re)theorising Cities from the Global South: Looking Beyond Neoliberalism. *Urban Geography,* 33(4), pp. 593-617.

PATEL, S., 2015. The 20-year sanitation partnership of Mumbai and the Indian Alliance. *Environment and Urbanisation,* 0956247815569698.

PATERSON, C., MARA, D. and CURTIS, T., 2007. Pro-poor sanitation technologies. *Geoforum,* 38(5), pp. 901-907.

PEINE, A. and HERRMANN, A.M., 2012. The sources of use knowledge: Towards integrating the dynamics of technology use and design in the articulation of societal challenges. *Technological Forecasting and Social Change,* 79(8), pp. 1495-1512.

PENNINGTON, D.D., SIMPSON, G.L., MCCONNELL, M.S., FAIR, J.M. and BAKER, R.J., 2013. Transdisciplinary research, transformative learning, and transformative science. *Bioscience,* 63(7), pp. 564-573.

PERIAGO, M.R., FRIEDEN, T.R., TAPPERO, J.W., DE COCK, K.M., AASEN, B. and ANDRUS, J.K., 2012. Elimination of cholera transmission in Haiti and the Dominican Republic. *The Lancet,* 379(9812), pp. e12-e13.

PERRY, G., MALONEY, W., ARIAS, O., FAJNZYLBER, P., MASON, A. and SAAVEDRA, J., 2007. Informality: Exit and Exclusion, World Bank Latin America and Caribbean Studies. World Bank, Washington DC.

PIETERSE, E., 2011A. Rethinking African urbanism from the slum. *Power,* 26(14.1), pp. 40.8.

PIETERSE, E., 2011B. Building new worlds: Design and the second urban transition. In: C.E. SMITH, ed, *Design with the other 90%: Cities.* New York: Cooper-Hewitt, National Design Museum, Smithsonian institution, pp. 40-53.

PIETERSE, E., 2010. Cityness and African urban development, *Urban Forum* 2010, Springer, pp. 205-219.

PIETERSE, E., 2013. Grasping the unknowable: coming to grips with African urbanisms. In: E. PIETERSE and A. SIMONE, eds, *Rogue urbanism: emergent African cities.* Jacana Media, pp. 19-36.

PINK, S., 2012. *Advances in visual methodology.* London: Sage Publications Ltd.

PITHEY, S., 2007. Water and Sanitation in the City of Cape Town–Integrated Analysis Baseline Report. *Report compiled for the UNDP. Stellenbosch:* Sustainability Institute.

PITHOUSE, R., 2014. The Shack Settlement as a Site of Politics: Reflections from South Africa. *Agrarian South: Journal of Political Economy,* 3(2), pp. 179-201.

POHL, C., RIST, S., ZIMMERMANN, A., FRY, P., GURUNG, G.S., SCHNEIDER, F., SPERANZA, C.I., KITEME, B., BOILLAT, S. and SERRANO, E., 2010. Researchers' roles in knowledge co-production: experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. *Science and Public Policy,* 37(4), pp. 267-281.

POHL, C., 2011. What is progress in transdisciplinary research? *Futures,* 43(6), pp. 618-626.

POHL, C. and HADORN, G.H., 2008. Core terms in transdisciplinary research. In: G.H. HADORN, H. HOFFMANN-RIEM, S. BIBER-KLEMM, W. GROSSENBACHER-MANSUY, D. JOYE, C. POHL, U. WIESMANN and E. ZEMP, eds, *Handbook of transdisciplinary research.* Springer, pp. 427-432.

POLK, M., 2015. Transdisciplinary co-production: Designing and testing a transdisciplinary research framework for societal problem solving. *Futures,* 65(0), pp. 110-122.

POLK, M., 2014. Achieving the promise of transdisciplinarity: a critical exploration of the relationship between transdisciplinary research and societal problem solving. Sustainability Science, 9(4), pp. 439-451.

PORTABLE SANITATION ASSOCIATION INTERNATIONAL, 2013. The poo wars in Cape Town, South Africa have escalated. [ONLINE] Available at: http://psai.org/the-poo-wars-in-cape-town-south-africa/ [Accessed 3 April 2015]

POULIS, K., POULIS, E. and PLAKOYIANNAKI, E., 2013. The role of context in case study selection: An international business perspective. *International Business Review,* 22(1), pp. 304-314.

PRACTICAL ACTION, 2014. Water and sanitation. [ONLINE] Available at: http://practicalaction.org/water-and-sanitation. [Accessed 23 April 2015]

PRAHALAD, C., 2012. Bottom of the Pyramid as a Source of Breakthrough Innovations. *Journal of Product Innovation Management,* 29(1), pp. 6-12.

QUESENBERY, W. and BROOKS, K., 2010. *Storytelling for user experience: Crafting stories for better design.* New York: Rosenfeld Media.

RADMORE, J.V., 2015. Microfranchising alternative service delivery configurations–creating economic and energy resilience with the iShack, Unpublished Masters Thesis, Stellenbosch University.

RAIJMAKERS, B., VAN DIJK, G., LEE, Y. and WILLIAMS, S.A., 2009. Designing Empathic Conversations for Inclusive Design Facilitation. *Include 2009.*

RAZZOUK, R. and SHUTE, V., 2012. What is design thinking and why is it important? *Review of Educational Research,* 0034654312457429.

REGEER, B.J. and BUNDERS, J.F.G., 2009. Knowledge co-creation: Interaction between science and society. *A Transdisciplinary Approach to Complex Societal Issues.* Den Haag: Advisory Council for Research on Spatial Planning, Nature and the Environment/Consultative Committee of Sector Councils in the Netherlands [RMNO/COS].

REMENYI, D., 2012. *Case study research, the quick guide series.* United Kingdom: Academic publishing ltd.

RICHARDS, L., 2009. *Handling qualitative data: A practical guide.* London: Sage.

RICKINSON, M., SEBBA, J. and EDWARDS, A., 2011. *Improving research through user engagement.* New York: Routledge.

RITCHIE, J., LEWIS, J., NICHOLLS, C.M. and ORMSTON, R., 2013. *Qualitative research practice: A guide for social science students and researchers.* Los Angeles*:* Sage.

ROBERTSON, T. and SIMONSEN, J., 2012. Challenges and opportunities in contemporary participatory design. *Design Issues,* 28(3), pp. 3-9.

ROBINS, S., 2014A. Poo wars as matter out of place: 'Toilets for Africa' in Cape Town. *Anthropology Today,* 30(1), pp. 1-3.

ROBINS, S., 2014B. The 2011 Toilet Wars in South Africa: Justice and Transition between the Exceptional and the Everyday after Apartheid. *Development and Change,* 45(3), pp. 479-501.

ROSENDAHL, J., ZANELLA, M.A., RIST, S. and WEIGELT, J., 2015. Scientists' situated knowledge: Strong objectivity in transdisciplinarity. *Futures,* 65(0), pp. 17-27.

ROY, A., 2014. Worlding the South- towards a post-colonial urban theory. In: S. PARNELL and S. OLDFIELD, eds, *The Routledge handbook on cities of the global south.* Routledge, pp. 9-22.

ROY, D., LEES, M.H., PALAVALLI, B., PFEFFER, K. and SLOOT, M.P., 2014. The emergence of slums: A contemporary view on simulation models. *Environmental Modelling & Software,* 59, pp. 76-90.

SAHRC (South African Human Rights Commission) 2014. Report on the right to access sufficient water and decent sanitation in South Africa. SA: SAHRC.

SALDAÑA, J., 2013. *The coding manual for qualitative researchers.* London: Sage.

SANDERS, E.B. and STAPPERS, P.J., 2008. Co-creation and the new landscapes of design. *Co-design,* 4(1), pp. 5-18.

SANTOLARIA, M., OLIVER-SOLÀ, J., GASOL, C.M., MORALES-PINZÓN, T. and RIERADEVALL, J., 2011. Eco-design in innovation driven companies: perception, predictions and the main drivers of integration. The Spanish example. *Journal of Cleaner Production,* 19(12), pp. 1315-1323.

SATTERTHWAITE, D., MITLIN, D. and BARTLETT, S., 2015. Is it possible to reach low-income urban dwellers with good-quality sanitation? *Environment and Urbanisation,* 27(1), pp. 3-18.

SCHAPER-RINKEL, P. and WAGNER-LUPTACIK, P., 2014. Design thinking. In A. BUTZIN, A. DAVIS, D. DMITRI, H. JÜRGEN, K. CHRISTOPH, A. KESSELRING, R. KOPP, J. MILLARD, P. OEIJ, D. REHFELD, P. SCHAPER-RINKEL, M. SCHWARZ, A. SCOPPETTA, P. WAGNER-LUPTACIK, and M WEBER, 2014. Other authors. *Theoretical Approaches to Social Innovation–A Critical Literature.* D1.1. Dortmund: Social Innovation: Driving Force of Social Change (SI-Drive)

SEBITOSI, B., 2012. Alternative solutions for sustainable waste water management. In: M. SWILLING, B. SEBITOSI and R. LOOTS, eds, *Sustainable Stellenbosch: Opening dialogues.* Stellenbosch: AFRICAN SUN MeDIA, pp. 139-150.

SEELIGER, L. and TUROK, I., 2014. Averting a downward spiral: building resilience in informal urban settlements through adaptive governance. *Environment and Urbanisation,* 26(1), pp. 184-199.

SENGERS, P., BOEHNER, K., DAVID, S. and KAYE, J., 2005. Reflective design, *Proceedings of the 4th decennial conference on Critical computing: between sense and sensibility* 2005, ACM, pp. 49-58.

SERNA-MANSOUX, L., POPOFF, A. and MILLET, D., 2014. A Simplified Model to Include Dynamic Product-User Interaction in the Eco-Design Process. Journal of Industrial Ecology, 18(4), pp. 529-544.

SHI, L. and CHEW, M.Y.L., 2012. A review on sustainable design of renewable energy systems. *Renewable and Sustainable Energy Reviews,* 16(1), pp. 192-207.

SHORTT, N.K. and HAMMETT, D., 2013. Housing and health in an informal settlement upgrade in Cape Town, South Africa. *Journal of housing and the built environment,* 28(4), pp. 615-627.

SILVA, C.N., 2013. Colonial architecture and urbanism in Africa. Intertwined and contested histories. *Planning Perspectives,* 28(1), pp. 156-159.

SILVA, C.N., 2012. Urban planning in Sub-Saharan Africa: A new role in the urban transition. *Cities,* 29(3), pp. 155-157.

SIMONE, A. 2015. "Infrastructure: Introductory Commentary" Curated Collections, Cultural Anthropology Online, [ONLINE] Available at: http://www.culanth.org/curated_collections/11-infrastructure/discussions/12-infrastructure-introductory-commentary-by-abdoumaliq-simone [Accessed 2 February 2016]

SIMONE, A., 2006. South African urbanism: between the modern and the refugee camp. In: M.J. MURRAY and G.A. MYERS, eds, *Cities in contemporary Africa.* Palgrave Macmillan, pp. 241-247.

SKUSE, A. and COUSINS, T., 2007. Spaces of resistance: informal settlement, communication and community organisation in a Cape Town township. Urban Studies, 44(5-6), pp. 979-995.

SLAVIN, T., 2015. The winning entry in a Bill Gates-funded design challenge provides clean water, generates power ... and makes a profit. [ONLINE] Available at: http://www.theguardian.com/sustainable-business/2015/jan/20/turning-human-waste-into-drinking-water. [Accessed 30 January 2015]

SMITHSONIAN DESIGN MUSEUM, n.d. Design other 90 network. [ONLINE] Available at http://www.designother90.org/ [Accessed 5 May 2015]

SMULDERS, F., DORST, K. and VERMAAS, P., 2014. Applying design thinking elsewhere: Organisational context matters, *Proceedings of the 19th DMI: Academic design management conference, 2797-2817. (2014).* The Design Management Institute.

STANFORD UNIVERSITY, 2012. Extreme, design for extreme affordability. [ONLINE] Available at: http://extreme.stanford.edu/. [Accessed 2 February 2015]

STAPPERS, P.J. and VISSER, F.S., 2007. Bringing participatory design techniques to industrial design engineers, *DS 43: Proceedings of E&PDE 2007, the 9th International Conference on Engineering and Product Design Education, University of Northumbria, Newcastle, UK, 13.-14.09. 2007* 2007.

STATISTICS SOUTH AFRICA, 2012. Census 2011. Statistical release (Revised) P0301.4.

STEEN, M., 2011. Tensions in human-centred design. *CoDesign,* 7(1), pp. 45-60.

STELLENBOSCH MUNICIPALITY, 2013. *Enkanini (Kayamandi) Household Enumeration report,* Stellenbosch.

STERN, N.H., 2007. *The economics of climate change*: *the Stern review*. Cambridge University press.

STILL, D. and LOUTON, B., 2012. Piloting and testing the pour-flush latrine technology for its applicability in South Africa. WRC Report No. 1887/1/12. Gezina: WRC.

STRAUSS, M. and LIEBENBERG, S., 2014. Contested spaces: Housing rights and evictions law in post-apartheid South Africa. *Planning Theory,* 1473095214525150.

SUSTAINABLE DEVELOPMENT KNOWLEDGE PLATFORM, 2015. [ONLINE] Available at: https://sustainabledevelopment.un.org/topics/sustainabledevelopmentgoals [Accessed 11 May 2015]

SWAHN, M.H., BRAUNSTEIN, S. and KASIRYE, R., 2014. Demographic and psychosocial characteristics of mobile phone ownership and usage among youth living in the slums of Kampala, Uganda. *Western Journal of Emergency Medicine,* 15(5), pp. 600.

SWILLING, M., 2013. Reconceptualising urbanism, ecology and networked infrastructure. In: E.A. PIETERSE and A. SIMONE, eds, *Rogue urbanism: emergent African cities.* Jacana Media, pp. 65-82.

SWILLING, M., 2012A. So what is so unsustainable about the global economy?: main article. *CME: Your SA Journal of CPD: Climate change and health,* 30(3), pp. 68-71.

SWILLING, M., 2012B. Preface. In: M. SWILLING, B. SEBITOSI and R. LOOTS, eds, *Sustainable Stellenbosch: Opening dialogues.* AFRICAN SUN MeDIA, pp. xiii-xiv.

SWILLING, M., 2010A. Africa 2050–Growth, Resource Productivity and Decoupling, *Policy brief for the 7th meeting of the International Panel for Sustainable Resource Management of the United Nations Environment Programme (UNEP)* 2010.

TAEBI, B., CORRELJE, A., CUPPEN, E., DIGNUM, M. and PESCH, U., 2014. Responsible innovation as an endorsement of public values: The need for interdisciplinary research. *Journal of Responsible Innovation,* 1(1), pp. 118-124.

TAING, L., PAN, S., HILLIGAN, J., SPIEGEL, A. and ARMITAGE, N., 2013. Challenges facing sanitation-provision partnerships for informal settlements: a South African case study. *Journal of Water, Sanitation and Hygiene for Development,* 3(2), pp. 230-239.

TAVENER-SMITH, L., 2012. Housing: The challenge of informal settlements. In: M. SWILLING, B. SEBITOSI and R. LOOTS, eds, *Sustainable Stellenbosch: Opening dialogues.* AFRICAN SUN MeDIA, pp. 68-81.

TAYLOR & FRANCIS ONLINE, 2015. Codesign, international journal of cocreation in design and the arts. [ONLINE] Available at: http://www.tandfonline.com/toc/ncdn20/current [Accessed: 7 May 2015]

THOMAS, G., 2011. A typology for the case study in social science following a review of definition, discourse, and structure. *Qualitative inquiry,* 17(6), pp. 511-521.

TILLEY, E., STRANDE, L., LÜTHI, C., MOSLER, H., UDERT, K.M., GEBAUER, H. and HERING, J.G., 2014. (TILLEY ET AL. 2014A). Looking beyond Technology: An Integrated Approach to Water, Sanitation and Hygiene in Low Income Countries. *Environmental science & technology,* 48(17), pp. 9965-9970.

TILLEY, E., ULRICH, L., LÜTHI, C., REYMOND, P. and ZURBRÜGG, C., 2014. (TILLEY ET AL. 2014B). *Compendium of sanitation systems and technologies.* 2nd edition edn. Dübendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag).

TISSINGTON, K., 2011. *Basic Sanitation in South Africa: A Guide to Legislation, Policy and Practice*. Johannesburg: Socio-Economic Rights Institute of South Africa (SERI).

TINOCO, M., CORTOBIUS, M., GRAJALES, M.D. and KJELLÉN, M., 2014. Water Co-operation between Cultures: Partnerships with Indigenous Peoples for Sustainable Water and Sanitation Services. Aquatic Procedia, 2(0), pp. 55-62.

TONKISS, F., 2013. *Cities by design: the social life of urban form.* UK: John Wiley & Sons.

TROJER, L., RYDHAGEN, B. and KJELLQVISTT, T., 2014. Inclusive innovation processes–experiences from Uganda and Tanzania. *African Journal of Science, Technology, Innovation and Development,* 6(5), pp. 425-438.

TSANG, E.W., 2013. Case study methodology: causal explanation, contextualisation, and theorising. Journal of international management, 19(2), pp. 195-202.

TSENG, T. and RESNICK, M., 2014. Product versus process: representing and appropriating DIY projects online, *Proceedings of the 2014 conference on Designing interactive systems* 2014, ACM, pp. 425-428.

TUKAHIRWA, J.T., MOL, A.P.J. and OOSTERVEER, P., 2013. Comparing urban sanitation and solid waste management in East African metropolises: The role of civil society organisations. *Cities,* 30, pp. 204-211.

TUMWEBAZE, I.K., NIWAGABA, C.B., GÜNTHER, I. and MOSLER, H., 2014. Determinants of households' cleaning intention for shared toilets: case of 50 slums in Kampala, Uganda. *Habitat International,* 41, pp. 108-113.

TURNHOUT, E., STUIVER, M., KLOSTERMANN, J., HARMS, B. and LEEUWIS, C., 2013. New roles of science in society: Different repertoires of knowledge brokering. Science and Public Policy, 40(3), pp. 354-365.

TUROK, I., 2013. Securing the resurgence of African cities. *Local Economy,* 28(2), pp. 142-157.

UMANDE TRUST, 2014. Bio-centre innovations. [ONLINE] Available at: http://umande.org/bio-center-innovations/ [Accessed 12 December 2014]

UN (United Nations), 2015. We can end poverty, Millennium development goals and beyond 2015. [ONLINE] Available at: http://www.un.org/millenniumgoals/environ.shtml [Accessed 04 April 2015]

UNDERHILL, G., 2013. 'Zille: Poo-flinging attacks politically motivated', Mail & Guardian. [ONLINE] Available at: http://mg.co.za/article/2013-08-30-zille-poo-flinging-attacks-politically-motivated [Accessed 17 November 2014]

UN-HABITAT, 2004. The challenge of slums: global report on human settlements 2003. Nairobi: UN-Habitat.

UN-HABITAT. 2013. State of the world's cities 2012/2013: prosperity of cities. Routledge.

UN-HABITAT, 2014. The State of African Cities: Re-Imagining Sustainable Urban Transitions. Nairobi: UN-Habitat.

UNICEF, 2003. Water, sanitaiton and hygiene, Statistics. [ONLINE] Available at: http://www.unicef.org/wash/index_statistics.html [Accessed 15 April 2015]

UNICEF, 2014. WASH technical brief: Key findings of a sanitation supply chains study in Eastern and Southern Africa. Eastern and Southern Africa regional office.

USHIJIMA, K., IRIE, M., SINTAWARDANI, N., TRIASTUTI, J., HAMIDAH, U., ISHIKAWA, T. and FUNAMIZU, N., 2013. Sustainable design of sanitation system based on material and value flow analysis for urban slum in Indonesia. *Frontiers of Environmental Science & Engineering,* 7(1), pp. 120-126.

VAISMORADI, M., TURUNEN, H. and BONDAS, T., 2013. Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing & health sciences,* 15(3), pp. 398-405.

VALLET, F., EYNARD, B., MILLET, D., MAHUT, S.G., TYL, B. and BERTOLUCI, G., 2013. Using eco-design tools: An overview of experts' practices. *Design Studies,* 34(3), pp. 345-377.

VAN BOEIJEN, A. and STAPPERS, P.J., 2011. Preparing Western designers for the use of contextmapping techniques in non-Western situations, *DS 69: Proceedings of E&PDE 2011, the 13th International Conference on Engineering and Product Design Education, London, UK, 08.-09.09. 2011.*

VAN OUDHEUSDEN, M., 2014. Where are the politics in responsible innovation? European governance, technology assessments, and beyond. Journal of Responsible Innovation, 1(1), pp. 67-86.

VAN VLIET, B.J., SPAARGAREN, G. and OOSTERVEER, P., 2011. Sanitation under challenge: contributions from the social sciences. *Water Policy,* 13(6), pp. 797-809.

VAN VLIET, B., SPAARGAREN, G. and OOSTERVEER, P., 2010. *Social perspectives on the sanitation challenge.* Springer.

VAN VUUREN, L., 2014. No flash in the pan: how pour-flush toilets are driving away SA's sanitation backlog. *Water wheel,* 13(4), pp. 16-20.

VASUDEVAN, A., 2014. The makeshift city: Towards a global geography of squatting. *Progress in Human Geography,* 0309132514531471.

VERBEEK, P., 2012. Introduction: humanity in Design, a few notes on the relations between anthropology and materiality. In: W. GUNN and J. DONOVAN, eds, *Design and Anthropology.* Ashgate Publishing Ltd, pp. 163-176.

VEZZOLI, C. and MANZINI, E., 2008. *Design for environmental sustainability.* London: Springer Verlag.

VEZZOLI, C., DELFINO, E. and AMBOLE, L.A., 2014. System Design for Sustainable Energy for all. A new challenging role for design to foster sustainable development. *FORMakademisk,* 7(3).

VON DER HEYDE, V., 2014. *Towards a sustainable incremental waste management system in Enkanini: A transdisciplinary case study.* Stellenbosch University.

VON THIENEN, J., NOWESKI, C., MEINEL, C. and RAUTH, I., 2011. The Co-evolution of Theory and Practice in Design Thinking–or–"Mind the Oddness Trap!" *Design Thinking.* Springer, pp. 81-99.

WALDMAN, R.J., MINTZ, E.D. and PAPOWITZ, H.E., 2013. The cure for cholera- improving access to safe water and sanitation. *New England Journal of Medicine,* 368(7), pp. 592-594.

WALKER, S., 2011. *The spirit of design*. London: Earthscan.

WALL, J., STAHL, B. and DAYNES, S., 2014. Critical Discourse Analysis as a Theory and Review Methodology. *Proceedings of the Twentieth Americas Conference on Information Systems* 2014, Savannah.

WARR, A. and O'NEILL, E., 2005. Understanding design as a social creative process, *Proceedings of the 5th conference on Creativity & cognition* 2005, ACM, pp. 118-127.

WATER AND SANITATION PROGRAM (WSP), 2011. Water Supply and Sanitation in South Africa: Turning Finance into Services for 2015 and Beyond. Nairobi: World Bank.

WATER DIALOGUES SYNTHESIS REPORT 2009-CAPE TOWN CASE STUDY, THE. 2009. Cape Town (informal sanitation). [ONLINE] Available: http://www.waterdialogues.org/south-africa/documents/p.46CapeTownCaseStudySummary.pdf. [Accessed 14 February 2015]

WATER RESEARCH COMMISSION (WRC), 2014. Sanitation matters a magazine for Southern Africa. Issue 6- 2014. Gezina: WRC.

WATKINS, A., PAPAIOANNOU, T., KALE, D. and MUGWAGWA, J., 2014. National innovation systems, developing countries, and the role of intermediaries: a critical review of the literature. In *15th International Conference of the International Joseph A. Schumpeter Society (ISS)*, 27-30 July 2014, Jena, Germany.

WATSON, V., 2014. African urban fantasies: dreams or nightmares? *Environment and Urbanisation,* 26(1), pp. 215-231.

WATTSJOHNSON, Y., 2009. Narrative inquiry and the discovery of self within the academy. In: S. KOURITZIN, N.P. PIQUEMAL and R. NORMAN, eds, *Qualitative research: Challenging the orthodoxies in standard academic discourse (s).* New York: Routledge, pp. 247-262.

WEISS, L.M., 2014. Informal settlements and urban heritage landscapes in South Africa. *Journal of Social Archaeology,* 14(1), pp. 3-25.

WESSELS, B.S., 2015. Turning points: Exploring power transitions in an incremental upgrading process in Enkanini, Unpublished Masters thesis, Stellenbosch University.

WHAT IS UNIVERSAL DESIGN? 2015 [ONLINE] Available at: http://www.universaldesign.com/index.php?option=com_content&view=article&id=327:what-is-universal-design&catid=2196:universal-design&Itemid=113 [Accessed 23 April 2015]

WHO\UNICEF, 2014. Progress On drinking water and sanitation- 2014 update. Geneva: WHO.

WHO\UNICEF, 2008. Progress On drinking water and sanitation- special focus on sanitation. New York: UNICEF, and Geneva: WHO press.

WICKSON, F. and CAREW, A.L., 2014. Quality criteria and indicators for responsible research and innovation: learning from transdisciplinarity. *Journal of Responsible Innovation,* 1(3), pp. 254-273.

WICKSON, F., CAREW, A.L. and RUSSELL, A.W., 2006. Transdisciplinary research: characteristics, quandaries and quality. *Futures,* 38(9), pp. 1046-1059.

WIEK, A., HARLOW, J., MELNICK, R., VAN DER LEEUW, S., FUKUSHI, K., TAKEUCHI, K., FARIOLI, F., YAMBA, F., BLAKE, A. and GEIGER, C., 2015. Sustainability science in action: a review of the state of the field through case studies on disaster recovery, bioenergy, and precautionary purchasing. *Sustainability Science,* 10(1), pp. 17-31.

WINTER, K., 2010. Water and sanitation in the city of Cape Town: Sustainability uncertain. In: M. SWILLING, ed, *Sustaining Cape Town: imagining a livable city.* Sun Press/Sustainability Institute, pp. 101-114.

YANG, C.J. and CHEN, J.L., 2011. Accelerating preliminary eco-innovation design for products that integrates case-based reasoning and TRIZ method. *Journal of Cleaner Production,* 19(9), pp. 998-1006.

YIN, R.K., 2013. *Case study research: Design and methods.* Sage publications.

YIN, R.K., 2011. *Qualitative research from start to finish.* Guilford Press.

YIN, R.K., 2009. *Case study research: Design and methods.* London: Sage Publications, Inc.

ZAKARIA, F., GARCIA, H.A., HOOIJMANS, C.M. and BRDJANOVIC, D., 2015. Decision support system for the provision of emergency sanitation. *Science of the Total Environment,* 512–513(0), pp. 645-658.

ZAPPULLA, C., SUAU, C. and FIKFAK, A., 2014. The pattern making of mega-slums on semantics in slum urban cultures. *Journal of Architecture and Urbanism,* 38(4), pp. 247-264.

ZIERVOGEL, G., WADDELL, J., SMIT, W. and TAYLOR, A., 2014. Flooding in Cape Town's informal settlements: barriers to collaborative urban risk governance. South African Geographical Journal, (ahead-of-print), pp. 1-20.

ZURBRÜGG, C. and TILLEY, E., 2009. A system perspective in sanitation - Human waste from cradle to grave and reincarnation. *Desalination,* 248(1–3), pp. 410-417.