A Case Study of Transdisciplinarity and Biomimicry: The Restoration of Water Systems using Eco-machines within the Informal Berg River Community

by

Gabriel Wolfaardt

Thesis presented in partial fulfilment of the requirements for the degree of Master of Philosophy in Sustainable Development in the Faculty of Economic and Management Sciences at Stellenbosch University

Supervisor: Professor Mark Swilling

March 2017

Declaration

By submitting this thesis 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.

Gabriel Wolfaardt

Date: March 2017

Abstract

The Berg River catchment, which originates in the Drakenstein Mountains, has significant agricultural and economic relevance. Greywater and stormwater drainage from informal settlements such as Langrug near Franschhoek into the catchment is often the result of insufficient infrastructure, especially to service shack dwellings. This leads to ecosystem degradation, with far-reaching negative implications, including human health risks, and contamination of agricultural produce, which have caused tensions among the various inhabitants of the catchment and thus have driven the need for sustainable and economically viable solutions.

The Genius of SPACE (GoS) project is an attempt to address the life-world problem of contamination of the Berg River due to untreated greywater entering the system from the informal settlement of Langrug. Invariably, the design of such intervention requires involvement of various disciplines ranging from civil engineering to ecology. However, there is ample evidence that water management and sanitation in these settings present complex challenges that cannot be resolved purely from a technical perspective and therefore an attempt was made by applying a transdisciplinary (TD) approach to actively include, from the initial stages, the community for the at-source treatment of the greywater, as opposed to planning towards piping the greywater to a treatment plant before entering the Berg River. An important component of GoS's initial plan was the installation of Eco-Machines, which essentially consist of a series of tanks that resemble constructed wetlands / mimic natural wetlands through which the water flows; each subsequent tank having a different biota and improved water quality. The TD approach was thus applied in an effort to ensure inclusion of the community as active participants in project design without their involvement becoming the primary focus of the project, but rather a means to achieve the overall goal of contributing to the creation of an environment conducive to human dignity and health. Presented here is a report, in the form of two journal articles, on the progress made in this on-going project, the need to adapt and modify, lessons learned and reflection on future initiatives.

Opsomming

Die Bergrivier, met sy oorsprong in die Drakenstein Berge is van beide landbou en ekonomiese belang. Onvoldoende infra-struktuur, veral om informele nedersettings te bedien, lei dikwels tot hoë vlakke van grys- en stormwater afloop vanuit informele nedersettings soos Langrug naby Franschhoek wat tot ernstige besoedeling van dié opvangsgebied lei. Dit hou nadelige gevolge in vir ekosisteem gesondheid met ver-reikende gevolge wat ook ‘n bedreiging is vir mense-gesondheid en kontaminasie van landbou produkte. Laasgenoemde is dikwels die oorspong van spanning tussen die inwoners van die opvangsgebied en noodsaak dus volhoubare en ekonomies lewensvatbare ingryping.

Die “Genius of SPACE (GoS; Systems for Peoples Access to a Clean Environment) projek is ‘n daadwerklike poging om oplossings te vind vir die problem wat onstaan het a.g.v. die onbehandelde gryswater wat in die Bergrivier invloei vanaf die Langrug informele nedersetting. Die ontwerp van sodanige intervensie vereis uiteraard die betrokkenheid en insette van verskeie dissiplines vanaf siviele ingeneurswese tot ekologie. Daar is egter oortuigende voorbeelde dat water bestuur en sanitasie in sulke ostandighede komplekse vraagstukke skep wat moeilik opgelos kan word vanuit ‘n suiwer tegniese benadering, en daarom was ‘n poging aangewend d.m.v. die volg van ‘n trans-dissiplinêre (TD) benadering om gemeenskaps-betrokkenheid van die begin af te verseker vir die behandeling van gryswater by die bron, in teenstelling met die afvoer daarvan met pype tot by ‘n konvensionele aanleg vir behandeling voor storting in die Bergrivier. Die aanvanklike plan van GoS was om sg. Eko-masjiene te installeer, wat vergelyk kan word met kunsmatige vleilande, of ‘n namaak van natuurlike vleilande d.m.v. ‘n reeks tenks waardeer die water vloei; met verskillende biota in elke opeenvolgende tenk soos wat water gehalte verbeter. Die TD benadering het gepoog om aktiewe deelname van die gemeenskap te bewerkstellig, maar terselfdertyd moet dit nie die primêre fokus te word nie. Die deelname moes meehelp tot pogings gemik op die bevordering van ‘n omgewing waar menswaardigheid en gesondheid bevorder word. Hier word verslag gedoen op die vordering wat gemaak is tot hede, met verwysing na behoefte vir aanpassing en

verandering wat opgemerk is, lesse wat geleer is, asook oorweging van moontlike toekomstige inisiatiewe.

Acknowledgements

I would like to thank the Water Research Commission and BiomimicrySA for their funding and support throughout the project.

I would also like to thank my supervisor, Mark Swilling, for his academic inspiration, and also thank my un-official supervisor, Claire Mollat, for her great support and insight throughout my research.

This paper could not have been achieved without the enthusiasm and time given by the Langrug community. This also applies to Jonny Harris, Karabo Chadzingwa and the rest of the Isidima team.

To my peers and friends, thank you for the support over the last several years.

Thank you Amanda for letting me attempt a masters.

I would also like to thank my father, Gideon, for all his support over the years and throughout this project. A son could not ask for a better role model.

I would also like to acknowledge that my sister, Helenja, is still the hardest working and best debater in the family.

Lastly, while writing this thesis, my mother Susan, successfully battled through chemotherapy to beat lymphoma. This paper is dedicated to you Mom.

Table of Contents

List of Acronyms and Abbreviations

CLO	Community Liason Officer
GoS	Genius of SPACE
PSF	Project Steering Forum
SPACE	Systems for Peoples Access to a Clean Environment
TD	Transdiciplinary

List of Figures

List of Tables

Chapter 1 – Introduction

1.1 Introduction

The two journal articles in this paper researches the Genius of SPACE project in Langrug. Langrug is an informal settlement out of Franschhoek in the Western Cape, South Africa. The Genius of SPACE project uses biomimicry designs to treat stormwater and greywater within Langrug. Local community particpation was strongly encouraged with the hopes of meaningful implementation that addresses the needs of the community. Literature in transdisicplinary studies, biomimicry and stakeholder engagement in these contexts are reviewed and are compared to the Genius of SPACE context.

1.2 Rationale for the Study

The rationale for the project was to analyse a trandisicplinary project. This project used biomimicry as an design tool, while including the local community to inform the implementation. The study analyses the synthesis of technical and social sciences bound by an ethical framework.

1.3 Problem Statement

Due to an informal ablution and stormwater infrastructure, the Berg River catchment area has greywater flowing into its water system causing heavily contaminated water to enter the water supply. By introducing biomimetic designed treatment facilities, such as Eco-Machines, the amount of contaminants can be reduced. However, there is uncertainty with regards to the societal interaction with the implementation of designs such as Eco-Machines. The purpose of this project is to determine whether biomimicry designs are efficient in reducing contaminants in greywater and to identify the local societies interactions with the design. Water samples will be taken to determine the effectiveness of the Eco-Machines and the study of the engaged stakeholders will help reveal the societal interaction. The research project is a conceptualised attempt at transdisciplinary methodology.

1.4 Research Objective(s) / Question(s)

This project asked whether implementing biomimetic designs, such as Eco-Machines, can restore the informal Berg River community water systems. It also analysed whether community participation could inform and guide the implementation process for better results. These questions linked with the goals of this project, which were to determine the social and economical dynamics of the initial introduction and implementation of the biomimetic designs and their functional ability to treat greywater.

1.5 Overarching Research Approach / Design / Strategy

The Genius of SPACE project used a mixed method approach to frame research designs. Quantitative and qualitative research methods were used to subtantiate the results of each other. The process was observed to identify the strengths and weaknesses of this approach.

1.6 Delimitations of the overall study

The biggest challenge in analysing transdisciplinary studies is to identify clear performance indicators in qualitative analysis. Due to the unique context, results are not predicable and rather emerge from the system in dynamic and non-linear ways. Thus continual reflection and analysis is required, which takes time, and thus the Genius of SPACE project has many areas to study or analyse. The technical systems also take time to stabilise to work effectively and also require long-term analysis to determine intervention success.

Chapter 2 – A Literature Review of Transdisicplinary Methodologies to Collaborate Biomimetic Designed Systems with Societal Needs.

2.1 Introduction

This project analyses the implementation of transdisciplinary methodologies within a South African urban developmental context. The intervention, named the Genius of SPACE project, is implementing greywater treatment facilities within the Franschhoek informal community of Langrug. This intervention is required due to the environmental degradation of the Berg River catchment area and the risks to human health due to untreated greywater. The Stellenbosch Municipality and the Western Cape Government are committed to service delivery, but have acknowledged that traditional means of greywater treatment might not be appropriate in the informal urban context. The Genius of SPACE project uses the principles of Biomimicry in its design with the purpose of integrating a system within the Langrug community that provides local economic opportunities, infrastructure and environmental restoration.

There is no single discipline that can adequately achieve the goals set out by the Genius of SPACE project. From a technical perspective, and interdisciplinary approach is required as Biomimicry design requires knowledge and application from various academic fields. These include engineering, natural sciences, chemistry, architecture, design and social science sources of knowledge to generate research questions and formulate implementation design. However, the socio-ecological interface is a complex space, particularly in the South African context where social inequality and urban divisions exist. The Genius of SPACE Project acknowledges these complexities and is pledged to urban service delivery and to uplift poverty. This series of research papers argue that the Genius of SPACE project is transdisciplinary, as the interdisciplinary concept of Biomimicry design is driven by an ethos to address societal needs deeper than technical levels.

The first paper of the series frames Biomimicry as a conceptual design tool within transdisciplinary research and implementation. The design will acknowledge the complexity of urban and ecological systems to further strengthen the design. The philosophies of disciplinarity and complexity are briefly introduced here. These summaries will show that the information framing the research questions and purposes requires contextualised references, thus there is a need for active non-academic stakeholder engagement and inclusion. As with scientific research and design, traditional participation methods do not adequately address representation or inclusiveness of marginalised citizens. Participation within a transdisciplinary structure is thus explored. The topics above provide a philosophical ethos for the Genius of SPACE project.

The Genius of SPACE project is primarily an endeavour of urban design. Ecological design as a response to modern and reductionist design is reviewed. It is seen that the purpose of ecological design is to generally incorporate benefits to the environment and society within its implementation. An analysis of biomimicry shows that while it falls under the wider description of ecological design, biomimicry is inspired by nature's forms and functions based on eons of evolutionary design, and can be considered an interdisciplinary concept. However it transcends its disciplines when used in a framework that addresses societal and ecological inequalities, demanding contextual and non-academic stakeholder engagement.

In conclusion, this paper provides a literature review that provides the framework for analysing transdisciplinary and biomimicry methodologies and research designs in an informal urban development context, with the Genius of SPACE Project as a case study where the initial information gathering and implementation is documented and analysed. This process is addressed in the accompanying research paper.

2.2 Describing Transdisciplinarity

"Transdisciplinarity" has been introduced to challenge the rigid disciplined nature of how society conducts research and obtains information. This is particularly important in the context of 21st century developing states, such as South Africa, due to society's expectation of social justice and addressing of historical inequality and inequity. At the same time, there has been an undeniable disintegration of the societal and ecosystem realms (Goebel et al. 2010). Traditional modern science and humanities have failed to address these issues, partly due to their findings not being accessible or relevant to non-academics or policy makers. The purpose of transdisciplinary research is to achieve use-inspired, adaptive and reflective research at the interface of resilient human societies and sustainable natural environments (Burns et al. 2006). The following section attempts to unpack the meanings and uses of transdisciplinarity as a philosophical and methodological tool, as it provides a crucial narrative for the research performed in the Genius of SPACE project. In order to understand "transdisciplinarity", one has to consider how modern research is performed, evaluating the strengths and weaknesses of modern methodologies. Below is a brief hierarchal breakdown of how knowledge is generated in modern research.

Disciplinarity is the formation of specialized faculties and the multiplication of disciplines and sub-disciplines within modern research and society (Max-Neef 2005) resulting in detailed knowledge areas with defined borders that have ritualized and coded ways of building, evaluating and disseminating knowledge (Leavy 2011). This traditional way of performing research in modern times has come under heavy criticism for not acknowledging or being able to compute the complexity of dynamic systems, and thus there is a great reduction in generated knowledge (Max-Neef 2005). It is important to note that reductionism and disciplined science is still important in the appropriate context. In linear, non-dynamic conditions, the scientific method is still a critical tool in

research. However, issues arise when the results are applied into dynamic and non-linear conditions where they are less applicable or relevant.

Due to the linearity of the knowledge generated by rigid disciplines, “multidisciplinarity” was the next logical step to enriched research. Multidisciplinarity is when research is conducted in more than one specialised discipline in an attempt to improve the understanding of topics and generating enhanced data for all the participating disciplines (Max-Neef 2005 & Nicolescu 2002). A criticism of this format is that analysis is done separately in isolated discipline perspectives, resulting in a report without any "integrating synthesis" (Max-Neef 2005), as the goal remains limited to the frameworks of disciplinarity research (Nicolescu 2002).

Interdisciplinarity is closely linked to multidisciplinarity (Leavy 2011), and is defined as the transfer of methods from one discipline to another to formulate novel applications, epistemology and new disciplines (Nicolescu 2002). Interdisciplinary research is organised between two hierarchical levels, the higher one being the empirical discipline, and the lower ones being pragmatic and purposive subjects related to the purpose of the research (Max-Neef 2005). Increasing magnitude of interdisciplinarity, this form of research promotes disciplines to cooperate, appreciate, dismantle, reconstruct, modify and transform each other (Leavy 2011). Interdisciplinarity can add valuable information of high quality, as it opens up disciplined knowledge generation and analysis. However, the main weakness regarding interdisciplinarity is the disconnect between the knowledge produced and its implementation in society (Leavy 2011 & Max-Neef 2005). This disconnect is argued to be caused by the lack of understanding of the complexities of the various societal and environmental relationships. Often these complexities arise from context specific conditions, thus the implementation and synthesis of interdisciplined research requires localised frameworks to be established. This drove the conceptualisation of transdisciplinarity.

A leading scholar in transdisciplinarity, Manfred Max-Neef, argues that transdisciplinarity is the coordination between all the above hierarchal levels, determined

by ethical values and philosophy (Max-Neef 2005). Transdisciplinarity concerns itself with what is between disciplines, across the disciplines and beyond all disciplines (Nicolescu 2002). Pohl and Hardorn 2008 (in Leavy 2011) argues that transdisciplinarity research attempts to grasp the complexity of problems and the diversity of perceptions of the problems. This form of research also tries to link abstract and case-specific information that develops knowledge and practices for the perceived common good. This is social and natural science research that synergistically collaborates between disciplines (Leavy 2011), with the hopes that the sum of the final knowledge is greater than the sum of its disciplinary components (Giri 2002 in Leavy 2011). For Max-Neef (2005) the principles on how to approach a question using transdisciplinarity include:

- What exists?
- What are we capable of?
- What is it we want to do?
- What should we want to do? Or, How should we want to do it?

Patricia Leavy, a leading scholar in qualitative research, argues that the principles of transdisciplinary research are problem- or issue-centred, that incorporates synergistic approaches to transcend disciplines (Leavy 2011). However, researchers should be wary to advertise “transdisciplinarity” as a one-size-fits-all solution (Russel et al. 2008). Transdisciplinarity as a concept should, by definition, be open to challenge and engagement to address contradictions and strengthen the research. The Genius of SPACE project, which is in attempt in transdisciplinary action, can allow for a conceptual space for transdisciplinarity to be challenged, tested and analysed. If this is done it will allow for the properties of the system to emerge and allow for the research to be flexible and innovative. These aspects will likely reveal how transdisciplinarity is tied to the complexity and systems thinking paradigms (Preiser & Cilliers 2010) as briefly described in the next section.

2.3 Complexity and Systems Thinking

The aim of transdisciplinary research is to translate research results into relevant and useful practices (Lilja & Bellon 2008). Traditional societal interventions have been based on the rationality found in various disciplines such as economics and science. However, the information generated is predominantly in a "Northern" first-world contexts, and are at times ill equipped for developing contexts such as those experienced in Southern Africa. Societies, particularly those with great degrees of inequality, are complex and do not typically behave to prevailing "Northern" norms. Society is not homogenous, thus applying concepts that predict linearity are usually ineffective at predicting real-world effectiveness. The Genius of SPACE project investigates and operates at the societal and environmental interfaces in the Berg River catchment area. Development of a better understanding of these complex interfaces can allow for better implementation and research development. It can be argued that there is a strong relationship between transdisciplinary studies and the acknowledgement of complexity.

Before one can discuss complexity within systems, the definition of a system must be discussed. Typically a system has components, or actors, that are interconnected to serve a purpose or function (Cilliers 2008). While describing a system may be simple, classifying complexity can be difficult. A universal definition of complexity and systems thinking is still being developed (Chu et al. 2003). Cilliers and Chu et al. both argued that a universal definition of complexity and how to measure it is impossible because of the paradox of applying a reductive quality, such as universalism, on something that opposes pure reductionism (Chu et al. 2003 and Cilliers 2008). There are systems that are not complex. Systems may invariably appear complex, yet they do not meet the various criteria that Cilliers deemed necessary to make a system complex (Cilliers 2008), which include:

- heterogeneous components
- dynamic components

- rich and diverse interactions
- non-linear interactions
- mediation between elements
- abundance of feedback loops
- interaction between internal and external factors (open system)
- the system in a state of inequilibrium
- system has history
- subcomponents do not have all the information of the rest of the system and react locally
- the behaviour of the system is a relational and emergent property

Complexity and systems thinking has a strong relationship with transdisciplinarity because both are tools to critically evaluate and reveal shortcomings associated with modern science and thinking, or more specifically, Newtonian science and reductionism (Andonin et al. 2013). Studies using Newtonian science are based on classical mechanics, where the components are reduced to individual constants and are then observed (Heylighen et al. 2007). Newtonian science uses "distinction conservation", where there is precise distinction between the components, and they remain so over time. The conditions are absolute and objective, the results must be repeatable and the theories universal. In other words, the results obtained must be empirical, derived rationally and be verifiable through repetition (Morin 2007). This is known as the "scientific method", and ironically, the focus on determinism and universalism has also led to the ostracising of multi-disciplinarians and the formation of rigid professional disciplines that do not communicate or collaborate (Montuori 2013).

Systems within the Newtonian paradigm are "closed" and insular (Montuori 2013), and when the strict conditions of Newtonian science are applied to dynamic non-linear systems the limits of reductionism are revealed (Andonin et al. 2013). Analyses of systems under these conditions resulted in unrealistic and over-simplified models that are unable to accurately predict future trends or even accurately depict the system in study (Chu et al. 2003). Application of reductionism to social systems has led to borderline

social and natural disaster, despite the initial optimisms that Newtonian models provided for the socio-economic South (Swilling 2004). For example, modern reductionist models did not predict the world financial crash in 2008 (Montuori 2013), and worldwide issues such as global warming and social injustice have come from exploiting the earth's resources under the banner of industrialization (Swilling 2004). The world has thus become the object of willed action driven by our human component of "dualism"; the material world obeys mechanical law while the mind does not (Heylighen et al. 2007). There is a strong case for arguing that application of classical science to the world ignores ethics or values, and abuses our sacred relationship with nature (Swilling 2004).

One of the interesting additions that complexity brings to system studies is the more transparent relationship of the observer and the observed (Andonin et al. 2013). Cilliers argued (in Andonin et al. 2013) that the observer is blind to some of the knowledge of the observed, and that knowledge attained is interpretation and that meaning is accomplished through interaction. This part of complexity challenges how the modern mind analyses complex systems. Swilling (2004) explores how Snow in 1959 described economic and mechanistic models from the modern "North" and how it can save the impoverished "South". It failed due to a lack of integrative study of dynamic cultural and social components, as science has an institutionalised fear of intuition and feeling (Max-Neef 2005), which is particularly limiting when dealing with diverse and culture-rich societies. There was very little direct interaction, and applying complexity theory can show that to analyse a system as complex as African social structures, one needs to vibrantly interact with it to achieve meaning and understanding (Swilling 2004). One major omission of the "North" was the transparency of the inquirer and its integration with the inquiry or the observed (Montuori 2013). This led to exploitation and political tyranny in the name of rationality, tarnishing the ethical image of modern science (Swilling 2004). Max-Neef (2005) eloquently elaborates on this issue with regards to how post-modern science needs to look "beyond reason". Science needs to realise that "contemplative or inward looking" of the inquirer is not in opposition of rationality but complementary. It can be strongly argued that science has a communication problem, in understanding each other and relating to the lay audience (Max-Neef 2005).

The Genius of SPACE project aims to address the multiple challenges associated with service delivery in informal urban contexts, water treatment and ecological restoration. Clearly, these problems cannot be solved within the confines of a single discipline. Using Max-Neef's frameworks, transdisciplinary implementation requires taking the disciplines that exist, and working together to achieve what we are capable of doing, driven by what we want to do and controlled by what we should do (Max-Neef 2005). In other words, the goal is to conduct the research with actors united by a purpose, driven by normative and ethical values that control how the outcomes are achieved. The context then becomes crucial, as the system's environment, and who will benefit from the study need to be determined (Montuori 2013). Most importantly when studying human systems the powers, be it political or otherwise, of the situation have to be considered (Young 2008). Overall, a strong case can be made for the integration of transdisciplinarity, with complexity and systems thinking to develop innovative ways for dealing with current challenges and paving the way to transform such challenges into future opportunities.

2.4 Participation within Transdisicplinary Research

An understanding of complexity is crucial to performing transdisciplinary research. As mentioned in sections 2.2 and 2.3, the purpose of transdisciplinary research is to delve into life-world problems by utilising and integrating disciplinary paradigms. This is research conducted through scientifically framed activities with life-worldly references and partners beyond disciplinary boundaries (Wechsler 2014). Flyvbjerg (in Polk & Knotsson 2008) argues that the social sciences can become important in solving social and environmental issues when driven by ethics and values rather than just universal truths and relativism. In fact, the incorporation of social sciences is arguably a essential requirement; this section therefore explores the importance of the sources of research narratives and the requirement of representation and participation within ethical based research. It has to be asked what the role of the various stakeholders are, especially when the research is inclusive of non-scientific players (Wechsler 2014). This was a

particularly important consideration when the Genius of SPACE project was conceived, and it became clear that the participation of the various stakeholders are crucial to the project's short and long-term success.

Participation with non-academic stakeholders is driven by the need of more democratic inclusion between industry, science and community. While collaboration between industry, the scientific community and government is common, meaningful inclusion of non-scientific expertise is a rarity (Polk & Knotsson 2008), which let Hajer (2005) to state that traditional public participation methods do not work. Public policy informed by public participation has suffered from the implementation of orderly and modernistic philosophy. Modern public policy actors, and social scientists in general, often seek rational foundations when formulating public policy areas – relying on predictable, verifiable and repeatable outcomes. Such reliance of social science on 'orderly' natural sciences used as template with the goal of creating improved and stable orders of society has been met with little success in the developing context (Swilling 2004). These arenas of public participation tend to create antagonistic and competitive environments that result in poor public representation and insufficient information sharing. Similar to multidisciplinary research, traditional participation is generally an attempt to include a variety of actors into the decision making space to work out solutions for collective problems from their isolated positions (Young 2000).

As in the case of the natural sciences, the reasoning for reductionism is to address the issue of scale. A key component of participation is democracy and inclusion, in which scale is undeniably a variable that needs to be taken into account (Young 2000). The need for inclusion results from the demonstrated limitations of present and historical exclusion, and is emphasized by various factors such as marginalisation, oppression and inequality. Young (2000) points out that a response to exclusion is to form specific thematic social groups, such as gender, racial or religious groups in an attempted large-scale representation. However a criticism of this method is that there is an assumption that everyone belonging to a group has attributes that can be universally represented. Members in society have an ideological make-up and needs that span across groups,

exposing the limitations of group representation. Group representation also reduces members of a group to a common essence, resulting in further "othering" of social groups. Thus there is a paradox in representation; no single individual or organisation can represent a group due to the complex relationships among its members, however there is a call for the marginalised to represent and provide a voice for excluded issues, analysis or positions (Young 2008). In order to achieve quality public representation and information, the conditions in which participation takes place need to be challenged and analysed, as opposed to just the research arguments (Young 2000). These conditions include the physical, technical and theatrical staging of the participatory exchange can result in collaboration or protest.

Participation within transdisciplinary research is a novel concept used to address the weaknesses of applying conventional participation practices to local contexts. This form of collaboration undermines blanket knowledge claims, recognizing that knowledge is contestable and is based on perspective (Young 2000). In the South African context, transdisciplinary participation can be used to liberate privileged knowledge and power by drawing attention to the vast source of information and resources that the marginalised can provide (Young 2000 & Reed 2008). Reflexivity is the constant critical analysis of a research's constituents such as bias, progress, sensitivity and methodologies (Bryman et al. 2011). Reflexivity through greater participation can introduce feedback loops between the process and outcomes (Lilja & Bellon 2008); therefore involving the marginalised offers a wealth of unexploited know-how.

There are challenges for values-based research, as there can be the lack of clarity or agreement on which value rationalities are more important than others (Polk & Knotsson 2008). Also there is a question of who decides these rationalities. Is this done through populous democratic processes or through cross-scale, multi-level governance driven by stakeholders (Young 2000)? Transdisciplinary can be a tool to unveil value rationalities and reveal the powerful relationships within specific knowledge production (Polk & Knotsson 2008). Through participatory transdisciplinarity research, reciprocity and reflexivity between stakeholders driven by informal knowledge exchanges can allow

for the foundations of legitimate of socially accountable knowledge. It is important to note that traditional disciplined-oriented science is still very important to establish and legitimize transdisciplinary studies (Cilliers 2008). In response, transdisciplinary science can allow for reflection within the traditional science fields, a pause that allows for identifying the limitations and potential of the various fields of study. It must be incorporated with development and research by supporting participatory processes and contextualised knowledge production (Polk & Knotsson 2008).

Participation theories in transdisciplinary research are still in its infancy, and are often only present in the first phase of project planning when the problem is identified and structured, and in the final implementation phase (Wechsler 2014). Processes between planning and implementation tend to not have transdisciplinary participation due to resource and functions isolation as a result from having a variety of stakeholders from different locations. It may be important to differentiate between consulting and participation, where the life-worldly knowledge is given equal credit to the scientific knowledge in true participation. This relates to the concept of reflexivity to identify systemic boundaries in the research space. These boundaries are sources of motivation, power, knowledge and legitimation. They are also context specific and correlate to the social roles of the participant. Therefore it is important to have an analytical framework that defines:

- typology of actor roles (knowledge holders, researchers, involved citizens: concerned/responsible/competent participants, interested citizens, supporters, examiner and evaluators)
- research phases
- objectives and forms of actor integration
- types of knowledge (Enengel et al. in Wechsler 2014)

These frameworks are being challenged in the Genius of SPACE project, and will be analysed in the case study. A major area of study for this project is the non-academic stakeholder engagement and participation with a biomimetic-designed system

implemented in an informal South African context to provide crucial service delivery. It can be argued that the design must be in a form of socio-technological innovation to maintain project legacy and meaningful execution.

2.5 How is Modern Design Unsustainable and Unhealthy?

"Design" is defined by leading environmental architect, Sim Van Der Ryn, as ""the intentional shaping of matter, energy, and process to meet a perceived need or desire" (Van der Ryn & Cowan 2007). Modern design is argued to be unsustainable and based on reductionism that promotes resource transfers that deteriorate human and environmental health (Birkeland 2002). Van der Ryn supports the view that modern design is unsustainable when he states, "in many ways, the environmental crisis is a design crisis" (Van der Ryn & Cowan 2007). This idea can be taken a step further by stating that design is best described as open systems thinking (Birkeland 2012). Without going back too deeply into complex systems thinking, a system has components, or actors, that are interconnected to serve a purpose or function (Cilliers 2008). The described "openness" of design is due to the tangled strings of relationships between the various dimensions of design (Birkeland 2012). Thus design drives, and is derived by the relationships between societies, economies, ecology, and other resource flows. The definitions above provide the contextual basis for system design that we encounter on a daily basis.

Modern design is reductionist, and argued to be "shaped by the prevailing paradigm and value system of the societal and cultural context with which they emerge" (Cole 2012). It can be reasoned that this reductionist design paradigm and societal context stems from the fact that humans simply did not achieve the discipline required for good design before, as stated by Orr (1992). Modern design is typically optimised for cost reduction, profit and convenience due to the initial abundance of space and resources (Orr 1992; Van der Ryn & Cowan 2007). This follows the idea that design links with how the markets have behaved, namely that the 19th century was about production, the 20th about selling and consumption (Drew 2013). Birkeland approaches the argument of unsustainable design by suggesting that urban resource transfers deteriorate human and

environmental health, means of survival and food and water security (Birkeland 2002). She calls modern reductionist design “dumb design”, as it enforces these negative urban resource transfers, as well as being built on competitive values and a dependency on fossil fuel exploitation. Van der Ryn supports Birkeland by stating, “dumb design is wasteful of energy and resources” (Van der Ryn & Cowan 2007). The evidence of crises such as pollution, disease, social violence and economic waste show the effect of dumb design (Orr 1992). The author suggested three primary reasons for poor design, before phenomena such as global warming or the oil peak became widely recognized:

- Humans simply didn't have to master the discipline of good design.
- Design fails when greed, individualism and self-interest take over.
- Poor design stems from poorly equipped minds.

The first two points go hand in hand, as the world had an abundance of cheap space and resources. This allowed for economies to be built on competition, convenience and waste (Orr 1992). In other words, dumb design optimizes for reducing cost, maximizing profit or waste producing convenience while ignoring the consequences to the environment (Van der Ryn & Cowan 2007).

It is argued that good design can only come through the understanding of open systems and that the modern professional climate inhibits this understanding through its obsession with disciplines (Birkeland 2012). This has led to what Van der Ryn eloquently calls “the poverty of the industrial imagination…” (Van der Ryn & Cowan 2007), saying that the modern mind has reduced a complex landscape into templates of asphalt networks containing environmentally devastating infrastructure. Bergen et al. (2001) laments the limitations of professional disciplines as engineers are attempting to take on design projects without a solid understanding of ecological systems, while very few ecologists are trained to apply engineering designs into their research. These authors did not suggest that a union of ecology and engineering is enough, which is a view shared by Van der Ryn quoting Einstein (in Moffat 2007) that “the same thinking that produced the problem can never solve it”. Design must incorporate with the 21st century economy,

which must be about sharing, repairing, durability and upgrading (Drew 2013). And even before solving the complex environmental and economic interfaces, the interdisciplinary issue of assessing the environmental and social damages needs to be achieved (Olgyay & Herdt 2004). Van der Ryn elaborates by saying that solving sustainability issues is not an inter-discipline problem, but a meta-discipline one.

2.6 Ecological Design

Ecological design is a concept driven by the fact that current design and development practices are exceeding the resource capacities of earth (Birkeland 2012). The increased occurrence of environmental disasters and the growing scarcity of natural resources is starting to force humans to prioritise design that solve ecological issues to help deal with economic and social ones (Cole 2012). The problem is that traditional design is not designed to restore, regenerate or coexist with ecological systems (Olgyay & Herdt 2004). While there are numerous interpretations of ecological design, the main theme tends to be that human design needs to positively incorporate itself with the natural world (Van der Ryn & Cowan 2007). Areas of debate centre around questions on how to achieve these goals and how the implementations are to be done. It is alarming that even though Orr pointed out more than three decades ago that a sustainable future requires energy efficient designs that reduce greenhouse emissions, tap renewable energy resources and focus more on localised organic economies that promote recycling (Orr 1992), relatively little has been achieved in this regard. More recently, Van der Ryn and Cowan supported these concepts and add that eco-design will minimize natural capital loss through ecosystem conservation, regeneration and stewardship (Van der Ryn & Cowan 2007). It is clear that these ideals promoted by Orr (1992) will assist in promoting human competency over dependence, greater efficiency in resource use, stronger regional economies which all lead to social resilience.

In summary, ecological design is a relatively novel concept that incorporates interdisciplinarity and transdisciplinarity, and is subject to various interpretations and critiques – the latter including the stigmatisation of terms such as “green design” and

"sustainable design" (Birkeland 2012). However the intentions of ecological design as a practical and conceptual tool is aimed at reducing resource use and environmental damage while maintaining optimal function with hopes of adding societal benefits.

2.7 Biomimicry and its Applications

bi-o-mim-ic-ry: bios-life-mimesis-imitation (Benyus 1997).

The universal understanding of biomimicry is that it is seen as a tool for ecological design by using nature as a model, measure and mentor (Benyus 1997). The principles of biomimicry expressed by Benyus are based on the facts that nature:

- Runs on sunlight.
- Uses only the energy it needs.
- Fits form to function.
- Recycles everything.
- Rewards cooperation.
- Banks on diversity (and redundancy).
- Demands local expertise.
- Taps the power of limits.

The Biomimicry Guild (in Gamage & Hyde 2012) argues that nature helps us model by emulating natural forms, processes and ecosystems. Thus when analysing a human design challenge, a biomimetic approach is to understand and conceptualize how the natural world solves similar issues (Gamage & Hyde 2012). This is further emphasised by Benyus who argued that when innovation is inspired by nature rather than extracting from nature, the focus shifts to what we can learn from nature (Benyus 1997). She further pointed out that human inventions already appear in nature in more elegant and less energy intensive forms.

Three realms of design methods determine the engineered biomimicry perspective (Lakhtakia & Martin-Palma 2013). Bioinspiration reproduces ecological function but not

always the biological structure. Biomimetics is the replication of the functionality of a biological structure inspired by the essential features that defines the structure. It is argued that designers and engineers have not achieved the third design method, bioreplication, which is to directly replicate structures found in natural organisms in hopes of achieving one or more functionalities. These concepts require a forensic analysis of natural mechanisms to model the factors, constraints, relationships, synergies, antagonisms and sensitivities of various combinations of elements of a system (Vallero 2010). In order to achieve the study of these functions and apply them to societal systems, an understanding is required that goes beyond the realm of conventional disciplines.

The Genius of SPACE project uses design that mimics the functionality of natural wetland systems. The project identified that wetlands have important ecological principles that should be mimicked to achieve urban greywater treatment. These properties of wetlands, when they are not drained, render them extremely resilient due to the huge biodiversity when compared to other more vulnerable ecosystems (Folke et al. 2004). This resilience is built on the redundancy of functions that biodiversity provides. Process regulation within a wetland ecosystem is not the function of a single entity but a complex web of micro and macro-organism relationships. These relationships result in crucial eco-services provided by wetlands, which are typically the result of slow accumulation and release of water from their systems (Zedler & Kercher 2005). This mechanism allows for water purification and allows for the varied mix of nutrient and chemical cycles within the biodiverse wetland network. This complex of cyclical relationships performs critical functions such as denitrification and sulphate reduction (Odum & Barrett 2005).

Another attribute of wetlands is the high level of concentrated biological activity when compared to other land based ecosystems (Odum & Barrett 2005). This is due to the high rate of nutrient flow and an increased contact time between aqueous and terrestrial elements. Organic matter is broken down aerobically and anaerobically into simple building blocks by decomposition through denitrification, sulphate reducers and

methane producers. These processes release gases into the atmosphere and nutrients such as phosphorus into the soil. The marsh plants use these breakdown products to sustain growth and have their own nutrient cycles. Eventually larger species such as amphibians and fish will be able to flourish which then concurrently leads to predatory bird species appearing. The types of plants and animals are unique to the locale of the wetland and the species make-up will be defined by the system inputs (Zedler & Kercher 2005). Thus design based on wetland functionality and structure can help manage issues such as phosphorus overloads, human residential or industrial waste, sediment erosion, enhance flood control, and thus promote ecological restoration. These are all issues that need to be addressed in Langrug and the Berg River catchment area. Additionally, the eco-services that are included in biomimicry design can provide local economic opportunities if the local communities engage with the design in order to ensure that it would allow for activities relevant to the needs and culture of the community, which is further discussed in 2.8.2.

2.8 The Realtionship Between Transdisicplinarity and Biomimicry

2.8.1 Does Biomimicry Transcend Disciplines?

There are some valid critiques of ecological design and the various methodologies, such as biomimicry. It has been strongly criticised for not allowing for the evolution of designs with net positive benefits for society and nature; instead it is rather being perceived as an attempt to restore local ecology and reduce society's impact to an acceptable standard (Birkeland 2012). As often is the case with novel terminologies, "ecological design" is in danger of becoming another short-lived buzzword in the space of "sustainable", "green" or "resilience" development (Cole 2012). For example a "green building" is to have less of a negative impact on the environment than a conventional building. The key attributes to a "green building", which can also be applied to any structure, is described by Cole as follows:

- Reduces damage to natural or sensitive sites

- Reduces the need for new infrastructure
- Reduces the impacts on natural features and site ecology during construction
- Reduces the potential environmental damage from emissions and outflows
- Reduces the contributions to global environmental damage
- Reduces resource use – energy, water, materials
- Minimizes the discomfort of building occupants
- Minimizes harmful substances and irritants within building interiors

These, admittedly appealing, attributes link strongly to the conservation and stewardship concepts described by Van der Ryn and Cowan in 1996. “Green design” or “sustainable design” is seen to meet human needs without compromising natural systems (Olgyay & Herdt 2004). However, it can be argued that the social and ecological interfaces are so degraded that it is too late to implement conservation and sustainable methodologies to design. Therefore critics would rather see a move into a concept such as “regenerative design”, where sustainability serves as a transitional phase between “green design” and “regenerative design” (Cole 2012). Regenerative design promotes a co-evolutionary relationship between humans and nature that builds both capitals instead of a management relationship. Van der Ryn and Cowan (2007) proposed the incorporation of regeneration into ecological design, as the restoration of highly degraded ecosystems will increase natural capital (Van der Ryn & Cowan 2007).

The main issue with such criticism, and with mainstream literature regarding the philosophy of ecological design, is that the contexts under which these theories are developed are very North-centric. Within the developmental urban context, as found in informal settlements in South Africa, one cannot simply focus on societies reintegration with nature. There is the added need for integrating marginalised with privileged society in a fair and sustainable way. Thus instead of asking “Does biomimicry transcend disciplines?”, one should ask can a tool like biomimicry be used in a complex and dynamic context like those found in informal urban developments?

Within the sustainability perspective, where ecology, human health and economy are seen as crucial interlinked components of a greater system (Goebel et al. 2010), biomimicry can be used as a concept and design tool. Biomimicry uses nature as a design template ultimately to reduce inputs into a system, and builds upon system synergies and cooperation. Thus biomimetic design requires several technical disciplines such as engineering, ecology and urban planning. It is interdisciplinary because the outcomes and emergent properties of the implemented design cannot be analysed separately by different disciplines (Benyus 1997). However, biomimicry is being used as a design tool in the South African urban context, and is being implemented to provide essential services to informal dwellings and marginalised citizens to address the inequality, inequity and poverty found in South African society. Since the design demands complex system understanding, it requires participation from the communities found in these urban contexts to understand the day-to-day issues that outside stakeholders simply cannot make any sound judgment on without making erroneous assumptions (Goebel et al. 2010). Thus it can be argued that applying the principles of biomimicry in design within informal urban and environmental interfaces will automatically require the design to transcend academic disciplines as well as social sphere in order to achieve short- and long-term success.

2.8.2 Transdisicpliary Stakeholder Participation with Biomimetic Design Implementation

As mentioned in chapter 2.7, biomimicry is argued to be interdisciplinary by nature (Benyus 1997), as it encourages the collaboration between designers, engineers and natural scientists. Ecological design is to use ecosystems as a template and requires multidisciplinary collaborations to achieve a functional transition to a sustainable future (Van der Ryn & Cowan 2007). While the design of research may be an inter- or multi-disciplinary endeavour, it can be argued that the implementation and analysis of these systems require a transdisciplinary approach. This is due to the integration of environmental, societal and economic components (in addition to the conventional collaboration between designers, engineers and natural scientists) studied within the

framework of the relationships of biotic and abiotic components within an ecosystem (Gamage & Hyde 2012). The result is a framework that facilitates the breaking down and careful analysis of the needs and requirements from the various stakeholders, and subsequent incorporation of the various knowledge sources with regards to the challenges, design and desired outcomes.

Clearly, ecological design holds notable promise as a tool to facilitate successful integration of different disciplines and interest groups. Yet it is also recognized that that social and natural systems are complex (Vallero 2010), as exemplified by the description of the barriers to change in the social context by Lawrence (2010):

- Conceptual barriers formed by analogies, metaphors and models that express rationality by reduction without incorporating the complexity of social and natural environments.
- Institutional barriers such as specialization and bureaucratic nature of expertise and knowledge.
- Social barriers such as access to knowledge and privatization of information and resources.
- Historical marginalisation and inequality.

These barriers inhibit the understanding of ecological and social integration while also reducing the ability for research to be conducted that conceptualises the complexities of society and ecosystems (Gamage & Hyde 2012). These barriers need to be challenged in any research project or intervention, thus analysing and including various stakeholders is crucial for project success.

Like many developing states, South Africa needs to manage a balance in environmental preservation and socio-economic progress (Makina & Luthuli 2014). Any development design and implementation in this context needs to be assessed within the realms of financial feasibility and viability. It is then in the best interest of design to allow for space for corporate citizenship and entrepreneurship, while also reaping the

benefits of ecological preservation and restoration. Biomimicry-inspired approaches acknowledge natural control systems, and that natural processes yield a variety of useful by-products resulting from a diverse array of feedback loops that provide valuable cues to address contemporary challenges as diverse as pollution control, energy generation and supply chain management. Imbedding these properties within a design can therefore provide for localised financial stimulus. In the Genius of SPACE context, the intervention is taking place within the Langrug community and hopes to provide business and employment opportunities. Successful implementation within Langrug will reduce the stresses on the local ecology, allowing for restoration within the Berg River catchment area, reducing the costs for the municipality and industries to clean the water for irrigation use. It is important to emphasize here that ultimately the success of any intervention in this, and similar communities will largely be dependent on meaningful engagement from localised and marginalised participants.

It has been argued that dealing with barriers to successful interventions go beyond the respective capabilities of governments and NGO workers (Goebel et al. 2010), a view supported by Zoomers (2005) who stated that it is now widely accepted that isolated projects are not sustainable unless they are embedded in a supportive macro-economic governance structure (Zoomers 2005). If not in a supportive environment, development resources are generally mismanaged due to lack of local ownership and the local capacity being overloaded and unable to coordinate intervention. There is also the issue of one-way information flow, as the external intervention groups typically do not have the knowhow in sourcing local information pools. Transformation within an informal urbanised space requires existing power relations and structures to be challenged, as it is unlikely that the motives and problem perspectives will be shared among the actors within, for example, a local South African municipality.

It becomes crucial then to acknowledge the power that the informal community has on intervention success and include them in the process (Goebel et al. 2010). There has been a history of intervention failure in developing contexts, as projects rarely attend to the needs and wants of those marginalised. This is also partly true in the Langrug

context, since the Genius of SPACE project is ultimately about treating and restoring water quality. It is thus clear that, for the project to be a success, it must incorporate the concerns of the local community including clear articulation that with restoring water quality also come better health, and ideally employment opportunities. Thus the Genius of SPACE project must reach out within these communities to gather quality information to ensure that the legacy of the project will extend beyond water quality as simply an analytical parameter. Asking relatively simple questions, such as those described by Wechsler (2014) to guide localised transdisciplinary projects will go a long way to achieve this goal:

- why participation?
- how much participation?
- what should participation be about?
- who to involve?
- what forms and methods to look for?

In essence, these questions seek to clarify why participation is important, who to include, and what the motives are for their inclusion. Focussing on the 'who to involve' question, the value of a transdisciplinarity approach that acknowledges system complexity and the value of non-academic stakeholders becomes evident for defining participation roles. As example, even a relatively small project will involve:

- knowledge holders (integration of private, public, specialised and contextual knowledge)
- researchers
- involved citizens: concerned (affected) and responsible (potential cause of problems) participants
- interested citizens
- supporters (facilitators and data collectors)
- examiner and evaluators

It is clear that finding effective communication between the various groups becomes essential, as perspectives will differ and viewpoints or frames of reference of one group may be difficult to relate too by another. The process undoubtedly needs facilitators to organise and provide a positive and comfortable space for information gathering, debate and education. Facilitators must provide the ability to manage power, communication and clarity during meetings between stakeholders of various societal and technical backgrounds (Reed 2008). Their goal is to reduce the knowledge gaps between the various stakeholders, and to provide a participatory environment that emphasises empowerment, equity, trust and learning by ensuring participants that their inputs are valued and equally important. Most importantly, though, is that the facilitators managing the power inequalities in a group, be it education, age, race, creed or gender. Thus facilitators manage the process leading to the project outcome, and are responsible for reflexivity and communication between the various stakeholders. The continual evaluation of the process requires the questions (Lilja & Bellon 2008):

- How were the stakeholders selected?
- At what stage of the research did stakeholders participate?
- What types of participatory tools were used?

The hope is that this streamlines the intervention process while adding value to the quality of the decision-making. As argued before, true transdisciplinary participation does not just practice consultation with a particular stakeholder (Weschler 2014), as context specific information and perspectives should be treasured and not be discarded for the purpose of universalism (Young 2000). These contexts are dynamic, non-linear and in a state of inequilibrium and require near constant reflection and good communication (Leavy 2011). It is, and should therefore be an overarching goal that these considerations drive the research methodology and research design within the Genius of SPACE Project.

2.9 Conclusions of Literature Review

The complexity found within Southern African developmental landscape challenges the status quo of classic economic development by pitting rationality against resilience and adaptability (Polk & Knutsson 2008). Social sciences have long critiqued the application of rational sciences on social development, arguing that focusing on specific rationalities leads to short-term gains at the expense of sustainable development. It could be asked whether dominant political and economical rationalities are compatible with the sustainable integration of complex social and ecological systems.

Knowledge production outside the traditional university boundaries promotes context specific research, reflexivity, accountability and novel forms of quality control. Merging various disciplines and incorporating non-academic stakeholders such as the Langrug community to determine values will promote this form of knowledge generation. This will help address the most pressing point, where development research in the Southern African context should be scrutinised for their applicability for short- and long-term goals in uplifting poverty, equality and social justice.

Transdisciplinary knowledge production can assist the designs within the developmental context. The diverse knowledge accumulated allows the design to tackle problems at various scales, perspectives and contexts. Biomimicry provides a design concept that reduces energy inputs, demands the incorporation of local expertise and rewards system cooperation. Thus, the biomimetic design in the developmental context requires the transdisciplinary paradigm to achieve its goals of societal development and improving ecosystem health.

Traditional discipline-oriented science still has its place, and indeed provides a foundation to establish and legitimize transdisciplinary studies. Similarly, the concept of biomimicry can be strengthened when tested by the norms of traditional research. It can also be strengthened conceptually when applying transdisciplinary research designs by allowing reflection within the traditional science fields. This helps with identifying the limitations and the seeds for potential growth within the various academic stakeholders.

Finally, biomimicry will greatly benefit by supporting participatory processes and contextualised knowledge production.

The Genius of SPACE project implements design based on biomimicry within a complex socio-environmental context. There is compelling evidence that a traditional approach will not address the needs of the various stakeholders, and is not positioned to address the societal need for equality and social justice. Therefore the project implements a transdisciplinary approach to formulate research questions and provides the narrative for the design. This methodology and research design requires the input of non-academic stakeholders, who in this case is the Langrug community. They can provide important, contextualised information that strengthens the design by adding system resilience and adaptability. The process of attaining this information, and including the community in the design process requires an arena for open, fair and transparent dialogue. This process challenges the societal barriers within South Africa brought upon from historical injustices and prevailing inequality.

Chapter 3 – Analysing the Genius of SPACE Project through the Lens of Transdisicplinarity within the Langrug Context

3.1 Introduction

3.1.1 The Langrug Informal Settlement

The informal township of Langrug is located outside the town of Franschhoek, in the Western Cape province in South Africa. Its jurisdiction falls under the Stellenbosch municipality. The systemic boundaries present at Langrug informal settlement are not unique in the South African context, and the various motivations for this project are complex and diverse. In essence, municipalities are required by law to manage their water systems to ensure safe conditions for human health and agriculture. Water from the Berg River is used extensively to irrigate vineyards and other agricultural produce, with about 65% of the near 300 km of catchment area being under irrigation (Winter et al 2008). Together with tourism, exports from agriculture make a significant contribution to the region's economy, and it's protection is thus important. The financial considerations have to be balanced with another common issue facing South African municipalities, namely service delivery for informal settlements. Typically, the challenge is exacerbated by the inability of municipal infrastructures to cope with South Africa's rapid urbanisation. Arguably, the management of greywater in these settlements may be considered of lower priority, leaving an opening, or even need for other organisations, be it government funded (e.g. Water Research Commission), NGOs or private companies to assist with service delivery as long as it fits in their budgets and urban planning agendas (Winter et al. 2008). Government may potentially favourably view the incorporation of these projects as structural and service development provides work and the potential for entrepreneurship.

A strong motivation for the Langrug community to support intervention is the structural improvement around their homes and reducing the health risks associated with untreated greywater. A criticism of past projects in Langrug was that there was a lack of understanding community motivations, as the primary concerns for the locals was work

availability and land ownership, and not specifically greywater treatment. To date, this project has provided some temporary and permanent employment, and it can be argued that the formalisation of service delivery could be the first step to incrementally providing land ownership to a community that is built on municipal land (Winter et al. 2008).

In most developmental contexts, the degree of influence is determined by financial strength and availability of money. It is redundant, yet important to state that due to prevailing inequity and inequality in South Africa, those with the most unmet needs usually have the least financial security. There is a legitimate that, in the post-1994 democratic South Africa, those with financial means must help to close the inequity divide. Because of its economic significance, the agriculture sector has a strong influence on development and allocation of resources in the Berg River catchment area, and by extension the management of water resources by municipalities. Such management cannot be done in isolation of the various role players, and the municipality readily accepts outside support to manage these systems. The Western Cape Government opened a tender process for private companies and research institutions for assistance; a strong rationale being their technical know-how, and more generally, the need for research and development in the South African context. However, it is clear that such initiatives need to be approached with due consideration of the community - the Langrug community is no exception, having the power to disrupt intervention if they would perceive that they are inadequately informed, involved or respected. This power, derived from the democratic process, is what drove the current project to apply participatory transdisciplinary methodologies in its implementation to ensure that the various power sources are interrelated with knowledge and legitimacy.

3.1.2 Socio-Ecological Dynamics of Langrug

The population of Langrug is between 4000-5000, which is mapped in Figure 1(in Appendix A), with nearly 2000 shacks that are bordered by low-income housing and a school field (Winter et al. 2008 & Greenhouse 2013). It is estimated that 89% of the population within the informal settlement are isiXhosa speakers who recently migrated

from outside the Western Cape. All the municipal water services within the informal settlement are communal (Winter et al. 2008). Municipal ablution provides services to roughly 50 residents per toilet and 85 residents per tap (Greenhouse 2013).

While the water used for the toilets drain into the municipal sewage system, households gather water from the municipal tap for household use and often dispose the used water into existing greywater gutters and ad hoc greywater sewers (Greenhouse 2013). While gutters are easy to build and maintain, solid and liquid waste combine in these systems to produce stagnant conditions ideal for pathogen propagation (refer to Figure 2 in Appendix). The gutters also cannot separate stormwater and greywater, thus rainfall distributes the contaminated water throughout the community and into the river untreated.

Due to these issues and the high risk of human contact with water in existing gutters, ad hoc sewer systems were installed in Langrug between 2006 and 2007. These systems screen greywater and separate solid waste at centralised collection points to reduce human contact and greywater odour (refer to Figure 3 in Appendix A). While the ad hoc sewer systems provided some initial promise, several technical and social issues arose. From a technical perspective, it is undeniable the poor solid waste removal services within Langrug provide challenges for water management. The ad hoc sewers are prone to clogging and not easily cleaned. Another major limitation is that these sewers are, for the most part, not connected to municipal sewers and thus discharge further down the hill, often flowing onto streets. However the largest restrictions for these systems come from a lack of community maintenance and administrative buy-in.

Langrug has experienced more than a decade of interventions from NGOs, the Western Cape Government and research organisations (Winter et al. 2008). A common issue in the past was the clear misrepresentation and distrust between the community and the elected officials, such as the local ward counsellors, with accusations that ward counsellors seemed more interested in self-preservation and exercising political power than serving their communities. Researchers and NGOs have been accused in the past of

"stirring up" the community up against the elected officials (Winter et al. 2008). This atmosphere of distrust has led to breakdown of communication between the residents and their elected officials and has made genuine community representation a challenge. As local authorities generally did not monitor the water treatment systems installed in the settlement, residents did not report these issues to local officials due to the distrust, thus leaving the systems in a state of disarray.

In conclusion, the situation in Langrug is complex. Despite the continual failing of the local authorities to deliver essential services, the Langrug community still expects the municipality to provide these services (Winter et al. 2008). While many may ask why the community does not solve their own problems, it requires an understanding of the context from both historical and contemporary perspective – in a historical sense, the dependence on government services coupled with political and ideological rhetoric for government-initiated empowerment can lead to apathy due to poor executions of these projects and services (Winter et al. 2008). In contrast, poverty remains the largest issue at the individual level, as the key priorities for households in Langrug are nourishment, clothing and shelter. While these needs exist, it will remain a challenge for the community to meaningfully engage in issues regarding water quality and garbage disposal.

3.1.3 Timeline of the Genius of SPACE Project

In 2013, the Western Cape Government contracted BiomimicrySA (http://biomimicrysa.co.za) to design a bioremediation design for the informal settlement Langrug. Throughout 2014, BiomimicrySA, with the help of facilitators and local groups within Langrug, identified various stakeholders to participate in the project. BiomimicrySA organised design workshops, which allowed for a space for education and innovation for all in attendance, using biomimicry as the design philosophy. The purposes of these workshops were to:

- Identify effected communities and increase community awareness of the project.

- Map social actors and their relationship to the problem in order to establish relevant meetings and workshop schedules.
- Identify local material flow patterns.
- Understand available bioremediation technologies while integrating local community knowledge.
- Generate design proposal using biomimicry methodologies with input from the various stakeholders.
- Finalise the design proposal and submit to government as a tender.

The proposed design was to implement Eco-Machines as designed by John Todd Ecological design (Greenhouse 2013). An Eco-Machine is a collection of connected cells in which water passes through. These cells are essentially contained ecosystems that mimic the filtering functionality of wetlands (See Figure 4 in Appendix for visuals of a Eco-Machine). It was proposed that the Eco-Machine matrix should be located at the bottom of the hill by the local sports field, and fed by drainage systems (See Figure 1 in Appendix A). The drainage systems were to collect greywater in modified ad hoc sewers, connected to pipes that pass through "tree gardens" to aid in treatment (See Figures 3,5 in Appendix A). Stormwater was to be controlled by building walkways with trenches that direct flow. Isidima Design and Development would oversee construction (http://www.isidima.net/about2) and primarily employ residents from within the Langrug community for the construction phase and maintenance. The title of this project became "the Genius of SPACE", where "SPACE" is an acronym for "Systems for Peoples Access to a Clean Environment".

Once the proposal was submitted, it took half a year for the tender to be approved. The amount of funds designated to tender was reduced over the year, which forced the GoS project to smaller design and more localised treatment. Ultimately due to the cuts in budget, the Eco-Machine matrix could not be built as planned in the first half of 2016. Therefore, in 2016, the GoS project focused on building greywater disposal points that separate solid and liquid waste and are easy to clean (Figure 3 in Appendix). These disposal points are connected to underground pipes that transport the greywater to tree

gardens that assist with treating the greywater. Concrete and grass walkways were also built that channel and control stormwater flows. Currently the project employs 15 full-time workers, 11 of which are local Langrug residents. During construction phases, there are short-term contracts available.

The next steps for the GoS is to extend their existing systems throughout Langrug as there has been enthusiasm for the aesthetic appeal for the infrastructure upgrades, better lighting and green space. GoS aims to extend their services to solid waste removal and treatment. The ambitions to eventually construct the Eco-Machines remain, however the original space for the design has been built over by new shacks. The Western Cape government and a local school have agreed that the Northwest corner of their sports field would be a good place to place the Eco-Machines, as some of Langrug's untreated stormwater and greywater flow onto the field (See Figures 1,8 in Appendix).

3.2 Research Aims within the Genius of SPACE Project

The purpose of this research was to observe participatory transdisciplinary implementation in a South African informal urban context, with emphasis on the potential of biomimic design in the implementation of processes to enhance living standard through the improvement of water quality. Exposing weaknesses in methodologies allows for identifying crucial knowledge gaps to reduce the time of implementation and to provide realistic expectations to those effected by the project. The Langrug community has seen many projects come and go, with various degrees of initial success, with the gradual erosion of neglect inevitably taking place as funding and interest wanes. A fits-all solution to informal urban development in South Africa does not exist. There are many layers of complexity in these systems and thus requires human ingenuity and adaptability to cope with context specific problems, at least to a manageable degree. The ingenuity and adaptability in informal communities is an untapped resource for knowledge coproduction, which has not been sufficiently utilized in the past. This oversight may be directly linked to many failed efforts to reconcile human needs with available resources, emphasizing the need to design solutions with due consideration of area-specific realities. In ecology, a system is deemed resilient when

there is a significant amount of functional redundancy, which points to the danger in designing universal solutions to different problems, each with unique sets of characteristics and challenges. Similarly, reference is made in engineering of duplication of critical components to provide layers of protection against failure. Each system, including human settlements, has unique critical components, and the huge diversity of factors that impact on human settlements suggests that it would be foolhardy to aim for universalism.

It is important to explore how initiatives such as the Genius of SPACE project in Langrug can make valuable contributions to sustainable development. As Southern Africa develops, there has to be economic and social development without compromising environmental preservation. It is argued that ecological preservation can provide economic opportunities such as biodegradation of pollution, various forms of alternative energy, ecological designed industry and supply chain management (Makina & Luthuli 2014). The aim should be to achieve community engagement in these enterprises as viable economic opportunities and not just as a social service.

3.3 Research Design and Methods

A brief description of the research phases in the broader Langrug project is presented here to contextualize the methodology in the current case study: The first steps of the project included identifying the sources and extent of pollution in the Berg River system. Determining the appropriate responses to the problems showed a level of understanding how to approach complex problems, as there was an attempt to find strategies to please as many interests as possible. This is particularly true for the decision to implement Eco-Machines, as it was seen as a way to provide affordable at-source treatment of greywater, providing service delivery to an informal settlement and benefiting ecosystem health whilst protecting downstream agricultural interests. The next step was to consult with the Langrug community with regards to technical and social details required for the implementation of the Genius of SPACE project. Community input was encouraged, particularly with the implementation phase and when outlining

employment structures. Long-term planning was also addressed, as there were questions of maintenance, ongoing employment opportunities and project legacy. Throughout the project there has been a focus on reflexive critical thinking when engaging with the Langrug community; the process primarily being facilitated by NGOs. The current case study has been an attempt of objectively observing these processes, to determine how successful participatory transdisciplinary methodologies have been incorporated in the project, and to identify lessons learned for possible application to other communities in southern Africa. As such, the overall principle of this study was based on observing transdisciplinary methodologies.

Montouri 2005 (in Preiser & Cilliers 2010) defines transdisciplinary research as an inquiry-driven and meta-paradigmatic approach informed by rigorous creative, contextualised and connective thinking. The goal is to achieve innovative, flexible and participatory design strategies (Leavy 2011), that creates a "conceptual tool to think together" (Morin 2008 in Cilliers & Preiser 2010). In line with the goal of this project to incorporate the local society, the different perspectives of the various stakeholders were crucial for the implementation of biomimicry design, and especially for defining performance indicators as described by Brent & Rogers 2010. An effort was made to allow for the methodology to evolve in response to on-going communication and reflections, as described by Leavy 2011. Overall, this approach was selected as an effort to contribute to the formulation of integrated solutions to the problems as defined through consultation with the diverse perspectives of the stakeholders.

In line with the Genius of SPACE project's transdisciplinary perspective, the current study used a mixed methods approach, in which both quantitative and qualitative research methods are applied (Bryman et al. 2011). This approach was specifically selected to exploit two of the three pillars of a mixed methods approach, namely triangulation and complementarity. In the case of triangulation, the findings of quantitative and qualitative research methods substantiate each other, while the different hierarchal levels of a project can be explored with complementarity. This also applied to the objective observer, who analysed the implementation of these methods within the

project. The third mixed methods approach, facilitation, is used when a research strategy is used to aid data collection or to help hypothesis formation for another research strategy. This process was not intentionally used in this project, as there was a clear research question with distinct research methods.

As indicated, it was anticipated that the John Todd designed Eco-Machines would be implemented during this study, but for various reasons the installation was delayed, and a greater focus was instead dedicated to greywater disposal points and other biomimicry-inspired systems as an interim measure (Figure 3 in Appendix). In addition, an off-site work-scale Eco-Machine in Stellenbosch was tested for quantitative analysis. This Eco-Machine was fed by the Eerste River downstream the informal settlement of Enkanini. Preliminary data from this site was used to determine the general effectiveness of these designs. Quantitative data used in the current study to evaluate the performance of these systems were obtained from water quality analyses that were outsourced to a local private laboratory. Periodic sampling of the treated water was done to test for pathogens such as *E. coli* and other indicators of poor water quality. There was an attempt to sample from designated sampling points within Langrug, however due to the typical dynamics found in informal settings that often include unplanned developments and building of temporary dwellings, re-direction of water flow channels and volumes available for sampling occasionally necessitates changes in sampling sites.

The qualitative aspect of this research design was to determine the societal effects due to the implementation of the biomimicry designed technical innovations. This was conducted in a sense-making procedure, where a hypothesis is formed during the research (Bryman et al. 2011), as a pre-study hypothesis would risk over-simplification of the responses and outcomes extracted from complex social systems. To provide a basis to work from, the initial methods included interviews with the various stakeholders to determine why the project was initiated in the first place. The Langrug community meetings, Biomimicry design workshops and other stakeholder engagements were observed to generate primary data and to determine any trends of the societal effects or needs for the different stakeholders. Interviews were conducted when possible, and since

the subject of the research involves a complex socio-technical implementation, special effort was made to maintain objectivity by performing the research in a way similar to that of investigative journalism. This means that, as the observer, questions were framed only for fact seeking and perspective, and to avoid influencing the participants. The motive behind this research philosophy is that it is impossible to remain objective if one has a rooted interest in the success of a project. As complexity studies show, it is difficult to quantify and generalise societal behaviour and perspective. Therefore a clear conscience effort had to be made by the observer that any project result is data, and that interpretations of that result could be analysed in retrospect. Of equal importance was to ensure that the various perspectives of the stakeholders are viewed equally. Thus the arena of stakeholder participation was analysed, providing an opportunity to identify weak representation and unequal application of power. The obtained background informed the formulation of questions for the local residents and other stakeholders, and served as constant reminder to acknowledge the complexity of social systems, which necessitate reflective research from the various academic and non-academic groups. Figure 6 in the Appendix shows a schematic representation of the stakeholder analysis, with and the level of emersion suitable to yield representative data to also contextualize quantitative data obtained in the broader scheme of GoS.

3.4 Results and Discussion

The Genius of SPACE team analysed the rationale of the stakeholders by describing the relationship to the greywater issue. This has been researched before in Langrug by Winter et al. (2008), identifying that the water issues do not have the same priority as the challenges related to employment and land ownership. Nevertheless, it was deemed of sufficient importance to the community's well-being, as well as the region to launch a concerted effort aimed at mitigating the negative consequences of uncontrolled greywater flow through the community. The project team recognized the critical importance of the involvement and empowerment of key stakeholders and representatives in any attempt to legitimise decision-making. Identification of key stakeholders

connected to, and rooted in Langrug therefore became an objective already during the early stages of the project.

To achieve this, focus groups were formed using resources of existing NGOs and community groups, allowing space for interviews and snowball sampling, a technique where known sources can refer the outside stakeholders to other potentially important community members (Bryam et al. 2011). The following step was to categorise the stakeholders. Transdisciplinary studies have to categorise stakeholders by their knowledge types and relationships to the problem questions and the GoS was no difference, categorising stakeholders in an attempt to target specific actors for appropriate roles in the project. It was initially thought that questionnaires were to be used in this study in an attempt to quantify community trends and engagements with the project using Q methodology or interest-influenced matrices. However it became clear that this method would not gather sufficiently meaningful representation, as community engagement and trends in Langrug are dynamic and non-linear, and completely different to stakeholders outside the Langrug context. Questions that have binary answers, such as employment, have previously been well studied in Langrug and used to describe the Langrug context in this paper. Thus, after considering the potential value of repeating previous efforts – even with modification, it was concluded that there was a notable risk of not revealing new quantifiable data, particularly in a context with historical social inequality, and in view of working with a population group jaded with problems that were extensively studied in the past with little evidence of concrete solutions resulting from these efforts (Winter et al. 2008 & Young 2000). It was observed that formal methods of qualitative data collection do not translate well in the informal Langrug context. Investigative methods such as informal interviews and meeting sit-ins proved to invoke more genuine responses to the issues regarding the project. All actors were aware of my purpose as an observer, and generally seemed to appreciate that I did not represent any group in particular. In fact, these more informal methods allowed for the links between actors to be revealed and investigated. The process of data collection is illustrated in Figure 7 in Appendix.

3.4.1 The Initial Implementation of the Genius of Space Project

An interesting aspect of this research as an observant of the participatory process is analysing and challenging the conditions under which the meetings took place. It was important to note that all the meetings occurred in or near Langrug to maximise community involvement. It was interesting to note the variety of locales, from the formal Franschhoek Town Hall, the Rickety Bridge winery and finally Batho's Place, an African restaurant in Langrug itself where most of the community driven meetings took place (See Figure 9 in Appendix). The facilitator groups The Community Organisation Resource Centre (CORC; http://sasdialliance.org.za/about/corc/) and in/formal South (www.informalsouth.co.za) provided a forum style setting for the meetings. CORC also provided Xhosa translators, to assist communication. A problem encountered was that there were no Afrikaans translators, and a minority of the Langrug community prefer conversing in Afrikaans. Special effort was made to ensure that the purpose of the meetings was to enhance collaboration with the Langrug community. This was communicated to the forum from the start to avoid distrust and to make clear that there were no hidden motives amongst the contractors and the facilitators.

A common concern among participants in the Langrug community meetings was the question of representation, with community members often showing distrust to those who claimed to represent the community, especially those who live in different wards. Political affiliations also determined representation, which caused more divisions. A critique of the process is the time-consuming nature of the meetings, often resulting in participants losing interest in following up or attending subsequent meetings. An example of this was when it was stated that a meeting would not discuss employment structure or wages some members, particularly young men, did not attend the meeting. When asked to why this was, it was stated that they would rather look for other work in the meantime, and would revert back to the liaison officer for employment during the implementation phase. In an attempt to avoid these sorts of issues, facilitators made an attempt to frame meeting agendas in a way to target specific groups of the community so that participants did not feel like they were wasting their time.

As indicated, a challenge in transdisciplinary participation through community involvement is finding the balance of true participation and consultation. However an emergent property of giving implementation and participatory power to the community is that the community itself is a complex web of relationships and context specific issues. This can, and has created competitive and antagonistic environments. As stated in Winter et al. (2008), the main community need in Langrug centres around employment opportunities and land ownership. When the questions of employment and land use arose, it was observed that internal community competition was present. Thus, the democratic process was used to determine leadership positions within the community relating to this project. Obviously there are complications and inefficiencies with this process but the community agreed that this was the most appropriate method of determining leadership.

3.4.2 Stakeholders and Representation in Langrug

A challenge in informal settlements is the question of representation, which is a very political and competitive part of South African life. The issues observed are typically linked to the prevailing poverty and dynamic political conditions that prevail in South African urban slums. It can be argued that addressing these issues in the planning of technological or structural interventions is key to achieve meaningful community engagement and interest. This further supports the point that appropriate representation is crucial to meaningful information exchange with stakeholders. Three stakeholder meetings with strong linkage or relevance to the challenges described above were selected, and will be presented here to illustrate the stakeholder participation process of the Genius of SPACE project in Langrug. An effort was made throughout to ensure that the participation process is analysed objectively, observing the actors play out their roles, without becoming an active participant in the project.

The purpose of the first observed meeting at Banthu's Place in Langrug was to identify stakeholders in Langrug and determine appropriate representation. Facilitators

and NGOs were used to facilitate engagement between the community, and local and provincial government and contractors. The facilitators were particularly useful because they had already established contacts within Langrug and also provided crucial translation services. The facilitators mapped out the various groups present, and the participants distinguished between those outside and within the Langrug context to get an understanding of who the various actors are, and what their relationship with the problem is (See Figure 10 in Appendix). As with most of these types of sessions, particularly with a group of stakeholders with diverse backgrounds, a summary of the project had to be given. The stakeholders were told the project addresses greywater treatment in Langrug, and the facilitators opened up dialogue between the community and the designers to briefly converse about the technical and financial details of the design. It was stated to the community that the Provincial Government had approved the GoS project with two and a half years of funding support for restoring the Berg River using the principles of biomimicry. Some members within the Langrug community had attended prior biomimicry design workshops, and could engage in the discussion regarding the GoS designs and how it can fit within their built structures and systems.

With the stakeholders identified and the project purpose communicated, the question of representation had to be addressed. It was explained to the community that a Langrug GoS task team needed to be formed. This team was tasked with identifying relevant “block” committees who would be affected by the GoS project. It is important to note that Langrug is divided into “wards” that are then further broken down into “blocks”, which is a typical representation of how informal settlements in South Africa are organised and mapped. The blocks are represented through committees, and negotiation of land structure, use and ownership is done through these representatives. The GoS task team also needed to identify a construction team and related employment application process from within the Langrug community. A liaison officer also needed to be appointed, independent from the GOP task team, who’s responsibility included assisting with recruitment and communication on the project site. The GoS task team, with block representatives and a liaison officer, had to work with the Ward counsellors (who represent the municipality) and their committees within Langrug.

This is a clearly a complex system of political and social affiliations, and as expected the question of true representation came up immediately in the discussions about the GoS task team. A particularly contentious issue was that ward counsellors are appointed by the municipality, not the community, and do not necessarily live in Langrug. This was found to be a common complaint about any intervention within Langrug, especially that the Langrug community hold the opinion that Ward counsellors did not appropriately represent their interests. This point was strongly articulated by the community, and they demanded that ward counsellors must either fully commit to the project or allow the task team to go forth. It was clear that there were palatable tensions between the community and their elected officials. To diffuse the situation, the facilitators opted to work with their community contacts, the ward counsellors and the contractor to form a small task team.

At the time of the following meeting ten days later, the GoS task team had been identified. The next step in the process was to establish a project steering forum (PSF). The purpose of the PSF was to continuously review physical planning and labour structures – typically on a monthly basis. There were more people attending this meeting, and it became obvious that the reason was miscommunication related to the topic of labour structures. Unemployment is a pressing issue in Langrug, and many present in the meeting were under the impression that employment was the primary topic of the meeting. This created a tense atmosphere as facilitators had to determine which participants were there for planning, vs. those seeking employment. To diffuse the situation, the ward counsellor stepped in and suggested that all should stay to familiarize themselves with the project and it's planning to ensure appropriate representation within the PSF. This proved to be a good strategy and resulted in a productive turn of events, as the large number of attendees provided a platform for community input and identifying concerns. The facilitators felt that in order to get quality input from the attendees on other important items, it would be best to keep the question of labour as the last item on the agenda of the meeting. During the discussion of labour structures, the objective and commitment of GoS to involve the Langrug community was emphasised, in activities

ranging from construction, facilitation, quality control to resource management, all of which were presented as employment opportunities. The case was made that for a fair and transparent process, the contractor would manage employment. As the project was funded by the Western Cape Government, the pay structure would be similar to the standard rates that the municipality paid its workers. While some information related to employment was revealed at the meeting, such as the need for a South African ID and a bank account to facilitate direct deposit, it was decided to discuss the exact rates at a later date. This would allow for a liaison officer to be identified by the community through a vote, as the liaison officer would assist the contractor to manage applications through his or hers links and relationships to the community.

Also tabled during the second meeting was the need for a steering forum, with many members of Langrug expressing the view that the ward counsellors did not represent their interests. It was decided to appoint the steering forum through an application and voting process, and once commissioned, to oversee the hiring of the liaison officer. Despite reservations and misgivings about counsellors, there was acknowledgement from the community that the counsellors must be part of the steering forum. Finally, the need to keep the steering forum small was expressed, to promote efficiency. A voting date was determined from within the community, interestingly without much input required from the other stakeholders such as the facilitators. There was a great level of self-organisation observed in the Langrug community, as ten days later the PSF had been formed. Interestingly, the team of ten had four members who have not had leadership positions or clear political affiliations within the community. The remaining six represented organisations from within Langrug, such as Informal Settlement Council. Ward counsellors were also to be involved in the forum, but it was also acknowledged that these counsellors would be floating members, as the tenures seemed to be unstable. As this group was to represent the stakeholders within the Langrug community, the PSF had to determine the process of selecting the community liaison officer (CLO), whose role was to promote and maintain the link between the contractors and the community. The CLO assisted the PSF in identifying employment opportunities and to work with the site engineer’s site on labour management such as

ensuring attendance and maintaining site discipline. Again the community showed agency by organising the CLO nomination and election process while acknowledging the contractor's demand the CLO must be selected on the individual's ability to do the job and must have knowledge of labour recruits from within the community. Community members who were present brought up the question of appropriate representation. It was suggested that all the blocks vote in the CLO election, despite many blocks not being affected by the initial implementation of the GoS. This was to ensure fair labour recruitment and to pave the way for positive engagement if the GoS expands to new blocks. The community selected the CLO, who had prior experience with construction projects within Langrug that required organising labour from within the community, including management of disciplinary issues and to ensure site safety and productivity. Along with the CLO, he contractors hired eleven full-time employees, five of which were woman. Monthly meetings between the CLO, PSF and the contractor were held, with the PSF members being compensated for attendance.

It can be argued that the participation methodology used by the facilitators in the GoS project gave an arena for the Langrug community to engage with general problems and specific question to incorporate their concerns. The space given to dialogue encouraged the exchange of crucial information, and there was ample evidence that the community was empowered, and given a voice and responsibility that subsequently translated into adaptability and agency, further promoting the view that these attributes are underutilised in informal urban interventions.

3.4.3 Discusion of Stakeholder Participation

Post-modern participation has been driven by the need for informed democratic-driven decision making as an attempt to achieve social equality in specific development contexts where universalistic science theories and applications cannot work. In the South African situation, the constitution allows for participation to be a democratic right that should be institutionalised in development decision-making. However, there is much room for growth within participation-driven research and implementation, as too often participants feel let down with the results, as it has not been adequately proven that

stakeholder engagement leads to enduring decision-making or better implementation. Interestingly, or perhaps ironically, in a field that opposes scientific universalism, scholars debate the various ideologies, social, political and methodological typologies of participation. Even though healthy debate typically leads to the evolution of concepts and solutions, it also serves as a reminder of the need to reduce complex problems to an understandable or manageable level; i.e. an expert practitioner in complexity should be able to de-convolute complicated challenges so that, ideally, they can be solved by engagement within the means of those most affected. Participation typologies are defined by the degree at which stakeholders are engaged, ranging from consultancy to stakeholder empowerment. Principally three questions were asked to assess the degree to which the problems within the community could be translated into a shared response (Reed 2008):

- Are the stakeholders passive and being fed information?
- Is information being gathered from stakeholders?
- Is information being exchanged through dialogue or negotiating?

In the developed North, the frameworks of these discussions often face the risk of being distinguished between “research-driven” or “development-driven” (Reed 2008). However, in the South African context, and by extension the rest of the developing world, research and development are and should be interlinked. In such a scenario, Government should use research institutions to evaluate development objectively and also as a means for quality implementation. For researchers, the projects provide funding and opportunities for real-world testing and application. Thus, stakeholder participation is crucial to define ethical values from within the communities receiving the intervention. In essence, such participatory process allows for research questions that transcend the initial project objectives and help inform the implementation process to enable evolution that ultimately render the project more sustainable.

3.4.4 Benefits to Participation

In modern sustainable development, the application of participation in research is generally well intended. By determining local interests and concerns, the objective is to increase the probability of the local needs and priorities being met. This is because participation is viewed as a means to give voice and power to those previously marginalised in decision-making, thus promoting active citizenship and other societal benefits. Empowered stakeholders are also more likely to co-generate and increase the production of useful knowledge. The quality of the knowledge will be greater due to the incorporating of diverse value rationalities that take into account the complexity of social-environmental interfaces. These attributes are undoubtedly context specific, thus the technical intervention and subsequent information generated will be better adapted to the local conditions.

However, it was crucial to determine the successes and failures of participation in Langrug to validate participation as a viable tool for transdisciplinary studies. Idealistically, the aim was that the local stakeholders achieve a sense of ownership of the intervention. An important aspect though, which is underreported due to the unsavoury nature of the topic, is that interventions like the one in Langrug in which there is stakeholder agreement and participation are in part driven by the hope of reducing the cost of intervention implementation (Winter et al. 2008). This is important to note in the Southern African context. Informal settlements require service delivery, and in democratic South Africa, expect delivery quality to comparable to those of privileged backgrounds. Lilja and Bellon noted that the two barriers to intervention is the inability or the unwillingness to adopt the methodology (Lilja & Bellon 2008). Participation in South Africa will unlikely take place in a political power vacuum. There is too much inequality, thus researchers must always be aware of the complexities and sensitivities of power within communities that are formed from South Africa's past and present societal circumstances. If these factors are not taken into account, cynicism and reduced engagement can prevail, which may greatly negate the multiple benefits of participation. Northern literature increasingly suggests the focus on the process of decision-making and implementation rather than just the outcomes. Again, however, this is challenging in the

South African context as marginalised South Africans have been waiting for more than two decades to be included into the developed South African context and demand immediate outcomes. A study by Koontz, 2005 (in Reed 2008), suggests that participation is most successful when elected officials and citizens share the concerns about the issues involved, and have strong social networks between to the two parties. This appears to be largely lacking in South Africa where past and current inequalities result in a disconnect between elected officials and citizens that is still mirrored in the social fabric of the country.

3.5 Discussion of Qualitative Results

As mentioned before, Eco-Machines had not been built at Langrug by the end of this study. Other biomimicry inspired designs were implemented in the meantime with the focus on controlling water flow and providing green space, nominal water treatment and reducing the presence of stagnant untreated water. However for the purposes of this study, a pilot Eco-Machine in similar conditions was tested to determine the potential of the design. The Eco-Machines are fed by the Plankenberg River, which feeds into the Eerste River, located downstream the Stellenbosch informal settlement of Enkanini. The machine was sampled twice, and measured for faecal coliforms and *E. coli* as standard indicators of water quality. The results were processed by *walab: Water Analytical Laboratory* in Stellenbosch:

Table 1: Results from Plankenberg Eco-Machine sampling.

Faecal coliforms per 100 ml

Date	Source	Final Tank	% Reduction
May-16	496000	5800	98.83064516
Aug-16	6800	40	99.41176471

E.coli per 100 ml

Date	Source	Final Tank	% Reduction
May-16	404000	4700	98.83663366
Aug-16	3000	26	99.13333333

According to South African water quality guidelines states that having more than 100 faecal coliforms counts per 100 ml and 20 *E.coli* counts per 100 ml as high risk for infection (Department of Water Affairs and Forestry 1996). The water source of the Eco-Machine can be considered highly hazardous. Preliminary results show the Eco-Machines do not reduce the pathogen levels to a safe drinking level, however the system successfully reduced the pathogens by a 2-log reduction or 99%. This result shows that the system is a good first-step in water treatment. A more mature system could however further reduce these counts and show that there could be substantial potential for Eco-Machines in treating highly contaminated water. It should also be noted that the environmental conditions in which sampling took place. The May samples were taken at the end of a dry summer, while the August samples were taken on a seasonally rainy period of the year. Rain can dilute the river's sources of pathogens and this could explain the difference of the river source counts between the two sampling dates.

3.6 Conclusions and Project Legacy

The obvious strengths observed in this project was the integration of conventional and non-traditional knowledge sources to identify issues surrounding the Langrug socio-ecological environment. While the issues identified are complex, the GoS means of facilitating and data gathering allowed a space for the issues to be addressed within the project's framework. Meaningful participation allowed solutions to be identified that mostly appealed to most of the stakeholder's current concerns and desired outcomes.

A positive outcome of this project is the genuine observed interest from the Langrug community, due to the GoS project identifying their main concerns and integrating those needs into the implementation plan. Eleven fulltime Langrug locals are employed, and the construction that took place is a step towards formal land ownership. The new infrastructure, while treating the water and controlling untreated flows, is providing space within Langrug that is desirable for the local community. This outcome shows that biomimicry as a design tool and philosophy can be integrated to support societal needs beyond just water treatment. While the functionality of the designs still

need to be tested empirically, GoS has shown adaptability of their designs, and are providing infrastructure that can be modified and improved on, while providing passive treatment.

The transdisciplinary philosophy of this project allowed engineering, ecology and social sciences to come together and provide a technical solution in a dynamic social context that utilised community input and agency. At times the participation went beyond consultation, as the Langrug community actively engaged with the design, planning and implementation phases. A key point was when the Langrug community was given space from the other stakeholders to organise a steering forum committee to identify community members who would be appropriate representatives. Due to a variety a factors, the project was forced to be reflective and adaptive, as funding and deadlines became fluid variables. Thankfully, what stayed constant was the willingness of the Langrug community, the contractors and the various facilitators to remain engaged and continue to communicate. This was no doubt successful due to the hard work by the project stakeholders to develop strong relationships and clear communication lines.

However there were some issues that needed to be documented. Most issues relate to the fact that South African governments and municipalities are unable to provide adequate services to the rapid urbanisation found in South Africa. Meaningful participation and projects based on transdisciplinary methodologies are time-consuming. The Langrug project took two years to get from the initial planning to shovels into the ground. In that timeframe, new shacks have been built on the original sites for the Eco-Machines and a paved municipal road was built over a site for a main gutter. No doubt bureaucracy plays a role in project delays, however informal settlements like Langrug are extremely dynamic and unpredictable with high levels of population growth and turnover.

A lot of complex issues still need to be addressed in South Africa’s development future. Some of these issues are prevalent in Langrug. The local community greatly distrusts political representatives, yet expects the government to provide them with services. It has been suggested that municipalities are reluctant to provide services to

informal settlements with the fears that they might grow and add more stresses to their financial and functional capacity (Winters et al. 2008). These factors can provide an atmosphere of cynical hopelessness that reduces community agency. The GoS project, while funded by the government, actively promoted community agency. The community engagement observed addressing water treatment could be applied with regards to solid waste management, road and housing construction.

The GoS project has by no means concluded. Several components of the project still need to be implemented and analysed. The Eco-Machines need to be built and given time to stabilise to develop their key functionalities. These functionalities need to be tested empirically to ensure water restoration. There has been an observed interest in the project, due to the aesthetic appeal and reduction of odour, from the community to extend the initial phases of the project into other blocks in Langrug. The infrastructure designs must be adaptive to accommodate this potential growth, but will require government and community cooperation for maintenance. If this can be achieved, the GoS team could extend their services to solid waste disposal, road works or housing. This could be very useful for the government, as the GoS project has established connections with the various individuals and representation groups in Langrug. GoS could also become a social enterprise, as the municipality could contract local Langrug companies to perform service delivery.

Chapter 4: Conclusion

4.1 Overall findings of the study

This study attempted to analyse biomimetic-designed interventions in the South African informal context, using transdisciplinary methodology as a design philosophy. While performing the literature reviews for transdisciplinary research and biomimicry, and obtaining data on-site at Langrug, it became obvious that a crucial component of this research would be analysing stakeholder participation. Transdisciplinary research can be seen as values-based research, as Max-Neef asks, “What should we want to do? Or, How should we want to do it?”. The GoS identified that Langrug community engagement was ethically the right choice. It was shown that community engagement was key to any project success. The most rewarding part of this project was observing the transfer of power from non-Langrug members to the community, with the project giving space for the voices of marginalised citizens to be heard.

4.2 Critique of the study and its contributions

The biggest critique of the GoS study could be the time taken for implementation. Government funding delays, tender processes, design workshops, stakeholder meetings and community organisation have all contributed to project delays. Therefore it became difficult to maintain community interest in the project. This is an important point, as community involvement was crucial to the transdisciplinary process as non-academic stakeholders are seen as a key component for project success. The Langrug community showed self-organisation and agency, further supporting the view that the informal community agency is an untapped resource in South Africa.

Another potential criticism of this research project could be that there is little additional tangible data from the qualitative processes, in terms of community needs and demands. This is due to most of the relevant information about the demographics and needs of the Langrug community are readily available. The key point is that the largest

concerns for Langrug members are employment and land ownership. Thus any project with the hopes of community engagement needs to involve those concerns in its design.

A challenge in a transdisciplinary study is determining indicators for project success or failure. From a qualitative point of view, the GoS project provided some initial infrastructure and healthier environments around some homes, while providing some temporary and permanent employment. However, there is very little data to determine to what degree the water is being treated with the current designs. These criticisms link to the first critique of the time it takes to implement these systems. These systems need to be built and analysed to determine whether the project can be considered a success of failure from a technical point of view.

4.3 Recommendations for further research

As the GoS project is still on-going, there is plenty of room for further analysis, particularity with regards to quantitative analysis. Data that supports the technical success of biomimetic design still needs to be obtained. The University of Stellenbosch have two Masters-level students describing how the Eco-Machines could break down contaminants. However, these studies had to take place outside the Langrug context, as the Eco-Machines have not been built at Langrug. It is unrealistic to expect government funding for technologies that have not been empirically proven to work in the South African informal context.

The biggest risk for the GoS project is that the project fades into anonymity as so many intervention projects do, due to waning interest, interference or a reduction in funds. Ideally the project continues to grow by building infrastructure that provides the community with safer and healthier water management and potential employment opportunities. It is crucial that the following two years is observed to describe the successes or failures of the GoS project legacy within the Langrug community.

References

Audouin, M., R. Preiser, S. Nienaber, L. Downsborough, J. Lanz, and S. Mavengahama. 2013. Exploring the implications of critical complexity for the study of social-ecological systems. *Ecology and Society*, 18:3:12.

Benyus, J. 1997. *Biomimicry: Innovation inspired by Nature*. New York: Quill William Morrow.

Bergen, S., Bolton, S., Fridley, J. 2001. Design principles for ecological engineering. *Ecological Engineering*, 18:201–210.

Birkeland, J. 2002. *Positive Development*. London: Earthscan. Chapter 1: Design for Eco-services. 3-23.

Birkeland, J. 2012. *Design Blindness in Sustainable Development: From Closed to Open Systems Design Thinking*. Journal of Urban Design, 17:2:163-187.

Bryman, A., Bell, E., Hirschsohn, P., dos Santos, A., du Toit, J., Masenge, A., van Aardt, I. & Wagner, C. 2011. *Research Methodologies: Business and Management Contexts.* Southern Africa: Oxford University Press.

Burns, M., Audouin, M. & Weaver, A. 2006. Advancing sustainability science in South Africa. *South African Journal of Science*, 102:379-384.

Cole, R. 2012. Transitioning from green to regenerative design. *Building Research & Information*, 40:39-53.

Chu, D., Strand, R., Fjelland, R. 2003. Theories of Complexity. Common Denominators of Complex Systems. *Complexity*, 8:3: 19–30.

Cilliers, P. 2008. Complexity Theory as a general framework for Sustainability Science. In Burns, M., Weaver, A. (eds.). *Exploring Sustainability Science. A Southern African Perspective.* Stellenbosch: African Sun Media, pp. 39–57.

Department of Water Affairs and Forestry. 1996. *South African Water Quality Guidelines, Volume 1: Domestic Use*. Available on the web at website address https://www.dwa.gov.za/IWQS/wq_guide/index.asp. [accessed 8/10/2016].

Drew, J. 2013. *Sustainability revolution has begun.* Available on the web at website address www.afr.com/news/special-reports/sustainability-revolution-has-begun-20131020-j08k3. [accessed 06/06/2016].

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L. & Holling, C. S. (2004) Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology, Evolution, and Systematics*. 35, 557-581.

Gamage, A. & Hyde, R. 2012. A model based on Biomimicry to enhance ecologically sustainable design. *Architectural Science Review*, 55:3:224-235.

Goebel, A., Hill, T., Fincham, R. & Lawhon, M. 2010. Transdisciplinarity in urban South Africa. *Futures*, 42:475-483.

Greenhouse. 2013. *Genius of Place Phase Three.* Unreleased Company Report. www.biomimicrysa.co.za/genius-of-space.

Hajer, M. 2005. Setting the Stage: A Dramaturgy of Policy Deliberation. *Administration & Society,* 36:6:624-647.

Heylighen, F., Cilliers, P., Gershenson, C. 2007. Philosophy and Complexity. In Bogg, J., Geyer, R. (eds.). *Complexity, Science and Society*. Oxford, New York: Radcliff Publishing, pp. 117–134.

Lakhtakia, A. & Martin-Palma, R. 2013. *Engineered Biomimicry*. Waltham: Elsevier.

Lawrence, R. 2010. *Beyond Disciplinary Confinement to Imaginative Transdisciplinarity*, in Brown, V., Harris, J. & Russell, J. *Tackling Wicked Problems: Through the Transdisciplinary Imagination*. London: Earthscan. 16-30.

Leavy, P. 2011. *Essentials of Transdisciplinary Research: Using Problem-Centered Methodologies.* Walnut Creek: Left Coast Press.

Lilja, N. & Bellon, M. 2008. Some common questions about participatory research: a review of the literature. *Development in Practice,* 18:4-5:479-485.

Makina, A. & Luthuli, A. 2014. Corporate South Africa and biodiversity in a green economy. *International Journal of African Renaissance Studies - Multi-, Inter- and Transdisciplinarity*. 9:2:197-212.

Max-Neef, M. 2005. Foundations of transdisciplinarity. *Ecological Economics*, 53:5-16.

Moffat, D. 2007. The Coming Ecologic Epoch: Sim Van der Ryn at EDRA. *Places Journa*l, 19:2:82-83.

Montuori, A. 2013. Complexity and Transdisciplinarity: Reflections on Theory and Practice. World Futures: *The Journal of Global Education*, 69:4-6: 200–230.

Morin, E. 2007. Restricted Complexity, General Complexity. In Gershenson, C., Aerts, D., and Edmonds, B. (eds.). *Worldviews, Science and Us: philosophy and complexity*. London: World Scientific Publishing, pp. 5–29.

Nicolescu, B. 2002. *Manifesto of Transdisciplinarity*. Albany: State University of New York Press.

Odum, E. & Barrett, G. 2005. *Fundamentals of Ecology: Fifth Edition.* Toronto: Thompson Brooks/Cole.

Olgyay, V. and Herdt, J. 2004. The application of ecosystems services criteria for green building assessment. *Solar Energy*, 77:389–398.

Orr, D. 1992. Education and the Ecological Design Arts. *Conservation Biology*, 6:2:162-164.

Polk, M. & Knutsson, P. 2008. Participation, value rationality and, mutual learning in transdisciplinary knowledge production for sustainable development. *Environmental Education Research,* 14:6:643-653.

Preiser, R. & Cilliers, P. 2010. *Unpacking the Ethics of Complexity: Concluding Reflections,* in Cilliers, P. & Preiser, R. (eds). 2010. *Complexity, Difference and Identity. Issues in Business Ethics Volume 26.* New York: Springer Dordrecht. 265-288.

Reed, M. 2008. Stakeholder participation for environmental management: A literature review. *Biological Conservation,* 141:2417-2431.

Russel, A., Wickson, F. & Carew, A. 2008. Transdisciplinarity: Context, contradictions and capacity. *Futures*, 40:460–472.

Siebrits, R., Winter, K., Barnes, J., Dent, M., Ekama, G., Ginster, M., Harrison, J., Jackson, B., Jacobs, I., Jordaan, A., Kasan, H., Kloppers, W., le Roux, R., Maree, J., Momba, M., Munnik, A., O'Keeffe, J., Schultze, R., Silberhauer, M., Still, D. & van Zyly, J. 2014. Priority water research questions for South Africa developed through participatory processes. *Water SA*, 40:2:199-210.

Swilling, M. 2004. "'Two Cultures': an African perspective on the emerging intellectual basis for greater cooperation between the natural and human sciences in the Twenty

First Century", Pieterse, E. and Meintjies, F. (eds.), *Reflections on Ten Years of South African Democracy*, London, Heineman.

Vallero, D. 2010. *Environmental Biotechnology: A Biosystems Approach*. San Diego: Elsevier.

Van der Ryn, S. & Cowan, S. 2007. *Ecological design. 10th ed*. Washington DC: Island Press.

Winter, K., Armitage, N., Carden, K. & Spiegel, A. 2008. Why things fail: greywater management in informal settlements, South Africa. *Water Institute of Southern Africa*. www.ewisa.co.za/literature/files/2008_081.pdf, [acessed March 20th 2015].

Wechsler, D. 2014. Crowdsourcing as a method of transdisciplinary research – Tapping the full potential of participants. *Future*, 60:14-22.

Young, I. 2000. *Inclusion and Democracy.* Oxford. Oxford University Press.

Zedler, J & Kercher, S. 2005. Wetland Resources: Status, Trends, Ecosystem Services, and Restorability. *Annual Review of Environment and Resources*, 30:39-74.

Zoomers, A. 2005. Three decades of rural development projects in Asia, Latin America, and Africa. *International Development Planning Review*, 27:3:271-295.

Appendices

Appendix: Photos and Figures relating to the GoS Project.

Figure 1. An aerial view of Langrug, indicated in purple. The sports field to the South is the proposed site for Eco-Machine construction.

Figure 2: A typical scene in Langrug, where sewers get clogged with solid waste, resulting in stagnant contaminated water.

Figure 3: A ad hoc sewer implemented by the GoS team. Previous ad hoc sewers did not contain a removable sieve, making the system prone to clogging (http://www.acturban.com/genius-of-space-berg-river/, accessed 1/10/2016).

Figure 4: An Eco-Machine matrix at the Plankenberg pilot site. Eerste River water is pumped through the system connected by pipes.

Figure 5: An example of a “tree garden”. Underground pipes fed by ad hoc sewers pass through these systems. The purpose of the gardens is to provide initial greywater treatment and provide green space (http://www.acturban.com/genius-of-space-berg-river/, accessed 1/10/2016).

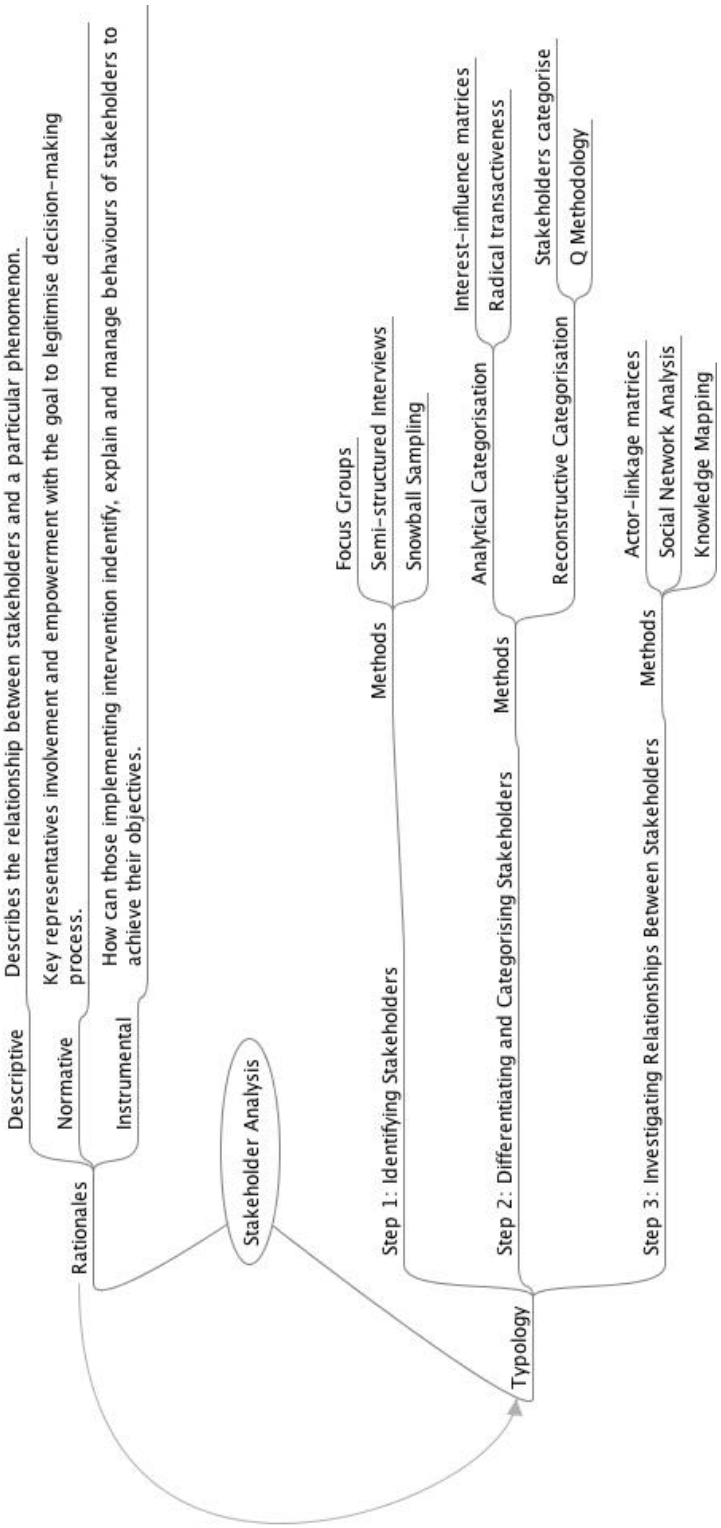
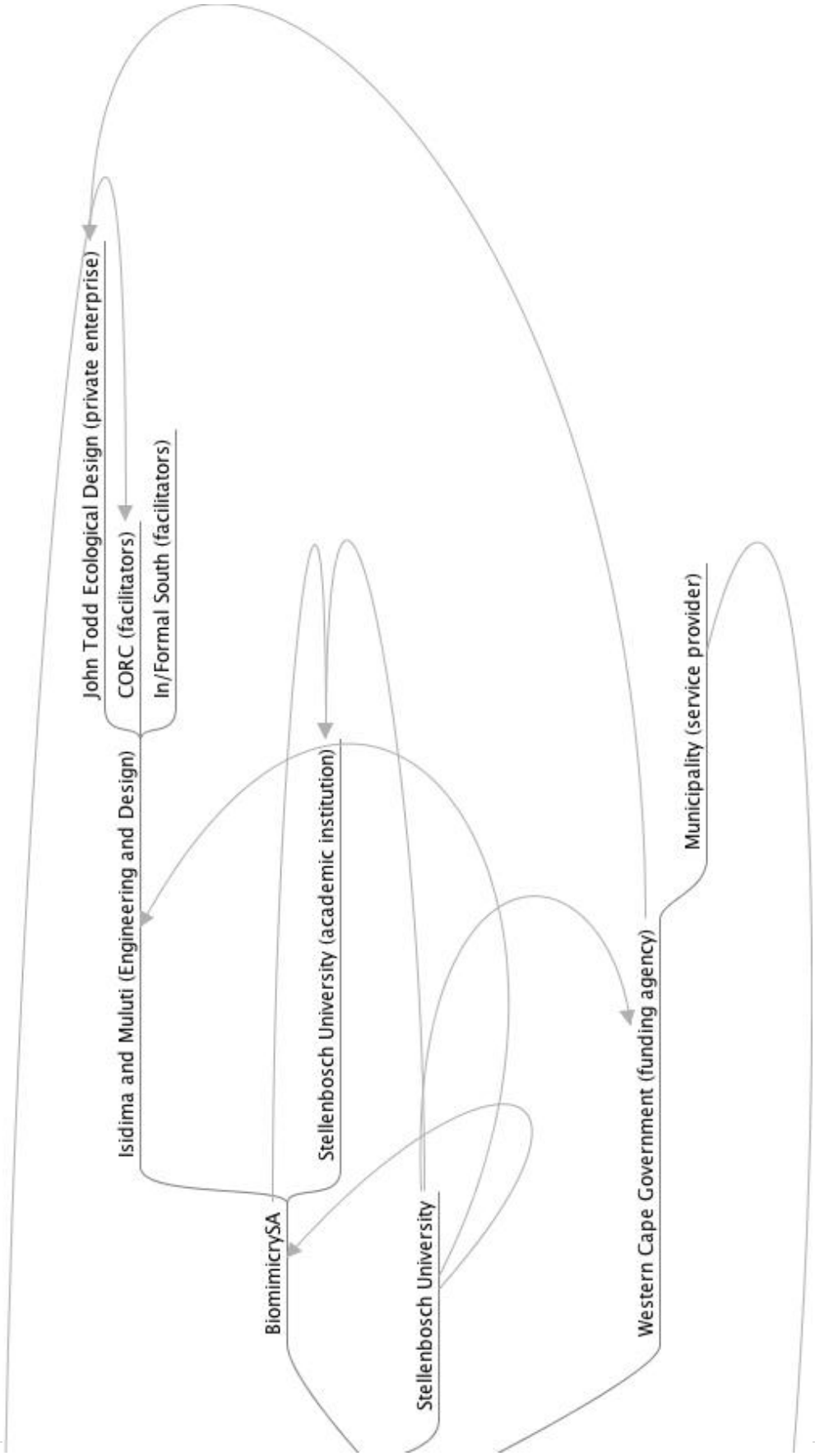


Figure 6: Schematic representation of the stakeholder analysis (adapted from Reed at al 2008)



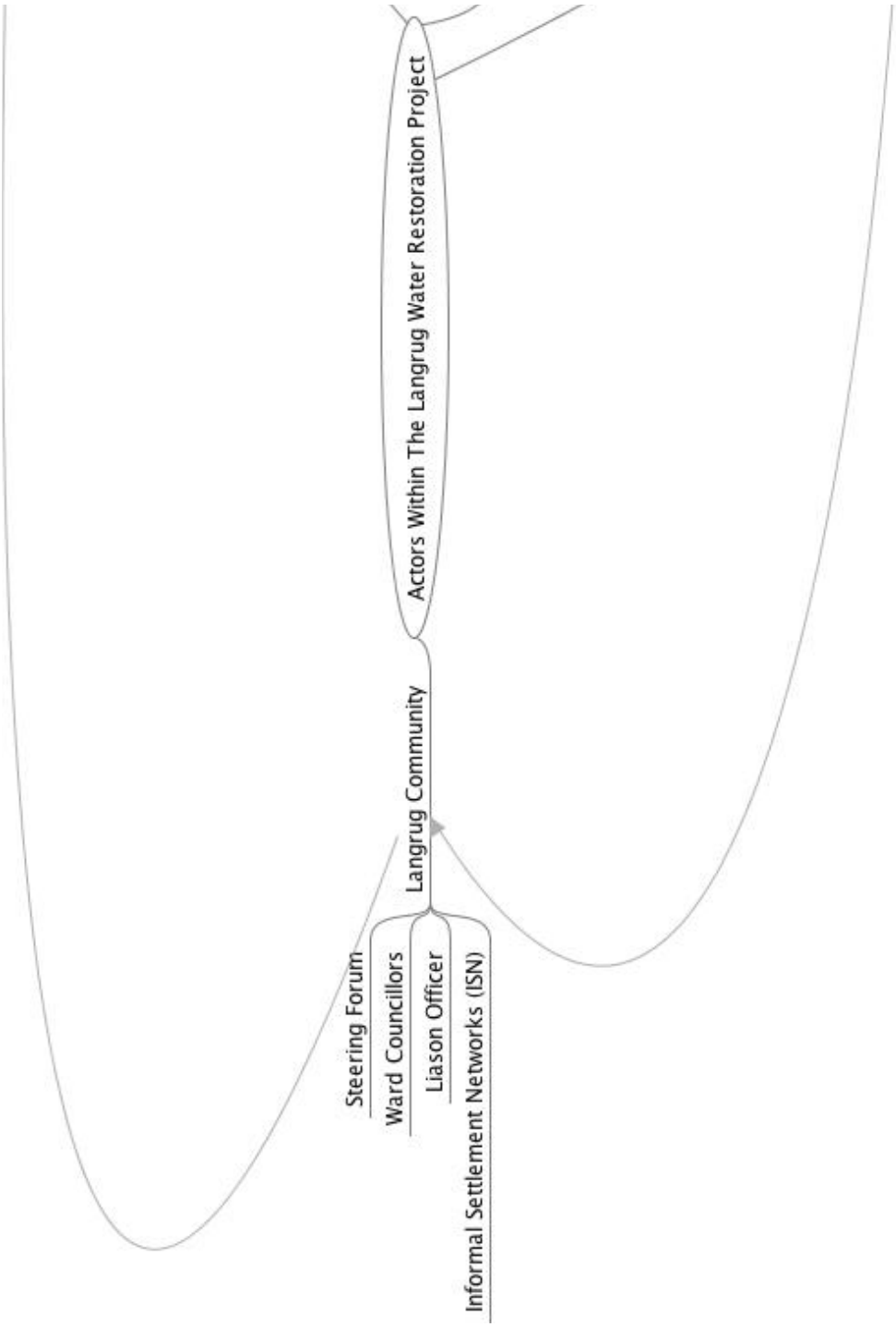


Figure 7: Mapping out the actors within the Genius of SPACE project.

Figure 8: The local sports field to which a lot of Langrug's stormwater drains. Original planned location for the Eco-Machines, however due to delays, new shacks have been built on the site. It is being planned that the Eco-Machines be built on the fields.

Figure 9: Inside Batho's Place, the meeting area for most of the stakeholder meetings involving the Langrug community.

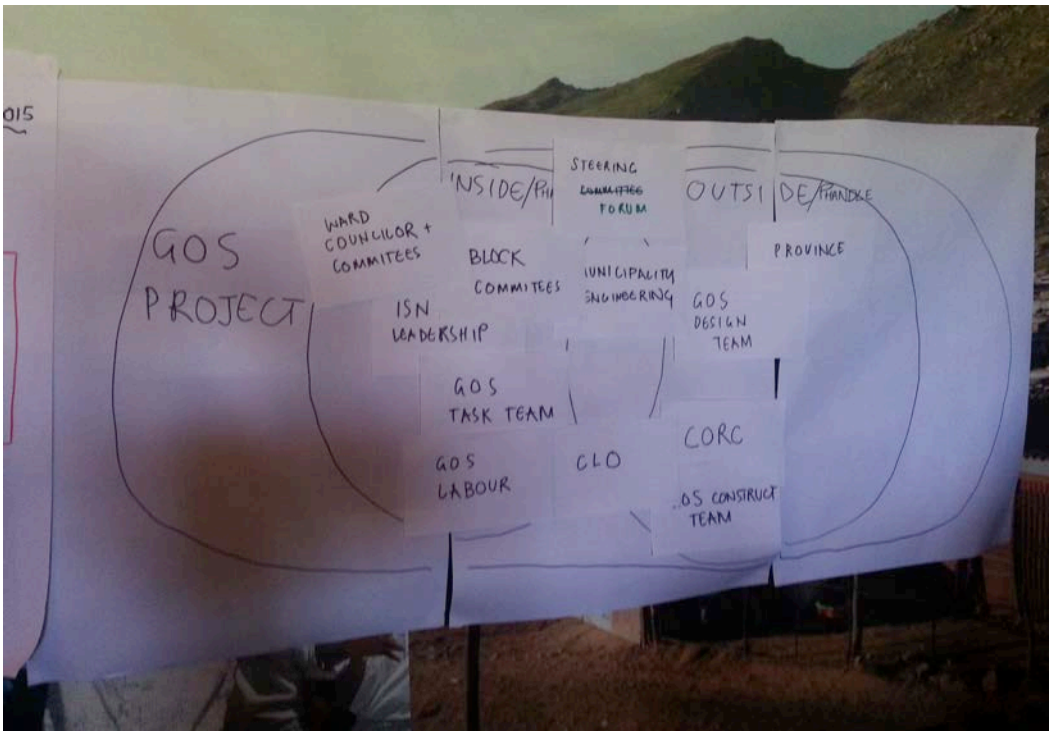


Figure 10: Identifying the key stakeholders inside and outside the Langrug community.