CITIZEN SCIENCE & WATER QUALITY IN THE UMGENI CATCHMENT AREA, KWAZULU-NATAL, SOUTH AFRICA

by

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Abstract

South Africa (SA) is considered to be water scarce under current climatic conditions. As such, the conservation of water quality is emerging as an increasingly urgent challenge as water resources face a growing number of natural and anthropogenic stressors. This thesis investigates how citizen science – the involvement of, and action by, everyday citizens in the collection of data and improvement of water resources- might contribute to the conservation of water quality in SA. The thesis used qualitative research methods, including interviews and participant observation. Mpophomeni Township (within the uMngeni catchment area), KwaZulu-Natal (KZN), SA is used as a case study to better understand the role of citizen science in addressing water quality challenges. Theory U is used as an analytical lens to understand the impact of citizen science as well as the extent to which citizen scientists engage with aspects of social learning and systemic change. Findings indicate that citizen science promotes empowerment and social learning amongst participants, in addition to fostering multi-stakeholder collaboration (on water quality issues), encouraging the establishment of new environmental connections, and enabling a shift in existing government-citizen power relations. Additionally, lack of education and awareness along with minimal or non-existent governmental support as key barriers to citizen science, are examined in further detail.
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“After climbing a great hill one only finds that there are many more hills to climb.”

-Nelson Mandela
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List of Abbreviations

ANC: African National Congress
CBM: Community-based monitoring
CLO: Cornell Lab of Ornithology
DUCT: Duzi uMngeni Conservation Trust
DWS: Department of Water & Sanitation
E. coli: Escherichia coli
ENGO: environmental non-governmental organization(s)
Enviro-Champs: Environmental champions
FEE: Foundation for Environmental Education
Howick WWW: Howick Wastewater Works
GPS: Global Positioning System
IFP: Inkatha Freedom Party
Injoloba: Injoloba Secondary School
KZN: KwaZulu-Natal province
Mathuba: Mathuba Schools and Citizens River Health Programme
Midmar: Midmar Dam
miniSASS: mini Stream Assessment Scoring System
Mpophomeni: Mpophomeni Township
MWWTW: Mpophomeni Wastewater Treatment Works
MSEP: Mpophomeni Sanitation Education Project
NGO: Non-governmental organization
RDP: Reconstruction & Development Programme
SA: South Africa
SARMCOL: South African Rubber Manufacturing Company Limited
UKZN: The University of KwaZulu-Natal (Pietermaritzburg campus)
UMDM: uMgungundlovu District Municipality
Umthombo: Umthombo Senior Secondary School
WESSA: Wildlife and Environment Society of South Africa
WWF – World Wildlife Fund
Zulu: isiZulu
Chapter 1: Introduction

1.1 Contemporary Water Quality Challenges

South Africa (SA) is considered to be water scarce. Presently, the country is faced with a looming water shortage as demand exceeds an already-limited freshwater supply\(^1\) (CIA, 2014). With limited quantity, the conservation\(^2\) of water quality becomes increasingly urgent; diminished water quality reduces the availability of usable freshwater supplies. Within this context, notable water quality challenges include contamination of freshwater resources as a result of untreated wastewater (raw sewage) and solid waste pollution (informal dumping). Throughout SA, a number of communities and townships experience similar water quality-related challenges on a daily basis\(^3\). Two key factors are often attributed to the continued degradation of water quality in Mpophomeni Township (Mpophomeni): lack of government support at the local level (challenges surrounding service delivery and access to adequate sanitation facilities and infrastructure\(^4\)) and lack of education/awareness regarding the pollution of freshwater resources.

1.1.1 Untreated Wastewater Contamination

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\(^1\) South Africa contains 51.4 cubic kilometers of renewable water resources with a per capita freshwater withdrawal rate of 271.7 cubic meters per year; freshwater is predominantly used to supply demand from the domestic, industrial, and agricultural sectors (CIA, 2014).

\(^2\) The use of the term ‘conservation of water quality’ and ‘conservation’ refers to the improvement and maintenance of improved water quality. In this way, the definition differs from the conventional understanding of water conservation, which is typically used to mean decreased consumption of water resources.

\(^3\) While the focus of this research is community-driven water quality contamination, it is equally important to acknowledge that agricultural (and industrial) pollutants are also important contributors to the degradation of water quality.

\(^4\) As of 2011, only 74% of South Africans had access to improved sanitation facilities (CIA, 2014). Furthermore, a study conducted by the Water Research Commission found that wastewater compliance (for minimum baseline requirements) ranged between 0-83% (WRC, 2013a).
Contamination resulting from untreated wastewater constitutes a significant source of water pollution throughout SA. It is well noted that wastewater infrastructure (development and management) plays an important role in addressing water pollution (DBSA, 2012). Like many townships in SA, lack of/poor maintenance of infrastructure is a significant contributor to water pollution in Mpophomeni. Mpophomeni contains a number of manholes located throughout the township. The manholes act as access points to the sewer system, which is used to move untreated wastewater to the Howick Wastewater Works (WWW) treatment facility, located approximately 7 km away. Unfortunately, the sewer system frequently becomes blocked, causing untreated wastewater to overflow out of the manholes and into the surrounding environment, which often includes nearby rivers, and streams (Figure 1). Blockages are largely attributed to inadequate/malfunctioning infrastructure as well as lack of education and awareness surrounding the proper use of infrastructure.

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5 Throughout the thesis, the terminology “manhole(s)” is employed in order to remain consistent with the terminology employed by citizen scientists. However, it is understood that manholes are merely access points to the sewer system and thus reference to an overflowing manhole refers to a blockage within the sewer system, the result of which leads to an overflow of untreated wastewater from the manhole(s).

6 An additional wastewater treatment facility, Mpophomeni Wastewater Treatment Works (MWWTW) exists in Mpophomeni, however the site is not currently in use. There are plans to reinstate this facility once uMgungundlovu District Municipality (UMDM) has acquired adequate funding (Umgeni Water, 2014a). While many research participants remain skeptical about the potential and timeliness of such a reinstatement, UMDM has put forth a proposal (July 2013) to redo some wastewater infrastructure in Mpophomeni as part of a larger upgrade which includes the MWWTW (Green Door Environmental, 2013).
The wastewater infrastructure is seen to be inadequate for two reasons. The pipes used to carry the wastewater are too small to adequately service the community, and the pipes are laid at improper gradients, with some infrastructure angled upwards. This is largely due to the history associated with the construction of housing and implementation of infrastructure in Mpophomeni. Following the end of the white minority rule of apartheid in 1994, the Reconstruction and Development Programme (RDP) was implemented under the newly elected African National Congress (ANC) political party. The primary aim of the RDP was to minimize the economic divide between the rich and the poor, by “…building new homes, redistributing land, creating jobs, expanding health care and education, and increasing the number of people with running water, electricity, and modern sanitation facilities” (Berger, 2009, p. 154).

Relating to the provision of homes as a mandate of the RDP, much of the housing in Mpophomeni is ‘RDP housing’ provided by the National Government (the ANC) in order to address the severe housing shortage following the apartheid era. However, when the houses were
built, the implementation of infrastructure was contracted out (by the government) to an independent third party. Consequently, it is believed that the implementation of the infrastructure was done incorrectly, contributing, in part, to the many wastewater pollution problems evident in Mpophomeni today.

Issues arising from inadequate wastewater infrastructure are further compounded by the improper use of such infrastructure. Within the community, it is common practice to dispose of foreign objects (e.g. clothing, diapers, toys, litter, vegetable scraps, construction debris, etc.) into household toilets and down the manholes into the sewer system. Consequently, the pipes become blocked causing the contents to overflow and seep into the surrounding environment and waterways; in some areas, the vegetation has become noticeably different as a result of increased nutrient input.

1.1.2 Solid Waste Pollution

Informal dumping results from the creation of informal dumpsites where household refuse is discarded (Figure 2). Often, several informal dumpsites are established within a township, usually located along roadways and waterways, contributing to the solid waste pollution of nearby waterways.

Additionally, disposal of litter and household waste directly into nearby rivers and streams remains another prominent and ongoing issue with respect to water contamination and conservation (both in Mpophomeni and other communities). Within Mpophomeni, a primarily Zulu community - approximately 90% of the population of Mpophomeni is Zulu speaking (Frith,
2014) - many participants in this research (both Zulu and non-Zulu alike) note that solid waste disposal in waterways is frequently linked to the cultural belief that water is a means of cleansing, or removing (“carrying away”) discarded solid waste. As a result, disposal of household waste and litter into rivers and streams is often viewed as an acceptable practice within the cultural context of the community.

![Figure 2: An Informal Dumpsite Located along a Main Road in Mpophomeni Township.](image)

1.2 Water Governance

With lack of government support identified as a key variable contributing to the ongoing degradation of water quality, it is useful to provide an overview of the water governance structure in SA. Presently, the Department of Water and Sanitation (DWS) - under the Minister of Environmental Affairs (Nomvula Mokonyane) (DBSA, 2012) - is responsible for overseeing water governance (policy formulation & implementation) (DWS, 2014). As part of this mandate,
the DWS is responsible for water service provision (including sanitation services) at the local level of government (DWS, 2014).

Although DWS oversees water service provision, following apartheid in 1994, much of the water legislation was overhauled to include a decentralization in water service provision with much of the responsibility for water service delivery being relegated to local (municipal) government (DBSA, 2012). In light of this, challenges surrounding effective service delivery are well documented, and many local levels of government suffer from a lack of capacity in this regard. More specifically, “…lack of political will at local government levels, low budget priority, insufficient capital, [and] lack of capacity and skill…” are identified as key contributors to ineffective local service delivery (WRC, 2013b).

Lack of financial resources plays an important role in relation to municipal water service delivery. Infrastructure is identified as a necessary component for improving water quality, yet the vast majority of municipalities do not have the financial resources necessary for updating/implementing bulk water infrastructure (DBSA, 2012). In addition, municipal service delivery is considered to be income generating, however, sanitation and solid waste removal constitute the least profitable services for municipal total income (for 2012-2013) (Stats SA, 2013).

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7 Local government is divided into both local and district municipalities, with each district municipality responsible for overseeing the local municipalities that fall within its designation. Within the study context, uMgeni Local Municipality, along with six other local municipalities, fall under the governance of UMDM (COGTA, 2014).

8 The National Treasury has allotted R5.738 billion to the Regional Bulk Infrastructure Programme (aimed at improving bulk water/sanitation infrastructure), however, the cost for meeting current infrastructure needs is estimated at R100 billion (DBSA, 2012).
2013); this may provide some insight into the frequency with which sanitation and solid waste-related water contamination events occur.

1.2.1 uMgungundlovu District Municipality

Within Mpophomeni, water governance is divided between both uMgungundlovu District Municipality (UMDM) and uMngeni Local Municipality. uMngeni Local Municipality is responsible for solid waste collection, while UMDM, the Water Services Authority for the area, is responsible for overseeing wastewater-related matters (Taylor, 2013) including wastewater treatment (DBSA, 2012). However, many of the wastewater services are contracted from UMDM to Umgeni Water, a state-owned water services provider focused on bulk [potable] water supply and sanitation in six municipalities, including uMngeni Local Municipality, throughout KwaZulu-Natal (KZN) (Umgeni Water, 2014b). A key informant in this research project, Participant CSUW2, emphasizes that given the significant service delivery challenges, it is important to note that while Umgeni Water provides potable water to UMDM, it is not the responsibility of Umgeni Water to oversee the distribution of water or ensure that community-members and residents are adequately serviced; rather, this falls under the responsibility of UMDM.

As such, wastewater contamination is the responsibility of UMDM. UMDM employs a number of plumbers who are responsible for repairing malfunctioning infrastructure (broken/blocked

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9 It has been estimated that the cost of waste management services in UMDM is 34% greater than the revenue generated by such services (Jogiat et al., 2010). In relation to wastewater, the national annual cost replacement for wastewater exceeds R23 billion while operational expenditure is greater than R3.5 billion (DBSA, 2012).

10 As reported by Participant CSUW2, within the study area, potable water is purchased from the DWS and sold to UMDM.
pipes and overflowing manholes) in Mpophomeni\textsuperscript{11}. UMDM is not, however, responsible for repairing manholes located within the confines of a resident’s personal property. In these cases, it is the resident’s sole responsibility to make the necessary arrangements (including financial) for reparation; this can represent a significant obstacle for residents who do not have the means (financial or otherwise) to arrange for an overflowing manhole to be repaired.

With respect to wastewater treatment, Umgeni Water is faced with a significant challenge of its own. Participant CSUW2 notes that it is well acknowledged (amongst participants, residents, and employees) that the Howick WWW treatment facility is running overcapacity with wastewater inflows exceeding current treatment capacity\textsuperscript{12}. This makes it difficult to meet baseline compliance objectives in order to provide adequate wastewater treatment\textsuperscript{13}. Plans to increase development in and around both Howick and Mpophomeni will further exacerbate existing challenges as the implementation of new/upgraded infrastructure is required to adequately treat current rates of inflow.

\subsection{1.2.2 uMgeni Local Municipality}

UMDM is responsible for overseeing solid waste management, but uMgeni Local Municipality is the local service provider responsible for solid waste collection services in Mpophomeni (uMgeni Municipality, 2013). Prior to outlining contemporary waste collection struggles in

\footnotesize
\begin{itemize}
\item \textsuperscript{11} It is the responsibility of citizen scientists, known as environmental champions (Enviro-Champs), to report overflowing manholes; these aspects of citizen science are discussed in more detail later in the thesis.
\item \textsuperscript{12} The Howick WWW has capacity to treat 6.8 Mega litres per day (Umgeni Water, 2014a), but as noted by Participant CSUW2, with input from Howick, nearby Merrivale, and Mppophomeni (and plans to continue development), Howick WWW experiences wastewater inflows that exceed infrastructural capacity.
\item \textsuperscript{13} Baseline wastewater compliance for Howick WWW was 83.1\%, 92.0\%, and 82.7\% for 2011-2013 respectively, largely due to issues with equipment and rain events (Umgeni Water, 2014c).
\end{itemize}
uMngeni Municipality, it is necessary to provide some historical context regarding the legacy of apartheid and solid waste infrastructure/collection in SA. During apartheid, resources (personnel and capital expenditure) for waste collection were “enormously skewed in favour of historically white neighbourhoods” (Qotole, Xali, & Barchiesi, 2001, p. 2); it was anticipated that a more equitable distribution of resources would occur following the end of apartheid, yet there remains a clear distinction between former ‘whites-only’ suburbs and black townships, the former receiving regular waste collection, while residents of townships are frequently forced to dispose of waste in open areas (Qotole, Xali, & Barchiesi, 2001). Regardless of attempts to create “unified, non-racial cities”, the redistribution of resources within the waste collection sector has been minimal (Qotole, Xali, & Barchiesi, 2001).

Therefore, it is not surprising that many residents of Mpophomeni and research participants note that waste collection services in Mpophomeni are largely inadequate, although the extent of such inadequacy remains somewhat ambiguous. Nonetheless, uMngeni Local Municipality maintains that waste collection is provided to approximately 80% of households\textsuperscript{14} within their jurisdiction (the distribution being unclear) and note that one of the key challenges around waste management is the extension of waste collection into rural areas (uMngeni Municipality, 2013). In general, there is a lack of information regarding waste collection within the study area, but the need to prevent solid waste pollution of water resources (within UMDM’s jurisdiction) is highlighted as critically important (Jogiat et al., 2010).

\textsuperscript{14} Compared to Jogiat et al. (2010) who found that only 60-70% of households in and around Howick have access to weekly waste collection services.
1.3 South African Context

More generally, within the South African context, the provision and/or maintenance of water quality can be thought of as a ‘wicked problem’ (M. Dent, personal communication, May 2013). Wicked problems are not inherently evil, but rather, wicked in the sense that they are complex, messy, and unsolvable (Rittel & Weber, 1973; Ritchey, 2013). They are problems that stem from governmental (societal or political) planning problems (Rittel & Weber 1973), and are constantly “evolving in a dynamic social context” (Ritchey, 2013, p. 2). In this way, wicked problems can be viewed as symptoms of other, higher (state) level problems (Rittel and Weber, 1973; Ritchey, 2013).

Exacerbating the complexity of wicked problems is the fact that they can be difficult to define, and even harder yet to manage or ‘solve’. Due to the multitude of stakeholders involved in wicked problems, it can be challenging to reach a majority consensus regarding a definition or understanding of the problem, let alone how best to manage it (Rittel & Weber, 1973; Ritchey, 2013; Rosenhead, 1996). The provision and/or maintenance of water quality in the uMngeni catchment area is no exception. One need only look at the numerous stakeholders involved to understand the extent and breadth of interest and perspective in addressing water quality challenges.

1.4 Research Justification

“We must also remember that we are of the earth too, having a place and a reason for our existence. The processes, in which we take part, should be reciprocal, balanced, giving back as much or more than we take.” (Lovelace, 2013, p. 31)
We cannot deny that water is absolutely essential to our wellbeing and the wellbeing of the planet upon which we depend. Due to the multitude of ongoing water-quality challenges currently facing SA, this research is pertinent to sustainability. In accordance with the principles of sustainability as outlined by The School of Environmental Studies, this research seeks to emphasize the relationship between community (human) wellbeing and water quality and seeks to understand the correlation between human behaviour and the degradation of water quality resources.

Understanding water quality, as a sustainability issue within SA, suggests a place for the use of citizen science. Given the complex nature of water quality as a wicked problem, it is useful to look at citizen science as a mechanism for promoting systemic environmental change.

Discussions around the state of water quality in the uMngeni catchment area (the study area is discussed further in Chapter 2) suggest that the current water management system is ineffective for enhancing/maintaining the sustainability of water resources and yet, water influences – and is influenced by - every aspect of citizens’ daily lives. Consequently, numerous sectors, interests, and actors must be accounted for when managing and improving water quality in Mpophomeni and the greater uMngeni catchment. As such, systemic change that accounts for all interested and affected stakeholders, their concerns, and contributions is essential to the improvement of water quality in uMngeni (and SA). Indeed, consensus through multi-stakeholder collaboration has

\[15\] Within the context of this research, the “system” under discussion can be thought of as the uMngeni catchment area (the study area), as well as the affiliated actors management practices, and behaviours currently influencing water quality in uMngeni.
been shown to alleviate uncertainty (increased stakeholder confidence in different management options) and conflict associated with environmental management (Dietz et al., 2003).

Meadows et al. (2004) note that “When its information flows are changed, any system will behave differently” (p. 4). Citizen science is a mechanism for changing information flows; it represents a network of collaboration (information flow) between various stakeholders (recipients), enabling the generation and transparency of water quality-related information (new content) that can be used to shape or inform a new system (rules and goals) relating to water quality management. Identifying the need for new system information and goals, and implementing the necessary changes for achieving such goals, are essential for systemic transformation (Meadows et al., 2004).

1.5 Research Question & Affiliated Objectives

In light of the complicated water quality context in SA, the following research question and affiliated objectives are examined in order to better understand the potential for citizen science to promote systemic environmental change (as it relates to water quality) in uMngeni Municipality:

How might citizen science contribute to (encourage and/or improve) the conservation of water quality in Mpopomeni Township (uMngeni catchment area), KwaZulu-Natal, South Africa?

To understand:

a) If, and how, citizen science promotes empowerment amongst citizen scientists

b) Whether citizen science promotes social learning amongst citizen science participants

c) If, and how, citizen science promotes multi-stakeholder connection, collaboration and
contribution to water quality-related work

d) Whether or not citizen science provides a mechanism through which new connections with nature, the environment, and others might be established

e) Whether or not citizen science promotes a shift in power-dynamics with respect to how citizen scientists view themselves in relation to power and the power dynamics at play (notably, government-citizen relations)

The research questions and objectives are largely aimed at understanding gradual, long-term processes. Thus, while the research objectives seek to understand whether or not these processes are occurring, the findings may only provide small indications, or glimmers, of evidence as to their occurrence.
Chapter 2: Methodology

2.1 Study Area

Mpophomeni, located in uMgeni Municipality, KZN, forms the basis of my study area and is contextualized in relation to the larger uMgeni catchment area. As a fairly typical South African township, a case study of Mpophomeni can suggest how to understand the potential usefulness of citizen science to address water quality in South Africa more generally.

2.1.1 uMgeni Catchment Area

The uMgeni catchment is 4416 km² in size and includes the Umgeni River which is 255 km long (WRC, 2002). The uMgeni catchment encompasses several ecoregions (from savannah to coastal belt) and includes a diverse range of land-use practices from conservation areas to areas of intense industrial development (WRC, 2002).

The catchment is divided into six resource units (Figure 3): Midmar, Albert Falls & Nagle, Inanda, Upper Umsunduze, Pietermaritzburg, and Lower uMgeni & Durban (WRC, 2002), with the study area, Mpophomeni, forming part of the Midmar resource unit. The Midmar resource unit contains a number of wetlands (‘Umgeni Sponge’), many of which (> 60%) have been destroyed, impairing their ability to provide ecosystem goods and services, including water purification (WRC, 2002). Furthermore, agriculture (including numerous farm dams) constitutes

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16 Along with its two key tributaries, the Umsunduzi and Umhlangane rivers (Lorimer, 2012).
17 Resource units are smaller sub-catchments within the larger catchment area that are divided into “sensible geographic” areas that make sense for river management; they are often seen as being more relatable than ecoregions as a result of their tendency to be affiliated with dams (WRC, 2002).
one of the key land-use practices in the area, often resulting in excessive nutrient input (WRC, 2002) into Midmar Dam (Midmar) and its associated tributaries.

2.1.2 Midmar Dam

Midmar is an important part of the Midmar resource unit and is commonly used for water sport and recreation in addition to being a major source of potable water in KZN\(^{18}\) (WRC, 2002). The

\[^{18}\text{Midmar, along with Albert Falls, Nagle, and Inanda, is one of four major dams used to supply water along the Umgeni River (Lorimer, 2012). Midmar is the first in a cascade of dams, its outflow feeding into}\]
Dam has a total catchment area of 926 m² and a total capacity of approximately 235,000,000 m³ of water (Umgeni Water, 2014a). In 2002, at the time the State of the Rivers Report was compiled (using data collected over a ten year period), water quality in the Midmar resource unit was generally good (WRC, 2002). However, agricultural input along with urbanization and urban development remain key variables associated with increased and ongoing water quality contamination (WRC, 2002; SARVA, n.d.).

Cholera and Escherichia coli (E. coli) are common bacterial contaminants resulting from the fecal contamination of Midmar (WRC, 2002). In their 2014 report, Umgeni Water (2014a) acknowledge that E. coli non-compliance has increased in Midmar as a result of poor infrastructure and sewage contamination from Mpophomeni. Not surprisingly, management of pollution from Mpophomeni has been identified as a key priority (WRC, 2002).

Mpophomeni is situated approximately 4km from Midmar (Figure 4) (DUCT, 2013) and contributes a significant amount of raw sewage/fecal contamination into the dam. Specifically, Mpophomeni constitutes 3% of the Dam’s catchment area, yet contributes “51% of the E. coli and 15% of the phosphorous load in Midmar Dam” (SANBI, n.d.). In conjunction with agricultural runoff, such heavy nutrient loads threaten to turn the dam eutrophic by 2028 (SANBI, n.d.).

Albert Falls Dam, followed by Nagle and then Inanda, respectively; consequently, the water quality in Midmar has a direct impact on these three reservoirs (SARVA, n.d.). Such projections are helpful, but it is important to acknowledge that eutrophication is dependent on several variables, particularly hydrology. Participant CSUW2 explains that under conditions of low rainfall/drought, when the dam impoundment volume is low and incoming contaminant concentration is high, there is potential for the dam to turn eutrophic very rapidly. Furthermore, Participant CSUW2 emphasizes that we do not know the tipping point for the system and thus, it is difficult to know if/when
2.1.3 Mpophomeni Township

Mpophomeni ("waterfall") Township is a peri-urban township (Baiyegunhi & Makwangudze, 2013; Masibumbane, 2014) located in uMngeni Municipality. It is located outside Howick (approximately 15km), and 120km from Durban (Baiyegunhi & Makwangudze, 2013; Masibumbane), and 30 km from Pietermaritzburg, well-known metropolitan areas within KZN.

the system might shift from one stable state to another more dangerous [yet stable] state (eutrophication).
Mpophomeni is predominantly isiZulu (Zulu) speaking and contains a population of approximately 25,000 people (in 2011) (Frith, 2014).

The township was first established in the late 1960s (during the apartheid era) to accommodate African citizens from surrounding areas (Baiyegunhi & Makwangudze, 2013; Denis, 2013; Sinomlando, 2012; Zulu-Mpophomeni Tourism Experience, 2010), who, at the time, were deemed to be “undesirable” residents in the nearby white-dominated cities and towns (Denis, 2013).

Like many other townships in SA, the history of Mpophomeni has been shaped by political conflict. In Mpophomeni, the history of conflict and poverty is associated with the South African Rubber Manufacturing Company Limited (SARMCOL) rubber factory. SARMCOL was located in Howick and employed 350 residents from Mpophomeni (Denis, 2013; Sinomlando, 2012). Tension between workers and SARMCOL management escalated, and following a workers strike in 1985, the entire SARMCOL workforce was dismissed and replaced (Denis, 2013; Sinomlando, 2012).

This resulted in violent political conflict, during the late 1980s and early 1990s, between the residents of Mpophomeni (largely former SARMCOL employees) and residents from surrounding areas (hired as replacement SARMCOL workers) (Sinomlando, 2012; Zulu-Mpophomeni Tourism Experience, 2010). The political conflict in and around Mpophomeni occurred during the height of the apartheid era in which violent, political conflict - notably

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20 This thesis does not endorse such thinking, but rather incorporates such terminology/ideology in an attempt to provide an accurate recollection of the historical context.
between the ANC and Inkatha Freedom Party (IFP) was occurring throughout the country, and especially in KwaZulu and Natal. Opposing political views escalated the conflict in Mpophomeni, as many Mpophomeni residents and former SARMCOL workers were ANC supporters, while residents from surrounding areas, hired as replacement workers, were primarily IFP supporters (Zulu-Mpophomeni Tourism Experience, 2010). The resultant conflict continued until 1993, when, following the death of 120 people, the conflict finally subsided (Denis, 2013; Sinomlando, 2012; Zulu-Mpophomeni Tourism Experience, 2010).

One result of such conflict-ridden history is that Mpophomeni is defined by high unemployment21 and low socio-economic status (Baiyegunhi & Makwangudze, 2013; Thorstenson, 2009). Living conditions are marginal (Thorstenson, 2009) and the township is not well serviced, nor does it contain urban facilities (Bekker et al., 1997; Thorstenson, 2009). As such, many residents are required to commute to surrounding urban/metropolitan areas (namely, Howick, Pietermaritzburg, and Durban) in search of employment (Baiyegunhi & Makwangudze, 2013; Bekker et al., 1997) and/or to access necessary services and amenities.

Unfortunately, these circumstances are not unique to Mpophomeni and many townships face similar challenges. In this way, Mpophomeni serves as a good case study for better understanding the role of citizen science within the contemporary South African context.

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21 In 2007, unemployment in Mpophomeni was estimated at 80% (Baiyegunhi & Makwangudze, 2013; Masibumbane, 2014). While significant, this is not unique to Mpophomeni: in 2013, 24.9% of the South African workforce was unemployed (total population: 51.8 million (Stats SA, 2013)), with approximately 31% of the population living below the poverty line (CIA, 2014). Not surprisingly, South Africa contains the second highest Gini coefficient (63.1) in the world (CIA, 2014).
2.2 Positionality

As a researcher, my positionality is that of an indigenous-outsider\textsuperscript{22}. Originally from SA, but having grown up in Canada, I am relatively familiar with the country and culture(s) of SA and was able to connect with individuals over a shared citizenship as well as my previous experiences visiting the country. My positionality influences my research and writing, in that it is important to me that this research is meaningful (reciprocal) to both the communities and individuals with whom I worked. I wanted the research process to be inclusive and participatory, and to foster a sense of empowerment amongst individuals; data collection thus became an exercise in listening to the concerns, experiences, knowledge and insight of those with whom I worked, rather than an exercise in imposing my own [predominantly Western-science based] assumptions and ideas onto the context and people. In conducting this write-up, it is my hope that the analysis and findings remain true to the conceptualizations of the individuals, and that the discussion is not regarded as a prescriptive solution borne of a western-science perspective and paradigm, but rather a collaborative effort that gives a voice to the many individuals with whom I worked.

2.3 Research Process

This research seeks to be comprehensive, exploratory and somewhat descriptive in nature, with the aim of contributing to social change research (Kirby \textit{et al.} 2006). In this way, methodological emphasis is placed on different forms of knowledge production and contextualizing the research.

\textsuperscript{22} An indigenous-outsider is someone who belongs to a certain community, but experiences a high degree of assimilation (or ‘de-socialization’) into an outside community, and consequently holds “values, beliefs, perspectives, and knowledge” (p.8) which are nearly identical to those of the outside community (Banks, 1998). While indigenous-outsiders are often seen as having betrayed their indigenous community (Banks, 1998), I did not experience or identify with this aspect of being an indigenous-outsider.
in a way that is inclusive to those who fall outside of scientific or empirical knowledge traditions (Kirby et al., 2006).

The methodological process for this research began a few months prior to departure for SA. I spent some time reading scholarly literature on water conservation and management in SA, as well as some water policy documentation, in addition to contacting various individuals and organizations while formulating my research proposal. During this period, Dr. Mark Dent from the University of KwaZulu-Natal (UKZN) graciously invited me to work alongside him on his citizen-science initiative, Mathuba Schools & Citizens River Health Programme (Mathuba), for the duration of my fieldwork in SA.

Fieldwork commenced in May 2013 and concluded 4 months later in August 2013. The first four (approximate) weeks were spent orienting myself in Howick, Pietermaritzburg, and Mpophomeni, as well as familiarizing myself with the Mathuba program, and formulating working relationships and connections, established largely through Dr. Dent’s existing networks.

During this period, I spent time meeting and speaking with members of two prominent environmental organizations based in the area, the Wildlife and Environment Society of South Africa (WESSA) and Duzi uMngeni Conservation Trust (DUCT). In addition, I was able to tour both Mpophomeni as well as Shiyabazali, an informal settlement located in the heart of Howick. I was fortunate enough to participate in various Enviro-Club work sessions held at Mpophomeni Public Library with students from Umthombo Senior Secondary (Umthombo) as part of the Enviro-Club, facilitated by Louine Boothway. During this four-week period, and throughout my
4-month stay, my experiences as well as the insights and information shared with me were recorded using audio recordings, photographs, and field notes (both in the form of a blog and field notebook).

Following initial orientation, time was spent reading familiarizing myself with some of the theoretical literature pertaining to water quality in KZN and SA (wicked problems, Theory U, and some systems theory) and an interview table was designed on the basis of these theoretical underpinnings. Interviews commenced at the beginning of July, and the following two months (July-August) were spent collecting data through interviews, and continued participant observation, as well as through [researcher] participation in various citizen science lessons, field trips, meetings, and workshops.

2.3.1 Change in Process

The basic methodology outlined in my research proposal did not change over the duration of my field stay. However, my involvement with various citizen science initiatives increased significantly from those initially identified. Originally, my intention was to focus primarily on Mathuba as a key citizen science case study. However, the scope of my research quickly shifted to include a host of different citizen science groups, most notably the Mpophomeni Sanitation Education Project (MSEP) and high school Enviro-Clubs program. It was my experience with these two initiatives that formed the basis of my data collection. It is worth noting that Mathuba is a multi-organization initiative, of which both MSEP and the Enviro-Clubs belong to.
While MSEP/Enviro-Clubs were the primary initiatives with which I was affiliated, I was fortunate enough to engage with a number of additional individuals and stakeholders in Howick, Hilton, Mooi River, and Pietermaritzburg, whose experiences and insight proved invaluable to the research. Subsequently, these findings are included in the analysis as a means of providing as holistic and complete an understanding of water quality and citizen science as possible.

2.3.2 Theory U

Theory U²³ forms a significant part of the research and is used as an analytical lens to interpret the process, and measure the impact of, citizen science. There are many theories or concepts which could be applied to the South African context in order to measure the impact of citizen science, however, Theory U was selected as a result of the guidance I received while in the field and because of its influence in shaping my interview questionnaire. As a result of the context of water quality as a wicked problem, Theory U was identified as being particularly helpful as a result of its ability to help make visible the subtle transformation that was occurring amongst participants. Individual-level changes amongst participants are much more subtle than some of the larger, structural changes that are also required for improving water quality, and Theory U was particularly helpful in bringing to the forefront some of these more understated changes and nuances that may not otherwise be visible.

The model of Theory U is based on the premise of social learning and can be viewed as a mechanism that empowers everyday citizens (and stakeholders) to help shape/influence future

²³ Theory U is regarded as more of a concept than a specific theory (unlike concepts, theories tend to address larger structural transformations). The terminology ‘theory’ has been employed in order to remain consistent, but it is recognized that the application of Theory U within this research is more consistent with that of a concept.
decisions and outcomes (Figure 5). As Scharmer (2009) notes, collectively, society regularly creates undesirable outcomes (which key decision-makers are often helpless to change).

Scharmer (2009) notes that the patterns of thought and behaviour that we have relied on for centuries, no longer fit our current reality, a reality that is vastly different to our previous experiences. Indeed, “leaders cannot meet their existing challenges by operating only on the basis of past experience” (Scharmer, 2009, “The Blind Spot”, para. 8). Thus, it becomes increasingly necessary to learn “from the future as it emerges” (Scharmer, 2009, “The Blind Spot,” para. 8).

Learning from the future occurs when individuals progress (often multiple times) through the U movement, which consists of various capacities that enable us to engage with social learning, as well as acquire/hone our capacity for progressive leadership, and ultimately shape the emerging future. The movement down the left side of the U is largely aimed at aiding in the transition from ‘downloading’ to ‘seeing’. Theory U requires that we “stop our habitual mode of downloading and open up to the reality in front of us” (Scharmer, 2009, “The Field Structure of Downloading”, para. 1). That is, break free from the habit of reproducing past and existing patterns of thought/behaviour in order to see beyond the “mental constructs that we project onto the world” (Scharmer, 2009, “The Field Structure of Downloading”, para. 2). Cultivating an awareness for habitual downloading can help prevent the reproduction of patterns of behaviour which were once logical, but have since become dysfunctional (Scharmer, 2009).

Once we are no longer trapped in the constant cycle of downloading and reproducing [problematic] mental constructs and/or behaviours, we are able to see the reality which surrounds
us (Scharmer, 2009). Presencing (presence + sensing), which occurs at the bottom of the U, is focused on connecting to our inner source\(^{24}\) of knowing (Scharmer, 2009), while crystallizing (both the vision and intent as we move back up the U) allows us to sustain and begin to operate from such a connection (Scharmer, 2009).

The final capacities of the U movement focus on bringing about the new intention or reality by implementing prototypes (‘living examples’) that enable feedback and adaptation before moving into the final phase of the U movement, shaping “larger institutional ecologies” and systems (Scharmer, 2009, “The Field Structure of Performing”, para. 1). Using this process, individuals can identify and implement the changes necessary to allow new systems to replace older, outdated, dysfunctional, and/or ineffective systems (Scharmer and Kaeufer, 2013).

For the purpose of this research, citizen science can be seen as a vehicle or platform that allows participants to engage with Theory U and ultimately social learning. In this way, Theory U is used to measure the impact of citizen science. Consequently, the research questions are largely aimed at understanding if and how citizen scientists engage with various aspects of Theory U as a mechanism for promoting social learning and systemic change. Admittedly, Theory U is an abstract concept that is difficult to measure; there is no precise science relating to its practical implementation. However, Theory U and its underlying principles contain “immense capacity[y] for changing social systems that previously appeared to many to be unchangeable” (Scharmer, 2009, “Forward”, para. 16). As such, it is a promising tool for helping to influence water quality in uMngeni.

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\(^{24}\) Inner source: “the place from which our attention and intention originate” (Scharmer, 2009, “The Blind Spot”, para. 7).
2.4 Data Collection

2.4.1 Methodology

The primary methodology for this research consisted of semi-structured interviews and participant observation. While participant observation provided meaningful context and insight, data obtained from the interview process provided the basis for my findings. Two sets of interviews were conducted, one with a theoretical (Theory U) basis (Appendix A) designed for citizen scientists, and a more general interview (specifically tailored to each interviewee) designed for individuals involved in water quality issues through their work and/or personal lives.
The theoretical interview questionnaire was designed using a framework provided by Dr. Mark Dent. Using this framework, I formulated possible interview questions relating to Theory U and then considered potential interviewee responses to each question as well as the relevance of those responses to the fulfillment of the research question (specific interview questions and their relevance to the research objectives are included in Appendix A). Using this method, I was able to ensure that each interview question remained relevant to the research objectives. A couple of pilot interviews were conducted using the original interview questionnaire. Following this process, some questions were removed from the questionnaire (due to redundancy), but no other changes were needed prior to conducting the remainder of the interviews.

Depending on the individual, interview duration ranged from approximately 10-60 minutes as a result of the semi-structured nature of the interview process. Contextual interviews were less structured, with specific questions relating to each participant’s area of specialty (citizen science, water treatment, mini Stream Assessment Scoring System (miniSASS)\textsuperscript{25}, environmental education), and the interview duration was typically longer with most interviews lasting approximately 30-75 minutes.

A thematic analysis of the interviews was conducted following my return from SA. After transcribing and reading through the interviews, a number of themes emerged from the findings. These included participants’ emphasis on community and community wellbeing, lack of/need for education and awareness relating to water quality, the importance of leadership and what

\textsuperscript{25} miniSASS is a biomonitoring tool used to assess the health of rivers and streams and is outlined in further detail in Section 2.4.4 (GroundTruth, 2013a).
constitutes strong leadership, the importance of working together, the role and influence of both culture and gender in relation to environmental work, the occurrence of intergenerational learning, environmental work as an opportunity (to better oneself and to connect with others in spite of the prevalence of significant societal barriers), and the government’s role and responsibility for improving water quality.

These themes provided further insight into the water quality context in the uMngeni catchment area and have been included in the discussion where relevant. However, following this initial thematic analysis, it was determined that further analysis was needed in order to move beyond the more obvious observations initially provided in order to gain a deeper-level understanding of the changes occurring amongst participants, so as to better understand the impact of citizen science. Consequently, as per Dr. Dent’s suggestion, more prominence was given to Theory U. Theory U provided a mechanism in which to deepen the analysis and examine if individuals were experiencing change(s) and if/how those changes may be conducive to contributing to/improving water quality.

Participant observation and [researcher] participation occurred throughout the 4-month stay and included observation of, and participation in, a variety of different activities. I was fortunate to be able to work alongside Liz Taylor and Louine Boothway, (coordinators of MSEP and Enviro-Clubs, respectively) who enabled me to fully immerse myself in their projects by allowing me to both facilitate and participate in a number of citizen science activities.
This included attending an MSEP workshop, participating in/observing several Enviro-Club activities including water-quality-related field trips, as well as overseeing multiple Enviro-Club work sessions, helping to facilitate a youth water workshop and attending a miniature environmental education conference. Additionally, I was able to visit both Umthombo and Injoloba Secondary School (Injoloba). I spent a considerable amount of time at Umthombo with both the students and teachers, where I observed (and participated in) a typical Enviro-Club session. I also spent some time at Injoloba, where I was fortunate enough to meet the ‘extended’ Enviro-Club participants with whom I was not able to work with during my fieldwork; I spent significantly less time at Injoloba, but the experience was equally meaningful and valuable.

Finally, I was provided several opportunities in which to conduct lessons and presentations for various students. I was invited to design a water-related lesson consisting of three potential activities for St. Nicholas Diocesan School, and while I was not able to oversee the implementation of this particular lesson, I was able to use this lesson plan to teach a lesson on water turbidity at Umthombo. In addition, I was afforded the opportunity to prepare and teach a similar water lesson (concepts included the water cycle, water quality/turbidity, and the conservation of freshwater resources), to a group of primary school students at an internationally recognized Eco-School, Carshalton Primary, in Mooi River.

Additionally, my colleague, Nduduzo Cele and I designed and delivered a presentation outlining the processes and underlying theories associated with the Mathuba program. We delivered this presentation twice, once at Carshalton Primary and once at Injoloba. The presentation included an overview of the Mathuba program, its history, and its goals. We also discussed the methods used in the program, including the use of citizen science and environmental education initiatives.

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26 All lessons were based on activities designed by the Orange-Senqu River Learning Box Project, a citizen science and environmental education initiative focused on developing teaching and educational materials for use both in and outside of the classroom in four countries, Botswana, Lesotho, Namibia, and South Africa, located along the Orange-Senqu River (Sinyama, n.d.).
presentation to various participants at multiple DUCT Enviro-Club meetings\textsuperscript{27}, as well as students from Nsikayethu Secondary School in Imbali Township, Pietermaritzburg. All of these experiences provided insight into some of the learning processes, and subsequent challenges, surrounding environmental education and citizen science in KZN and SA.

Lastly, in order to provide additional context and understanding, Dr. Mark Dent invited me to attend a sustainability (GreenMaps) forum, and organized a meeting with Andrew Muir, an environmental lawyer in the process of mapping existing environmental impact assessments onto Google Earth. These experiences were particularly useful for gaining insight into the other environmental work currently being conducted in KZN.

2.4.2 Limitations & Biases

Given the comprehensive nature of this research, an attempt has been made to provide “as complete a picture as possible” (Kirby et al., 2006, p. 65) regarding water quality in the uMngeni catchment area. However, the decisions associated with doing so incorporate my personal bias in terms of deciding which research area and participants were most likely to contribute to our understanding of a ‘complete picture’ (Kirby et al., 2006) with respect to water quality. In this case, focusing primarily on MSEP and Enviro-Clubs reflects my personal bias in prioritizing these initiatives as being important for gaining a better understanding of water-quality based citizen science work in uMngeni Municipality.

\textsuperscript{27} These [DUCT] Enviro-Clubs are based in Pietermaritzburg, not to be confused with the Enviro-Clubs in Mpophomeni and Howick with which I was affiliated. Unfortunately, I was not able to work as closely with these Enviro-Clubs due to logistical constraints.
Additionally, my inability to interview a representative from either uMngeni Local Municipality or UMDM is a notable limitation to the study as both the local and district municipalities are key actors in water management\textsuperscript{28}. As a result, this creates a bias within the research, as I was not able to learn first-hand what the local government’s perspective is on water quality, as well as some of the challenges they may be facing. This is especially pertinent given the general consensus amongst citizens and community members regarding the lack of governmental action at the local level with respect to addressing water quality. Gaining a first-hand understanding of the local government’s perspective would have been invaluable for better understanding the bigger picture of water quality. Fortunately, however, the individuals with whom I worked were able to share their insights into what the government’s perspectives may be and outline some of the challenges faced by government, as a result of their own experiences and involvement in water quality work.

2.4.3 Participants & Recruitment

Participants for both interviews and participant observation were drawn from a number of organizations. Because interviews didn’t commence until July, I was able to form working relationships with interviewees prior to the interview process, and thus participant recruitment was reliant on existing relationships\textsuperscript{29}.

\textsuperscript{28} Attempts were made at contacting representatives from both the local and district municipalities via e-mail, phone (if possible), or in person at the local municipality office in order to set up interviews. Unfortunately, none of these attempts were successful as only one response was received from a representative at UMDM who agreed to answer interview questions electronically but has not yet provided these responses. The difficulties I faced in connecting with local authorities are not unique, and are acknowledged as a common challenge faced by many involved in water quality work in this area (Liz Taylor, personal communication, May, 2013).

\textsuperscript{29} The nature of this research required me to establish close working relationships with the community members and citizens of Mpophomeni and Howick, and I was extremely fortunate in that I was readily
A total of 32 interviews were conducted; I determined 32 to be an adequate number as a result of having established relationships with many of the citizen scientists prior to conducting interviews. As such, I had an existing knowledge of who the key citizen science participants and facilitators were, and recognized the importance of including them in the interview process. Additionally, the snowball sampling method allowed me to identify additional key individuals involved in water quality work (primarily at Umgeni Water and GroundTruth) with whom I had no previous connection. These participants were identified through citizen science facilitators as well as Dr. Allison Goebel, Dr. Mark Dent, and their respective networks. I was able to contact and interview all suggested individuals, with the exception of a government official(s), resulting in a total of 32 interviews.

2.4.4 Organization Profiles & Protocols

Participants were drawn from an array of organizations and initiatives (Appendix B), including Mathuba, DUCT, WESSA, GroundTruth (an environmental consultancy organization), Umgeni Water, MSEP, and the Umthombo and Injoloba Enviro-Clubs. Both MSEP and the high school Enviro-Clubs formed the basis for my (theoretical) citizen science interviews, while the remaining participant interviews were largely contextual in nature.

Mpophomeni Sanitation Education Project

MSEP - coordinated by Liz Taylor - was first established in Mpophomeni in 2011 and represents a collaborative agreement between DUCT and UMDM, the local water services authority (Taylor,
The overarching goal of MSEP is to increase education and awareness around the pollution of water quality as well as the proper use of waterborne sewage systems and the prevention of blocked infrastructure (discussed further in Data Collection Protocols) (Taylor, 2013).

This work has been carried out using citizen scientists, known as environmental champions (Enviro-Champs), who are responsible for monitoring the manholes located throughout the township. Additionally, MSEP has incorporated a drama-based awareness campaign (Mpophomeni Youth Productions\textsuperscript{30}) and is closely aligned with the objectives and work being carried out by the Enviro-Clubs educational program (Taylor, 2013). At the time of research, eight Enviro-Champs were involved with MSEP (seven in Mpophomeni and one in Shiyabazali in Howick). Turnover rate with respect to participants has not been high and all current Enviro-Champs have been with the program for 2-3 years (L. Taylor, personal communication, June 2014), a significant fact given the program was only established three years ago.

At the time of its inception (2011), MSEP was funded by UMDM; this sponsorship provided the necessary start-up funding to cover costs associated with program implementation (training, workshops, and meetings) (L. Taylor, personal communication, June 2014). However, following January 2014, UMDM chose not to extend their sponsorship, and in February 2014, funding was

\textsuperscript{30} Mpophomeni Youth Productions, founded by Thandanani Luvuno, constitutes an important aspect of the MSEP initiative. Mpophomeni Youth Productions is a theatre-based education and awareness campaign. Members of the production team create and deliver performances relating to various and relevant environmental issues in and around the community (including the disposal of foreign objects into manholes). Plays are performed at different venues for audiences of all ages (daycares, high schools, adults) with the intention of creating awareness around various issues. These performances are an integral part of the citizen science currently being conducted in Mpophomeni by supplementing the scientific data generated by citizen scientists in an effort to help MSEP achieve its goals and objectives.
obtained from the World Wildlife Fund (WWF) Nedbank Green Trust (L. Taylor, personal communication, June 2014). Challenges related to funding and the long-term financial viability of both MSEP and the Enviro-Clubs program is discussed in the results section (Chapter 4).

Enviro-Clubs Program

The Enviro-Clubs program is coordinated by Louine Boothway and was first implemented in 2012. During the initial year of implementation, the program really only took hold at Umthombo (L. Boothway, personal communication, June 2014). Presently, there are five schools involved in the program, four of which are active in the Enviro-Clubs program\(^{31}\) (L. Boothway, personal communication, June 2014). This research examines both Umthombo as well as Injoloba’s involvement in the program.

Currently, Enviro-Club has 27 participants from Umthombo and 22 from Injoloba; of these, only a small group of students (approximately 15 from both clubs) are highly committed to the program (L. Boothway, personal communication, June 2014). Nonetheless, it is promising to note that the number of committed participants has increased since the program’s inception (L. Boothway, personal communication, June 2014). Notably, a core group of committed participants from both Umthombo and Injoloba, who have been involved with Enviro-Club since the beginning of 2013, “are visibly growing in knowledge and confidence” (L. Boothway, personal communication, June 2014). However, in order to abide by the Department of Basic

\(^{31}\) It is important to clarify that each school is unique, with differing dynamics and challenges (e.g. the number of teachers who are willing/able to support the Enviro-Club and help maintain contact between the students and coordinator which is vital to the success of the club) (L. Boothway, personal communication, June 2014). These varying dynamics affect each school’s ability to participate in the program (L. Boothway, personal communication, June 2014).
Education’s no interference policy, the Enviro-Clubs program is run as an extramural activity; this set-up tends to attract only the most dedicated of participants (L. Boothway, personal communication, June 2014).

Enviro-Clubs is run through the international Foundation for Environmental Education’s (FEE) Eco-Schools Programme, although there has been some amalgamation between the objectives of various different environmental organizations and programs. As such, the Enviro-Clubs initiative has incorporated DUCT’s “vision and objectives” resulting in an explicit water-quality focus, while attempting to meet the requirements of the Eco-Schools Programme as well as the requirements for FEE’s International Litter Less Campaign (run in conjunction with the Wrigley Company Foundation), who provide funding for the Enviro-Clubs program (Louine Boothway, personal communication, August 18, 2013). Additional funding for Enviro-Club (e.g. costs associated with field trips, such as fuel, food, facilitators, etc.) is obtained from the WWF Nedbank Green Trust.

Data Collection Protocols

One of the overarching goals of both the MSEP and Enviro-Clubs initiative is to provide education and awareness to the residents of Mpophomeni, Howick, and surrounding area. This objective is met, in large, using citizen science carried out by the Enviro-Champs (MSEP) and students of Umthombo and Injoloba high schools (Enviro-Clubs). As a result of the way that
citizen science has been defined within the context of this research, citizen science activities include both scientific and non-scientific activities and data collection\textsuperscript{32}.

Citizen scientists participate in collection/generation of scientific data from two key activities, the monitoring of wastewater infrastructure in addition to conducting miniSASS.

1. MSEP: Monitoring and Reporting Malfunctioning Infrastructure

One of the primary aims of the MSEP project is to equip the residents of Mpophomeni with the necessary skills and resources (cell phones, cell phone airtime) to report and monitor municipal (UMDM) response to blocked, broken, and/or overflowing wastewater infrastructure (Taylor, 2013). In order to do this, each Enviro-Champ is responsible for monitoring the manhole(s) located within the vicinity of their respective homes. Additionally, residents are able to report any problematic manholes that they may encounter to the Enviro-Champs, who then record the problem and follow up with the municipality.

The manholes are numbered and, where possible, contain GPS coordinates for reporting to UMDM. Enviro-Champs keep records outlining the number (and corresponding GPS location if applicable) of the problematic manhole(s), attempt to identify the underlying cause(s) of blockages (often related to the disposal of foreign objects), and monitor the repair process (which includes reporting to, and following up with the UMDM plumbers who are responsible for repairing blocked/malfunctioning infrastructure). These records are submitted to DUCT and used

\textsuperscript{32} The activities and protocols recorded here are based on my fieldwork experience and the citizen science activities I observed/participated in during my stay in SA and may not be representative of all activities and protocols experienced by citizen scientists.
to track the location, frequency, and cause of overflowing manholes, as well as [district] municipal response to blocked manholes.

2. MSEP and Enviro-Clubs: Conducting miniSASS to Monitor the Quality of Rivers/Streams in Mpophomeni and Howick

miniSASS forms an important part of the work being carried out by both the MSEP Enviro-Champs, as well as the Enviro-Club participants (citizen scientists). miniSASS consists of a set of standardized protocols (available to anyone) used to collect scientific data to assess the environmental health of rivers and streams (i.e. non-stagnant water bodies). miniSASS relies on “allocating a quality score to specific and readily identifiable aquatic invertebrate taxa” (Graham et al., 2004, p. 27); this is done by collecting a sample of river/stream water and identifying the macro-invertebrates present in each sample (Figure 6) (GroundTruth, 2013b; Graham et al., 2004). miniSASS requires the use of a score card upon which participants record their GPS location and findings (GroundTruth, 2013c).
miniSASS is conducted in rivers/streams containing one of each a rocky, vegetative, and gravel/sand/mud biotype; participants have five minutes to collect a sample of biota, using a net, from each respective biotype within their location of the river/stream (GroundTruth, 2013c). The biota collected from all three biotypes are collected in a [white] sample tray and river water is used to rinse the remains from the net into the collection tray; forceps may be used to help remove biota and/or plant debris from the net (GroundTruth, 2013c). A standardized dichotomous key is then used to identify each of the macro-invertebrates present in the tray.

Common insects and their sensitivity scores (sensitivity to water pollution) are provided on the scorecard, and participants record the sensitivity scores for each group of organisms (e.g. true flies, bugs and beetles, crabs, etc.) present in the sample (GroundTruth, 2013c). The sensitivity
scores from each group are added and then divided by the number of groups identified in order to provide an average river score (GroundTruth, 2013c). The average score is then used to determine the ecological condition (e.g. unmodified, moderately modified, critically modified, etc.) of the river (GroundTruth, 2013c). Finally, the results can be uploaded to the miniSASS website, which acts as a portal for individuals from all across the country to upload, compare, and discuss their results.

Additionally, although not a part of the required miniSASS protocol, citizen scientists may also conduct a water turbidity test to further determine the environmental health of the river/stream at which they are sampling (GroundTruth, 2013c). A turbidity test requires the use of a turbidity tube, in which a sample of water is collected. The turbidity tube contains a turbidity disk, which is lowered into the column of water until the reader is no longer able to see the disk (Figure 7). Based on this measurement, citizen scientists are able to read and record the turbidity score of the sample. A low turbidity score suggests the presence of many suspended solids, indicative of a cloudy (turbid) water sample (GroundTruth, 2013c).

![Figure 7: Citizen Scientist Conducts Turbidity Test in Howick, KwaZulu-Natal.](image)
In addition to the collection and generation of scientific data, citizen scientists also participate in a number of other activities, not necessarily scientific in nature, but equally important in contributing to the goals and objectives of both the MSEP and Enviro-Clubs citizen science initiatives.

1. MSEP and Enviro-Clubs: Workshops and Conferences

Citizen scientists from both initiatives participate in a variety of workshops (MSEP Workshop, Youth Water Workshop) and conferences (Eco-Schools Mini Conference). With respect to Enviro-Clubs specifically, the design and delivery of water quality related environmental presentations form an integral part of citizen scientists’ participation in workshops and conferences. Presentations include a variety of water quality-related issues, including the untreated wastewater contamination of Midmar Dam.

The MSEP workshop, which I attended, focused on collaborative learning and included a tour of problematic and overflowing manholes in Mpophomeni. The workshop provided an opportunity for citizen science facilitators, Enviro-Champs, and UMDM plumbers to learn from one another and gain insight into the challenges and struggles experienced by one another.

2. Enviro-Clubs: Facilitated Community Outreach

In addition to conducting miniSASS and participating in regular Enviro-Club sessions, the Enviro-Club citizen scientists also participate in community outreach initiatives aimed at increasing education and awareness of water quality related issues in and around the community. Notable examples of this include community-based interviews (designed and conducted by
citizen scientists) in addition to the creation of a video outlining the water quality challenges currently facing Mpophomeni (available at: https://www.youtube.com/watch?v=vH12NiLi9BA).

2.4.5 Participant Profiles

The aim of this section is to provide some insight into the typical citizen science participant involved in MSEP and/or Enviro-Clubs. The following does not include statistical demographics, but rather aims to provide the reader with a general sense of a typical citizen science participant currently engaged in water quality monitoring in Mpophomeni and Howick.

The age of a typical participant is variable and depends largely on the initiative with which they are involved. Enviro-Clubs is comprised of youth (high school students) aged 14-18 years (approximately), whereas MSEP includes a number of adult (> 18 years) participants. The ratio of female: male participants varies significantly between the two initiatives. Enviro-Club contains 7 females for every 2 males, whereas MSEP includes 3 females per 6 male participants. Many participants acknowledge that the majority of individuals involved in environmental work are female, a statement which is supported by the Enviro-Club gender ratio, but not the MSEP gender ratio. This imbalance between female: male involvement in environmental work is due, in part, to traditional gendered roles as defined by Zulu culture, in which it is the role of the women to care for the earth and thus undertake responsibilities associated with environmental stewardship. With respect to employment, most participants of MSEP are unemployed with the exception of a small stipend provided through MSEP as compensation for costs incurred from conducting citizen science (e.g. compensation for phone calls); employment is largely negligible for participants of Enviro-Club, who are still completing high school.
2.5 Summary of Methodology

Table 1 provides an overview of the methodological process outlined in this chapter, used to collect data relating to citizen science and water quality in Mpophomeni and the uMngeni catchment area.

Table 1: Summary of the Methodological Process

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>LOGISTICS</th>
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<tbody>
<tr>
<td></td>
<td><strong>Theoretical Interviews</strong></td>
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<tr>
<td>Interviews</td>
<td><em>Disclaimer: there is a significant amount of thematic overlap within each interview, thus, the participants have been separated into distinct areas of expertise to the extent possible</em></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Theme</th>
<th>Participants</th>
<th>Area of Expertise</th>
<th>Participants</th>
</tr>
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<tbody>
<tr>
<td>Theory U</td>
<td>20</td>
<td>Citizen science</td>
<td>2</td>
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<td></td>
<td></td>
<td>Environmental education</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contextual: water quality</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contextual: community</td>
<td>3</td>
</tr>
<tr>
<td>Contextual Learning Activities</td>
<td>Activity/Event</td>
<td>Attendance</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>GreenMaps Sustainability Forum</td>
<td>Attended</td>
<td></td>
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<tr>
<td></td>
<td>Informational meeting: mapping environmental impact assessments onto Google Earth</td>
<td>Attended</td>
<td></td>
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<tr>
<td></td>
<td>Eco-Schools mini conference</td>
<td>Attended</td>
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<table>
<thead>
<tr>
<th>Citizen Science: Observation &amp; Participation</th>
<th>Activity</th>
<th>Sessions</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Enviro-Club/classroom work session</td>
<td>Observation of Umthombo work session: Mpophomeni Library</td>
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<tr>
<td></td>
<td></td>
<td>Injoloba recycling: Injoloba school</td>
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<td></td>
<td></td>
<td>Follow-up Injoloba recycling meeting: Howick Museum</td>
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<td></td>
<td></td>
<td>Umthombo uMthinzima Hike: Mpophomeni</td>
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<tr>
<td></td>
<td></td>
<td>Injoloba miniSASS: Howick Falls</td>
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<tr>
<td></td>
<td>Enviro-Club field trip</td>
<td>DUCT Enviro-Club (Pietermaritzburg chapter) field trip to Bisley Park (nature reserve)</td>
</tr>
<tr>
<td>Activity:</td>
<td>Participation:</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>MSEP workshop</td>
<td>Participated</td>
<td></td>
</tr>
<tr>
<td>WESSA workshop and miniSASS (invited to join incoming interns for workshop)</td>
<td>Participated</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Facilitation Opportunities</th>
<th>Activity</th>
<th>Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enviro-Club work sessions</td>
<td>Umthombo Youth Water Workshop presentation preparation session (June 20, 2013)</td>
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<td></td>
<td></td>
<td>Umthombo Youth Water Workshop presentation preparation session (July 1, 2013)</td>
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<td></td>
<td></td>
<td>Umthombo Youth Water Workshop presentation preparation session (June 28, 2013)</td>
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<td></td>
<td></td>
<td>Injoloba Youth Water Workshop presentation preparation session (June 18, 2013, Youth Day)</td>
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<td></td>
<td></td>
<td>Injoloba Youth Water Workshop presentation preparation</td>
</tr>
<tr>
<td>Presentation Opportunities: Mathuba</td>
<td>Activity</td>
<td>Involvement</td>
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<tr>
<td>Presentation of Mathuba</td>
<td></td>
<td>DUCT Enviro-Club (Pietermaritzburg chapter)</td>
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<tr>
<td></td>
<td></td>
<td>DUCT Enviro-Club (Pietermaritzburg chapter)</td>
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<tr>
<td></td>
<td></td>
<td>Nsikayethu Secondary School</td>
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<tr>
<td><strong>Mathuba</strong></td>
<td><strong>Activity</strong></td>
<td><strong>Involvement</strong></td>
</tr>
<tr>
<td></td>
<td>Mathuba workshop</td>
<td>Coordinator/facilitator</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Lesson Plans</th>
<th>School</th>
<th>Lesson Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>St Nicholas Diocesan School</td>
<td></td>
<td>Water turbidity, ecosystems, pollution</td>
</tr>
<tr>
<td>Umthombo Senior Secondary</td>
<td></td>
<td>Water turbidity</td>
</tr>
<tr>
<td>Carshalton Primary</td>
<td></td>
<td>Water cycle, water turbidity, conservation of water quality and quantity</td>
</tr>
</tbody>
</table>
Chapter 3: Literature Review

This literature review is comprised of five sections outlining the history, emergence and proliferation of citizen science, followed by a definition of citizen science, and a discussion on the relevant frameworks/models, advantages, disadvantages, and recommendations for best practice.

3.1 History and Emergence of Citizen Science

Science was not regarded as a professional career until the late 1800s (Silvertown, 2009). Consequently, many early scientists, including Charles Darwin, and Benjamin Franklin could technically be considered citizen scientists (Dickinson & Bonney, 2012; Havens & Henderson, 2013; Silvertown, 2009). It was not until after “the professionalization of Western science”33 that citizen science became a distinct practice separate to citizen science (Havens & Henderson, 2013, p. 380). Consequently, although citizen science has technically been around for centuries, the number of participants, the scope of data collection, and the growing number of studies that rely on citizen science, have shaped modern day citizen science (Cohn, 2008), helping to differentiate it from the type of “citizen” science first conducted by individuals such as Darwin, Franklin and countless others34.

3.1.1 Proliferation of Citizen Science

33 “…science is a young intellectual pursuit” only a few hundred years old (Robertson & Hull, 2001, p. 971).
34 The term ‘citizen science’ is relatively new, having only been coined in 1996 by researchers from the Cornell Lab of Ornithology (CLO) (Cohn, 2008; Havens & Henderson, 2013) and has yet to appear in a dictionary (Dickinson & Bonney, 2012).
“Although human capacity to change the environment is responsible for accelerated losses of ecosystem attributes and functions, ironically, this capacity to implement change can also be tapped to address conservation problems” (Cooper et al., 2007, p. 8)

The past two decades have seen a significant increase in citizen science (Bonney et al., 2014; Conrad & Daoust, 2008; Conrad & Hilchey, 2011; Dickinson & Bonney, 2012; Havens & Henderson, 2013; Lawrence, 2006; Silvertown, 2009). Furthermore, the vast majority of current citizen science initiatives relate to environmental issues (Conrad & Hilchey, 2011; Dickinson et al., 2010; Dickinson et al. 2013; Dickinson & Bonney, 2012; Silvertown, 2009), and many specifically address water-quality monitoring (Conrad & Hilchey, 2011; Fore et al., 2001; Lawrence, 2006; Shirk et al., 2012).

The proliferation of citizen science has been largely attributed to increasing public awareness and concern over environmental degradation (Conrad & Daoust, 2008; Conrad & Hilchey, 2011; Lawrence, 2006; Whitelaw et al., 2003), technological advances, and growing Internet access (Cooper et al., 2007; Dickinson et al., 2010; Dickinson et al., 2012; Dickinson & Bonney, 2012; Havens & Henderson, 2013; Silvertown, 2009). Technological tools and the Internet have contributed significantly to the collection, dissemination, storage (large quantities of data can be submitted, shared, and stored electronically35), and quality of data (Dickinson et al., 2012; Dickinson & Bonney, 2012; Havens & Henderson, 2013; Newman et al., 2012; Silvertown, 2009).

35 The creation of online data entry systems means that citizen science projects can be implemented relatively quickly and inexpensively, while still maintaining the integrity (quality) of the data collected (Dickinson et al., 2012). Citizen science is most effective when data collection is both accurate and cost-effective as a result of public participation in the collection process (Cooper et al., 2012).
Indeed, mobile phone applications, wireless sensor networks, and video games have shown great potential for enhancing citizen science (Newman et al., 2012) by way of crowdsourcing (Dickinson et al., 2012) and community mobilization (Cooper et al., 2007). In general, technology has improved the capacity for collaboration amongst participants (Havens & Henderson, 2013) and engagement with larger, more diverse, and/or previously marginalized audiences (Bonney et al., 2014; Dickinson et al., 2012; Newman et al., 2012). However, the advantages cut both ways as technological advances have also increased the “digital divide”, expanding the gap between those who do and do not have access to the necessary technologies required to participate (Newman et al., 2012).

Nonetheless, many authors credit the Internet as having increased the ability for citizen scientists to report on large (continental and global) geographic and temporal scales (Bonney et al., 2014; Cohn, 2008; Cooper et al., 2007; Dickinson & Bonney, 2012; Havens & Henderson, 2013; Newman et al., 2012; Triezenberg et al., 2012; Worthington et al., 2012). This allows research to be conducted at “broadly ambitious scales” (Cooper et al., 2007, p. 2). This enables sufficiently large datasets to be collected in order to conduct large-scale analyses and comparisons (Trumbull et al., 2000) that exceed the limitations (time, resources) of conventional research and research techniques, resulting in findings that would not otherwise emerge (Bonney et al., 2014; Carr, 2009).

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36 This is particularly relevant to the South African context: access to technology is a key barrier to citizen science (further discussed in Chapter 4), yet it plays an important role in providing citizens with access to water quality monitoring resources and fosters collaboration amongst participants from different citizen science initiatives.
Due to increasing concern over environmental quality (Dickinson et al., 2010), citizen science, with its broad spatial and temporal scale, has a particularly important role to play in tracking large-scale environmental change (Bonney et al., 2009; Cooper et al., 2012; Dickinson et al., 2010) and advancing conservation theory and practice by addressing problems of “continental significance” (Cooper et al., 2007), like water quality.

### 3.2 Defining Citizen Science

“The scientific community is beginning to recognize citizen scientist partners as important collaborators, even as ambassadors for science” (Havens & Henderson, 2013, p. 378).

Generally, citizen science is defined to mean the involvement of everyday citizens, or volunteers, who collaborate on scientific research (Cohn, 2008; Conrad & Hilchey, 2011; Cooper et al., 2007; Dickinson et al., 2012; Dickinson & Bonney, 2012; Havens & Henderson, 2013; Phillips et al., 2012; Shirk et al., 2012) by contributing to the collection, provision, and/or processing of data (Dickinson et al., 2013; Jordan et al., 2012; Silvertown, 2009).

There are several terms and affiliated practices used to denote citizen science (or some variation thereof) including, community science (Carr, 2004; Conrad & Hilchey, 2011), voluntary biological monitoring (Lawrence, 2005), public ecology (Robertson & Hull, 2001), public participation in scientific research (Jordan et al., 2012; Shirk et al., 2012), and community-based monitoring (CBM) (Conrad & Hilchey, 2011; Whitelaw, 2003).
For the purpose of this thesis, the terminology ‘citizen science’ will be employed, however, “[c]itizen science can include CBM” (Conrad & Hilchey, 2011, p. 274), and indeed, the type of citizen science being conducted in the uMngeni catchment area most closely aligns with CBM. CBM is a citizen science practice in which “…concerned citizens, government agencies, industry, academia, community groups and local institutions collaborate to monitor, track and respond to issues of common community concern. Emphasis is placed on monitoring designed to promote sustainability…[and] inform decision-making” (Whitelaw et al., 2003, p. 410).

Within the citizen science literature, emphasis is often placed on scientific research, with several authors making a clear distinction between professional scientists and non-scientists, or amateur volunteers (Cohn, 2008; Cooper et al., 2007; Dickinson et al., 2012; Dickinson et al., 2013; Jordan et al., 2011; Jordan et al., 2012; Silvertown, 2009; Tulloch et al., 2013). While this is typical of many citizen science initiatives, the definition of citizen science as used here also includes non-science aspects and seeks to emphasize the importance of contributions from all relevant stakeholders, regardless of their designation as ‘amateur’ or ‘professional’. Thus, while citizen science in the uMngeni catchment area can be considered CBM, the type of citizen science currently being employed, also seeks to expand beyond the definition of CBM to include participation in, and contribution to, both scientific and non-scientific research and activities.

Indeed, there is growing acknowledgement of the importance (‘validity and utility’) of contributions from individuals who fall outside the conventional scientific realm when it comes to environmental decision-making (Carr, 2004). Funtowicz & Ravetz (1997) argue that relying on isolated pockets of expertise cannot solve complex environmental problems. Instead, there is a
need to expand existing ‘peer communities’ to include ‘extended peer communities’. That is to say, it is necessary to extend pockets of existing specialists and experts (often involved in creating and/or regulating the problem) to include local knowledge holders (including community members and environmental activists) capable of complementing expert knowledge with local, personal and practical knowledge (Funtowicz & Ravetz, 1997).

Therefore, the use of the term citizen science within the context of this research, seeks to overcome traditional academic boundaries by incorporating non-science based aspects and emphasizing the importance of both professional and amateur contributions through the expansion of academic peer communities to include extended peer communities.

3.3 Frameworks & Models

The recent proliferation of citizen science has resulted in a number of frameworks and models, designed to aid in the implementation of citizen science initiatives. Frameworks/models are important for allowing the implementation of effective monitoring programs that have a clear purpose (Conrad & Daoust, 2008; Conrad & Hilchey, 2011). Frameworks can be both theoretical (having practical applicability) and conceptual (used to identify the “key components and relationships of a problem or system”) (Whitelaw, 2012).

3.3.1 Citizen Science Model

Of particular significance to this research is a citizen science model (outlined by Bonney et al., 2009) developed over the past two decades by a group of researchers from the Cornell Lab of Ornithology (CLO). The model consists of nine steps (outlined below), aimed at allowing project developers to fulfill recruitment, research, conservation, and education objectives (Bonney et al.,
2009) while simultaneously integrating data collection with public outreach objectives (Cooper et al., 2007). The model is thought to be a well-established methodology for the advancement of scientific knowledge (Cooper et al., 2007), applicable to both participant-driven (bottom-up) and scientist/institution-led (top-down) initiatives (Dickinson et al., 2012). As such, the model (along with various endorsements/critiques) has been cited by a number of citizen science researchers over the years (including Cooper et al., 2007; Dickinson et al., 2012; Newman et al., 2012). While the model (outlined in Bonney et al., 2009) is designed for science-based research, aspects of the model are particularly relevant for the definition of citizen science (and subsequent research) as presented here:

**Choose a scientific question:** Citizen science is ideally situated for answering scientific research questions related to environmental monitoring which spans large temporal and/or spatial scales (Bonney et al., 2009). Newman et al. (2012) suggest that mobile applications and social media may play a key role in stimulating discussion around research questions, by enabling real-time dialogue between participants and professionals.

**Relevance to research context:** Water quality certainly spans a broad temporal and spatial scale; the Umgeni River encompasses several cities and regions within the catchment area. In addition, mobile phone applications are a key aspect of many of the citizen science initiatives, including miniSASS and Mathuba (of which MSEP and Enviro Clubs are part). While lack of access to the Internet and technology act as barriers to citizen science (discussed in further detail in Chapter 4), growing interest and reliance on such technologies are an important aspect of citizen science in the South African context.
**Form a team (consisting of a scientist, educator, technologist, and evaluator):** Successful citizen science projects rely on multi-disciplinary teams (Bonney *et al.*, 2009), consisting of “academic, project management, and informatics infrastructures” (Cooper *et al.*, 2007, p. 6). Technological and informatics infrastructures can be used to “receive, archive, analyze, visualize and disseminate” data and results (Bonney *et al.*, 2009, p. 979). Additionally, technological advances can accelerate team formation by aiding in the identification and location of professional scientists, participants, and resources (Newman *et al.*, 2012).

**Relevance to research context:** Both MSEP and Enviro-Clubs are relatively multi-disciplinary (by the standards outlined here). Both initiatives include academic connections (largely through UKZN and Mathuba). In addition, the coordinators/facilitators from local environmental, community-driven organizations (DUCT and WESSA) act as project managers for MSEP and Enviro-Clubs. Lastly, technology and informatics infrastructure are a challenge, although the Internet (particularly Google Earth and the miniSASS portal for documenting water quality results) remains a key aspect of ongoing initiatives.

**Develop, test, and refine protocols, data forms, and educational support materials:** The quality and accuracy of data collection is dependent on three factors: clear protocols, simple, logical data forms (designed to prepare the data for analysis), and participant support, by way of educational support materials aimed at enhancing participant understanding of protocols (Bonney *et al.*, 2009). Cohn (2008) notes that “…protocols should limit what citizen scientists are asked to do…” (p. 194) so as to prevent creating protocols that fall outside participants’ capabilities and
skill level; educational materials, such as guidebooks, can help volunteers to understand and follow the protocols (Cohn, 2008).

**Relevance to research context:** This particular step is more relevant for science-based citizen-science initiatives however participants do undergo training for data collection (e.g. workshops, miniSASS training). Unlike Cohn’s (2008) definition of citizen science in which citizen scientist responsibility should be limited, the definition of citizen science used in this research emphasizes the need to include and place equal value on contributions from local, non-professional participants.

**Participant recruitment:** Participant recruitment constitutes an important step and should make use of a variety of communication techniques, such as press releases, public service announcements, e-mail/mail, etc. (Bonney et al., 2009). A successful project requires adequate citizen buy-in to ensure sufficient participation over the course of the project (Cooper et al., 2007).

**Relevance to research context:** Participant recruitment and retention is not particularly problematic for MSEP or Enviro-Clubs, as participants tend to be highly committed to the projects (turnover is relatively low). Although the number of participants involved in each initiative is relatively small, participants are highly dedicated.

**Participant training:** Participant training is essential for enabling participants to understand project materials and feel comfortable with data collection protocols; the development of
educational support materials is fundamental to this process (Bonney et al., 2009; Cooper et al., 2007).

**Relevance to research context:** From my experiences in the field, educational support materials were used in training participants, notably brochures (to provide contextually relevant information) as well as instructive videos (for conducting miniSASS).

**Accept, edit, and display data:** Data should be accepted, edited, and made available to both professional and public spheres for analysis (Bonney et al., 2009). In this regard, technology (including mobile phone technology) is particularly useful for enhancing the rate and quality of data collection (Newman et al., 2012, p. 299) as well as validation and transmission of participant findings (Dickinson et al., 2010; Dickinson et al., 2012). Indeed, Newman (2012) notes that a growing number of participants are willing to adopt new technologies and share their geographic location when conducting citizen science.

**Relevance to research context:** Data collected through MSEP and Enviro-Clubs is shared through existing networks of individuals working on similar issues and amongst community members. Additionally, participants use Google Earth to map the Global Positioning System (GPS) coordinates of problematic areas (which aligns with Newman’s claim regarding increased sharing of geographic locations amongst citizen scientists). With respect to enhanced quality and validation of participant observations, GroundTruth recently launched a website which is used to rapidly share and disseminate participant results as well as aid in the validation of participant-collected data relating to miniSASS (which forms part of both MSEP and Enviro-Clubs).
Analyze and interpret data: It has been noted that technological advances such as grid and cloud-computing enhance both data storage and analytic capabilities (Newman et al., 2012) while enabling participants to engage with and interpret the data more easily (Dickinson et al., 2010; Howe, 2006; Newman et al., 2012; Tulloch et al., 2013).

Relevance to research context: Through the use of Google Earth and the miniSASS portal, participants are able to engage with the data collected by other citizen scientists.

Dissemination of results: There are several methods for disseminating project results, including publication in academic journals and the creation of technical reports and online support materials for policy- and decision-makers (Bonney et al., 2009).

Relevance to research context: Presently, some effort is being put forth with respect to disseminating project results (primarily through DUCT and WESSA). It would be useful for data to be further disseminated through organizations such as the Water Research Commission (WRC) by way of technical briefs/reports, as well as academic publications. However, there are challenges surrounding academic publications and citizen-generated data (outlined in Section 3.5.4).

Measure outcomes: Measuring project outcomes enables project developers and participants to determine if scientific and educational objectives have been achieved (Bonney et al., 2009).
Shirk et al. (2012) argue that in order for a project to yield specific, measurable outcomes\textsuperscript{37}, it is necessary to “begin with the end in mind” (p. 12) and to understand what exactly the project aims to achieve.

\textbf{Relevance to research context:} Presently, there aren’t specific protocols in place to measure participant and project outcomes. However, one of the key aims of this thesis is to provide a measure, or indication, of Theory U (and social learning) amongst participants as an outcome of citizen science. The underlying premise of the research seeks to measure the impact of citizen science by exploring the occurrence (or lack thereof) of Theory U amongst citizen scientists.

\subsection*{3.3.2 Community-Based Monitoring}

While this research is focused on citizen science, it is pertinent to include some discussion on CBM, which is closely related to the type of citizen science being conducted in the uMngeni catchment area. There are several approaches to CBM. Of relevance to this research is advocacy monitoring (Whitelaw, 2003), also known as bottom-up monitoring (Conrad & Daoust, 2008), and transformative governance (Conrad & Hilchey, 2011; Lawrence, 2006). Advocacy monitoring focuses on an existing local, community concern where monitoring and data collection are used to initiate governmental action (Whitelaw, 2003) or influence the decision-making process (Conrad & Daoust, 2008). Advocacy monitoring is therefore, not dependent on the government/private sector, but instead relies largely on community members and non-governmental organizations (NGO) (Whitelaw, 2003), as is the case in Mpophomeni.

\textsuperscript{37} Socio-ecological project outcomes may include: improved relationships (between communities and project managers), increased access to data that can be used to mitigate environmental degradation, and a greater “likelihood of participant engagement in policy processes…” (Shirk et al., 2012, p. 9).
Furthermore, emphasis is placed on action, specifically, moving beyond data collection and awareness to encourage and implement action on a specific issue(s) (Carr, 2004; Shirk et al., 2012; Whitelaw, 2003).

There are both advantages and disadvantages associated with adopting a bottom-up governance strategy for CBM. Citizen scientists are involved in all stages of environmental monitoring, from problem definition to the communication of results and any subsequent action\(^{38}\) (Conrad & Hilchey, 2011). Additionally in communities with limited access to the decision-making process\(^{39}\), bottom-up multi-party CBM can be more effective in terms of credibility and local compliance than top-down, formal regulation (Pollock & Whitelaw, 2005). Indeed, public participation in natural resource management responds to local community needs (Cooper et al., 2007; Shirk et al., 2012) and promotes ownership and accountability amongst those involved (Shirk et al., 2012). In this way, bottom-up governance aligns with multi-stakeholder collaboration and systemic change by encouraging collaborative construction of the problem, in addition to empowering individuals who may not otherwise have the opportunity to access/influence the decision-making process.

Indeed, integrating “experiential learning with scientific and technical knowledge” (p. 360) can prove difficult (Conrad & Daoust, 2008). To overcome this, the authors suggest establishing

\(^{38}\) In this respect, advocacy monitoring is ideal for water-quality monitoring, as it only requires “a small group of local citizens” (p. 278) rather than a large group of “far-flung” participants to collect data (Conrad & Hilchey, 2011).

\(^{39}\) This is contextually relevant to South Africa and the ongoing citizen science efforts within the uMgeni catchment area; many citizen scientists have expressed frustration at the lack of government (municipal and national) involvement in water quality issues in the area. Furthermore, it has been noted that many of those involved in citizen science do not have a voice that is heard or respected by the political system.
interdisciplinary, multi-stakeholder groups in order “to consider the issues, perceptions, and problems of the broad community” and ultimately establish “networks, trust, and relations” across several sectors of society (Conrad & Daoust, 2008, p. 360). As a result, although challenging, multi-party CBM is currently on the rise as it has the potential to afford citizen scientists greater influence over the decision-making process by promoting increased collaboration amongst affected stakeholders and concerned citizens (Conrad & Daoust, 2008; Whitelaw et al., 2003).

While the benefits of multi-party CBM and advocacy monitoring are significant, there are also notable disadvantages with adopting this approach. Advocacy monitoring may be appropriate in certain circumstances, but it is generally unsuccessful due to the fact that there are often “no comprehensive environmental laws or policies to remediate the concern” upon which the CBM group is focused (Conrad & Daoust, 2008, p. 359). The authors note that without an existing framework or structure to enable multi-stakeholder collaboration, the likelihood of CBM groups initiating such action is minimal as organizing such efforts diverts resources away from monitoring, and often results in compromised data quality and loss of volunteer interest (Conrad & Daoust, 2008). The South African context is slightly different; the challenge lies not in the establishment of water management policies, but rather the implementation of said policies. Thus, advocacy monitoring – the type of citizen science currently being conducted in Mpophomeni - may be an important mechanism for initiating action around, and strengthening, existing legislation.
3.4 Advantages of Citizen Science

The current literature highlights a number of relevant advantages associated with citizen science including the democratization of science, contribution to environmental literacy, and capacity to aid in government environmental monitoring.

3.4.1 Science: Trust & Democratization

“...lay trust in science is often conditional and marked by ambivalence” (Healy, 1999, p. 660)

“Science is increasingly accepted as both partial and incomplete, a sometimes privileged but forever limited body of knowledge” (Robertson & Hull, 2001, p. 972)

Science is often regarded as a universal truth (Robertson & Hull, 2001), a “systematic, rigorous, powerful, and prestigious method of analysis” (Carr, 2004, p. 844). And yet, there can exist a lack of trust in science (most often when the basis of a scientific claim is believed to have been compromised). Citizen science can help rebuild loss of trust by the general (lay) public in science/scientific institutions (Carr, 2004; Healy, 1999; Robertson & Hull, 2001). The re-establishment of lay trust in science first requires the public’s trust in “the institutions and procedures” that validate science (Healy, 1999). Thus, the ability of citizen science to encourage the democratization\(^{40}\) of science and foster collaboration between lay people and scientists is particularly pertinent.

\(^{40}\) Democratization of science is difficult to measure, but the process of democratizing science often means that those citizens most affected by the outcomes are largely in control of the data collection and processes driving such outcomes (Carr, 2004; Dickinson et al., 2010).
Within the context of this research and environmental decision-making, the democratization of science can be defined as “making environmental science and expertise more accessible to the public while also making scientists more aware of local knowledge and expertise” (Conrad & Hilchey, 2011, p. 280). Moreover, the democratization of science includes the rights of citizens to be involved in the environmental decision-making process, thus enabling alternate perspectives to influence scientific processes resulting in knowledge that is more robust (Carolan, 2006; Carr, 2004). Carolan (2006) argues that increased complexity should be addressed by increased democratization of science, a statement which is particularly important given the complexity of contemporary environmental problems. Science is regarded as the “cognitive authority in the modern world” (p. 971), yet science alone cannot determine decision-making goals and objectives with respect to conservation (Robertson & Hull, 2001). Rather, citizen science - which includes a means for evaluating how effective the knowledge it creates is at influencing environmental decision-making – should be employed (Robertson & Hull, 2001).

In addition, citizen science influences the manner in which environmental issues are “problematized and prioritized” by promoting active participation in broad-scale, societal-level environmental problems (Carr, 2004). Citizen science contributes to the democratization of science by increasing collaboration, and thus knowledge-sharing, between experts and non-experts alike (Conrad & Hilchey, 2011; Cooper et al., 2007; Pollock & Whitelaw, 2005); it is a mechanism for involving multiple different stakeholders resulting in the expansion of existing knowledge bases (Shirk et al., 2012). The democratization of science is an important consideration within the context of the research as a result of its ability to improve knowledge, education, and awareness around environmental issues such as water quality.
The evolving relationship between citizens and scientists is further aided by the proliferation of technology, which can act to shift more and more responsibility away from an elite minority of professional researchers to a vast majority of everyday citizens (Newman et al., 2012). As Lakshminarayanan (2007) notes, citizen science should strive to “move away from using citizens on unequal terms and toward treating citizens as scientists on equal terms” (p. 2). Technology, with its ability to connect the laboratory to the natural environment (e.g. wireless networks) increasingly enables citizens to conduct data collection (and analysis) in partnership with professional researchers; indeed, citizen science may become a part of citizens’ everyday lives (Newman et al., 2012).

Technology may increase participant diversity and blur the lines between science and citizen science, but it is important that adequate consideration and sensitivity still be awarded to factors and projects that rely on local and/or traditional ecological knowledge (Newman et al., 2012). Within the context of this research, consideration need be given to Zulu culture and traditions. It is the result of these cultural traditions (beliefs, behaviours, practices) which impact water quality, yet it is also an understanding of, and respect for, these traditions which enables one to connect with individuals of that culture, in hopes of remedying the current water quality situation.

Related to the democratization of science is the idea that citizen science has the capacity to build social capital within a community (Conrad, 2006; Sharpe & Conrad, 2006): social capital facilitates increased trust amongst community members (Conrad & Hilchey, 2011; Pretty, 2003).

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41 Social capital can be defined as activities and practices that enhance social and human networks and relations, improve mutually beneficial [cultural, social, natural] resources, and ultimately improve the wellbeing (Jordan et al., 2012; Whitelaw et al., 2003) and education of the community at large (Conrad & Hilchey, 2011).
and increased trust by community members in societal systems/institutions\(^{42}\) (Jordan \textit{et al.}, 2012).

Citizen science can help increase social capital (Pollock & Whitelaw, 2005) through the use of “…activities that engage volunteers, create agency connections, strengthen existing institutions, develop leadership capacity, solve problems, and identify community and resource values that would otherwise be overlooked” (Whitelaw, 2003) in order to promote collaboration amongst stakeholders (Conrad & Daoust, 2008) and ultimately, support local sustainability initiatives (Pollock & Whitelaw, 2005). Healy (1999) argues that “public ambivalence to science and expert skepticism of lay perspectives” (p. 668) result from institutional failings. Thus, one might argue that the facilitation of mutual trust is an important component of systemic change, specifically the reconceptualization of ineffective systems, like water management/quality within the uMngeni catchment area.

### 3.4.2 Environmental Literacy

The potential for citizen science to contribute to scientific and environmental literacy is one of the most common themes outlined in the literature. Given that lack of education and awareness (surrounding water quality issues) is well acknowledged amongst citizen science participants in uMngeni, the correlation between citizen science and environmental literacy is particularly relevant to this research. Scientific and environmental literacy is a growing concern (Trumbull \textit{et al.}, 2000). Of greater significance is the fact that literacy in the \textit{environmental} field is particularly poor (Jordan \textit{et al.}, 2009) and yet environmental literacy is essential for making

\(^{42}\) Thornton & Leahy (2012) found that interactions between citizen scientists involved in water quality data collection and community members not involved in citizen science resulted in increased trust (interpersonal trust) by community members in citizen science-generated data.
informed decisions (Brossard et al., 2005; Dickinson & Bonney, 2012; Dickinson et al., 2012; Jordan et al., 2009). It is also necessary for understanding complex environmental issues and making sense of environmental misrepresentations (Dickinson & Bonney, 2012).

In order to address this discrepancy, Jordan et al. (2009) suggest that an environmental literacy baseline can be achieved if education and awareness is extended beyond academically defined information and textbooks, to include a more multi-disciplinary approach (Jordan et al., 2009). Citizen science is well suited for achieving this. In comparison to the general public, citizen science participants tend to exhibit greater knowledge (Brossard et al., 2005; Jordan et al., 2011; Phillips et al., 2012), skill, and a more positive attitude towards science and the environment (Newman et al., 2012); this is supported by the research findings (discussed in Chapter 4) which provide evidence of increased environmental education and awareness amongst participants.

Furthermore, Cooper et al. (2007) argue that participatory research can improve collective community knowledge and awareness of environmental concerns. The community of Mpophomeni is in the midst of this transformation as citizen scientists share the knowledge they’ve gained through participating in citizen science. Through active participation in citizen science, participants gain a better understanding of their role in the environment while contributing to existing scientific and environmental knowledge bases (Conrad & Hilchey, 2011). However, in order for citizen science to be effective at improving scientific and environmental literacy, environmental education goals must be deliberately integrated into the project model/design (Dickinson et al., 2012). While many citizen science projects encourage participants to use critical thinking skills (Dickinson et al., 2012), evaluation of participant
learning outcomes should be explicitly included in the project design and used as a metric for determining project success\textsuperscript{43} (Jordan \textit{et al}., 2012; Phillips \textit{et al} 2012). As such, striking a balance between improved participant literacy and any remaining project research objectives is essential (Cohn, 2008; Cooper \textit{et al}., 2007; Jordan \textit{et al}., 2012).

Indeed, it has been argued that the most effective citizen science projects do both: enhance environmental literacy amongst participants, while still contributing valuable data and research to the project itself (Silvertown, 2009). Havens & Henderson (2013) note that education and data collection are not mutually exclusive, volunteers gain scientific/environmental knowledge by participating in citizen science projects, and subsequently, the satisfaction of knowing that their data is contributing to the advancement of scientific knowledge (e.g. academic publications) fosters continued interest in the learning process. Indeed, citizen scientists are essential in helping researchers to answer “real world” questions (Cohn, 2008, p. 193), and it is this same collaboration which in turn motivates participants, and ultimately provides more “robust learning outcomes” (Dickinson \textit{et al}., 2012, p. 295).

\subsection*{3.4.3 Government Monitoring & Legitimacy}

There has been growing concern over recent years, regarding governmental\textsuperscript{44} ability to conduct adequate environmental monitoring as a result of cutbacks (funding, staff) and lack of environmental expertise in the face of growing environmental uncertainty (Carr, 2004; Conrad &

\textsuperscript{43} Although Phillips \textit{et al} (2012) note that measuring citizen science outcomes is difficult and the best methodology for doing so is not yet fully understood.

\textsuperscript{44} In this instance, governmental ability relates to the Canadian government, however, the lessons and discussion are also relevant to the South African context.
Daoust, 2008; Conrad & Hilchey, 2011), a situation which is closely related to the lack of capacity which exists at the local level of government in SA. Thus, an added advantage of citizen science is its ability to supplement government monitoring (Carr, 2004; Conrad & Hilchey, 2011; Whitelaw et al., 2003) and improve the legitimacy and capacity of governmental institutions (Pollock & Whitelaw, 2005) by contributing to the quality assurance and quality control of monitoring data (Carr, 2004). As such, citizen science is ideal as it can occur during non-office hours and provide data for a large geographic area while fulfilling government monitoring objectives (Conrad & Hilchey, 2011; Whitelaw, 2003).

It is important, however, to emphasize that citizen science should be viewed as complementary to, rather than a replacement of, government monitoring (Whitelaw et al., 2003). In this way, citizen science data can highlight specific issues, warrant further investigation, facilitate option generation, and provide an indication of the efficacy of certain management decisions in achieving specified objectives (Whitelaw, 2003). While capable of providing valuable contributions to government monitoring, citizen science should not seek to assume governmental roles and responsibilities associated with environmental monitoring, but rather act to supplement government efforts.

3.5 Constraints & Best Practice

While there are several benefits associated with citizen science, there are also several constraints that have been identified in the literature. These include challenges around the recruitment and retention of participants (Conrad & Daoust, 2008; Whitelaw et al., 2003; Conrad & Hilchey, 2011), the acquisition of long-term funding (Conrad & Daoust, 2008; Whitelaw et al., 2003;
Conrad & Hilchey, 2011), and the collection and use of citizen science data (Conrad & Daoust, 2008; Conrad & Hilchey, 2011).

3.5.1 Recruitment & Retention of Participants

One of the downfalls to using citizen science to conduct research and/or monitoring is the need to recruit and retain participants over the long-term. Loss of volunteer interest is identified as one of the biggest challenges relating to citizen science (Conrad & Daoust, 2008; Conrad & Hilchey, 2011; Havens & Henderson, 2009; Whitelaw et al., 2003), yet participant retention is also an integral part of all citizen science initiatives, regardless of the nature or scope of the project (Worthington et al., 2012).

Retention of participants over the course of the project is particularly important as it reduces the demand on infrastructure required to continually market and recruit, and provides more reliable data collection; a core group of participants are able to gain advanced levels of experience and improved leadership capabilities (Cooper et al., 2007). Participant retention itself has not been overly problematic with respect to MSEP and Enviro-Clubs, although increased experience, leadership, and education as a result of long-term participation, has been a notable benefit.

Cooper et al. (2007) and Whitelaw et al. (2003) argue that establishing connections with existing community groups (non-profits, recreational groups, after-school programs, etc.) can be particularly effective at aiding participant retention and improving subsequent data collection; strong connections with local partners can improve the efficacy associated with project transfer (notably, participant turnover) (Cooper et al., 2007). Indeed, in a review of several Canadian
CBM projects, Pollock & Whitelaw (2005) found that affiliation with an institution (university, NGO, etc.) was fundamental to the successful implementation of a project. Furthermore, affiliation with an academic institution has potential to improve participant training and skills as well as increase access to information (Conrad & Hilchey, 2011) and enhance the likelihood of peer-reviewed publication of citizen science results (Cooper et al., 2007). Both MSEP and Enviro-Clubs (which is run as an extra curricular after school program) are affiliated with several organizations and institutions (ENGOs, non-profits, UKZN) within and around uMngeni Municipality; perhaps it is the result of such affiliations that has contributed to the long-term retention of participants and ongoing success of each initiative thus far.\(^{45}\)

Conrad & Hilchey (2011) and Whitelaw et al. (2003) suggest that challenges surrounding participant retention can be addressed using positive reinforcement and/or recognition of/feedback on volunteer efforts. Participant retention should be addressed in the beginning phases of a project when designing the framework or model. Working with a target audience and understanding the underlying motivation behind volunteer participation is helpful in designing data collection protocols and project objectives that match participants’ skill levels and interests (Conrad & Hilchey, 2011; Dickinson et al., 2012; Silvertown et al., 2013; Whitelaw et al., 2003) in order to create shared value (Dickinson et al., 2012) and keep participants engaged over the long-term.

\(^{45}\) It is worth noting that the Mathuba programme (of which MSEP and Enviro-Clubs contribute to) seeks to establish these kinds of connections amongst citizen science initiatives and individuals within SA. The energy, support, and inspiration gained from connecting with other individuals/organizations is invaluable when compared to the energy required to work alone.
Moreover, findings from Pollock & Whitelaw (2005) reveal that the establishment of project champions is highly effective in building capacity, improving project coordination, and disseminating results (and benefits) to the community at large. This has certainly been the case with the MSEP initiative in particular, as Enviro-Champs play an integral role in improving capacity and coordination amongst participants, in addition to enhancing education/awareness relating to project findings. Dickinson et al. (2012) note that various communication strategies – including occasional press releases, continual newsletters, blog updates, etc. – help build “a sense of community” (p. 296) and aid in participant recruitment and long-term retention. 

Lastly, Newman et al. (2012) argue that the collective capital resulting from the formation of collaborative teams (professional researchers and citizens) increases motivation and learning amongst participants. In this sense, technology has great potential to incorporate recreation into citizen science, making the process of “scientific exploration and discovery” (p. 302) more enjoyable for participants (Newman et al., 2012). Presently, access to technology (within the South African context) remains challenging, however, incorporating technology into citizen science where possible (e.g. Google Earth and Mathuba) has afforded participants insight into the global community to which they are contributing and has served as a point of pride amongst participants, particularly youth. Arguably, this has contributed to the enjoyment of participants’ experiences with citizen science.

46 While participant recruitment/retention are not particularly problematic in the context of MSEP/Enviro-Clubs, communication with citizen science participants can be difficult and is often facilitated through one or two key individuals who help arrange meeting times, upcoming activities, etc. It is, however, possible that the strategies outlined by Dickinson et al. (2012) may aid in communicating citizen science updates and results to the community at large, which may indirectly foster participant recruitment.
3.5.2 Funding

There is a growing need for funding agencies to recognize\(^\text{47}\) citizen science as an increasingly valuable and growing field; one which requires funding for participant training (Dickinson \textit{et al.}, 2012; Newman \textit{et al.}, 2012). Recognition and support for citizen science projects can also have a significant impact on helping to establish a dedicated group of participants (Dickinson \textit{et al.}, 2012) and combat challenges around participant retention.

Moreover, consistent funding is required in order to prevent the collection of inaccurate, fragmented data (Whitelaw \textit{et al.}, 2003) and to maintain project infrastructure and leadership (Dickinson \textit{et al.}, 2012). Given the growing emphasis on educational materials and improving environmental/scientific literacy, demonstrating a clear relationship between citizen science research and education can greatly enhance the chances of citizen science projects being funded\(^\text{48}\) (Dickinson \textit{et al.}, 2012). In order to help minimize funding constraints, Whitelaw \textit{et al.} (2003) suggest it wise to secure all necessary funding prior to the implementation of a project.

3.5.3 Data Collection

Due to the various levels of skill, ability, training and experience of citizen scientists, one concern regarding citizen science is the participants’ ability and capacity to conduct research comparable to that of professional researchers (Dickinson \textit{et al.}, 2010). However, this need not represent a

\(\text{47}\) Recognition can be achieved through the creation of an association of partners from all levels (“local, regional, national and international organizations, professional associations, and peer-reviewed journals” (p. 302)) whose aim it is to organize and support citizen science efforts (Newman \textit{et al.}, 2012).

\(\text{48}\) Funding for both MSEP and Enviro-Clubs remains an ongoing challenge. With education/awareness being a clear and demonstrated objective of each initiative, highlighting the educational component of this work may be beneficial with regard to future funding applications (recognizing that lack of funding may result from a lack of available funds rather than an unwillingness to fund these specific initiatives) in order to help mitigate this challenge.
significant barrier, and indeed some projects have provided thorough participant training, resulting in citizen scientists who are capable of conducting research akin to that of professional researchers (Bonney et al., 2014; Conrad & Hilchey, 2011; Fore et al., 2001; Sharpe & Conrad, 2006; Silvertown et al., 2013; Tulloch et al., 2013). Hence, obtaining funding for participant training is fundamental; deficits in participant training often result in increased bias or error in data collection (Dickinson et al., 2010).

Consequently, data collection often represents an important challenge in citizen science. Fragmented or inaccurate data and lack of objectivity can represent significant challenges in citizen science (Conrad & Hilchey, 2011; Pollock & Whitelaw, 2005; Whitelaw et al., 2003). This may be due, in part, to inadequate experimental design that does not account for accuracy in the data collection protocol (Conrad & Hilchey, 2011), an important consideration given that bias can vary significantly depending on experimental design (Dickinson et al., 2010).

Ultimately, it is important that the data collected or generated through citizen science is usable and of good quality. This is an important consideration, regardless of the nature (scientific or not) of the citizen science project. Data, irrespective of origin, that are not useful for key individuals, government officials, etc. will not be useful in influencing the decision-making process.

### 3.5.4 Use of Citizen Science Data

Two challenges emerge in relation to the use of citizen science data: lack of recognition of citizen scientists in peer-reviewed publications and an inability for citizen science to influence the decision-making process. Citizen scientists and the data they collect are seldom recognized in
peer-reviewed articles (Conrad & Hilchey, 2011; Dickinson et al., 2012; Fore et al., 2001), yet this is an integral aspect of citizen science (Havens & Henderson, 2009). Publication in peer-reviewed journals and other ongoing forms of communication\(^{59}\) (online reports, direct mail, etc.) are a fundamental part of the citizen science process and provide participants with important feedback regarding their results and data (Cooper et al., 2007; Worthington et al., 2012). It has been found that journal articles that cite volunteer collected data are uncommon\(^{50}\) regardless of the abundance of citizen science data presently available (Conrad & Hilchey, 2011).

In order to address this, Dickinson et al. (2012) recommend that researchers submitting articles for peer-reviewed publication acknowledge citizen scientists (and their contributions), along with an explicit description of each participant’s role in the project\(^{51}\) (recognizing that there may be challenges associated with the practicality/feasibility of doing so). To the best of my knowledge, publication of citizen science data is not yet a key consideration/objective for many of the ongoing citizen science initiatives within the uMngeni catchment area. However, as citizen science becomes more established, understanding the potential impact of peer-reviewed publications may be an important consideration for those currently involved in citizen science within uMngeni Municipality.

\(^{59}\) In addition to peer-reviewed formats, it is important to disseminate results using other forms of communication to provide participant feedback on the results (Worthington et al., 2012) and ensure “public understanding of the research outcomes” (Cooper et al., 2007, p. 447).

\(^{50}\) Academic papers citing volunteer-based research sometimes experience difficulty in getting reviewed for peer-reviewed publications because citizen science is not yet accepted (universally) as a valid method of investigation (Bonney et al., 2014).

\(^{51}\) Havens & Henderson (2013) outline various ways in which to recognize citizen scientists and their contributions, including a website containing: all participants and their contributions, updated data sets, summaries, site descriptions, and a request that any individual wishing to use the data provide proper credit to those responsible for collecting the data.
Moreover, citizen scientists have found that the data they collect are not being used to influence the decision-making process (Conrad & Hilchey, 2011). While the democratization of science enables citizen science to be used as a tool for informing local governments and influencing public debates and decisions (Whitelaw, 2003), Conrad & Daoust (2008) note that there is a general lack of interest amongst decision-makers with respect to using citizen science generated data. This is largely due to concern over the integrity of the data and an inability to provide citizen data to appropriate representatives (Conrad & Hilchey, 2011). Furthermore, there is concern amongst scientists and government agencies regarding the credibility and capacity (more specifically, the “non-comparability and completeness”) of citizen science data (Conrad & Hilchey, 2011, p. 281). In order to address concerns surrounding the validity and subsequent use of citizen science data, several authors have emphasized the importance of data validation (Cohn, 2008; Dickinson et al., 2010; Thornton & Leahy, 2012; Whitelaw et al., 2003).

Unfortunately, lack of trust in citizen science generated data limits the potential for citizen science to inform the decision-making process. Furthermore, as is the case in the South African context, lack of political will can act as a barrier preventing citizen science derived data from influencing the decision-making process (Conrad, 2006). Nonetheless, challenges surrounding data quality are not unique to the field of citizen science and should not be used as an excuse to disregard citizen-collected data (Dickinson et al., 2010; Szabo et. al., 2012; Tulloch et al., 2013). After all, “Citizen science is not perfect, but no data are” (Tulloch et al., 2013, p. 136).

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52 Communities participating in citizen science tend to have higher participation in local issues and community development, affording them greater influence over policy-makers (Conrad & Hilchey, 2011; Pollock & Whitelaw, 2005; Whitelaw et al., 2003).
Lastly, an additional challenge associated with citizen science and the decision-making process is the fact that stakeholders are not always interested in working with citizen science groups, unless there is an existing policy framework in place (Conrad & Daoust, 2008). This represents a significant challenge for citizen science groups hoping to influence decision-making bodies; participation by multiple stakeholders is necessary to inform policy, yet without existing policy, there can be little incentive for various stakeholders to participate (Conrad & Daoust, 2008).

In order to address this, and because many monitoring programs aim to influence the decision-making process, it is important to consider the type of information that is useful for decision-makers (and society) at the outset of the project/framework design process (Conrad & Daoust, 2008; Tulloch et al., 2013; Whitelaw et al., 2003). Conrad (2006) notes that citizen science often fails to influence decision-making processes when citizen science and policymaking are “developed apart…rather than emerging from within” (p. 26). Individuals expected to use citizen science generated data need to understand why/how it has been collected/produced (Conrad, 2006) and furthermore, the knowledge derived from citizen science should be clearly evaluated (by those who produce, review, and apply the knowledge) for its ability to inform policy (Robertson & Hull, 2001).

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53 Specifically, data/information should be “targeted and relevant to problems, accessible and understandable, usable and timely…[citizen science] information should suggest a course of action, allow decision-makers to weigh consequences, and make those involved feel they are in control of the problem” (Conrad, 2006, p. 34).
3.6 Conclusion

As a practice, citizen science has been around since before the professionalization of western science, but has experienced rapid growth over the last two decades. There are numerous advantages associated with the practice, including the ability of citizen science to facilitate the democratization of science, improve environmental literacy, and contribute to government monitoring and legitimacy. However, there are also a number of important challenges that warrant further consideration. These include ongoing recruitment and retention of participants, the acquisition of long-term funding, concerns over the quality of citizen science data, as well the use of citizen-generated data in influencing decision-making. Although there is much to learn in regards to overcoming such challenges, researchers have made great progress in terms of advancing the field and understanding the potential of citizen science to contribute to a number of research topics and projects, not least of which includes water quality.
Chapter 4: Results & Discussion

This chapter begins with a specific analysis of the findings, using Theory U as an analytical lens to answer the research questions and objectives. Emphasis is placed on understanding the extent to which citizen scientists undergo social learning and promote systemic change as a means of measuring the impact of citizen science within uMngeni Municipality and the greater uMngeni catchment area. The analysis is followed by a discussion on overall observations relating to the feasibility of citizen science as a solution to ongoing water quality challenges in SA. Finally, a conclusion and overall summation of the research, findings, and implications is included.

4.1 Empowerment

- Affiliated research objective: to understand if, and how, citizen science promotes empowerment amongst citizen scientists.

Empowerment is an important tenet of Theory U and social learning, and provides an indication of individual-level shifts in participant identity by highlighting an increase in participants’ confidence and ability to exert agency over water quality issues. In light of this, knowledge and leadership - two dominant themes to emerge from the findings, interviews, and discussions with citizen scientists – provide evidence of increased individual and community empowerment. Knowledge and leadership are two highly interdependent themes. For the purpose of the discussion, they have been separated to the extent possible; however, there remains a fair degree of overlap.
Knowledge

Increased knowledge as a result of participation in citizen science is a key indicator of empowerment at both the individual and community level. On an individual level, several citizen scientists note a change in behaviour after having gained an understanding of what comprises water pollution and an appreciation for the fact that solid waste (disposal into rivers and streams) and sewage both constitute pollutants. Citizen scientists no longer choose to participate in environmentally destructive behaviours and practices (such as disposal of rubbish [garbage, litter] into waterways) as a result of having a newfound understanding of the negative environmental implications of doing so:

- “...about 2 years ago, I didn’t care about the rivers. I thought: ‘Oh, stupid paper, let me throw it [in] the river.’ I didn’t know...what was going to happen if I threw that paper in the river...[but since] I’ve done this project, I think differently about if I [were to] throw this paper, what consequences [will] there be, you know. You [begin] to think differently, take your actions...[and] do them differently.” – Participant CSEC3

- “[My ideas] have changed ‘cause I didn’t know what animals you find in polluted water and in clean water. It’s helped me a lot to know about the water and why [it is] important and why we must keep it [clean] and [not] block the toilet that [causes] the spilling manholes. At first I didn’t know anything about spilling manholes, I just said ‘Water is water, it can be purified’, but now I have experience.” – Participant CSEC9

Not surprisingly, knowledge gained through citizen science has fostered an environmental ethic amongst citizen scientists:

- “I have learned not to look down on environment, but to love it.” – Participant CSEC4
• “...once you...experience that...[something]...is...not working...for the environment, you want to do more to try and save the environment...That’s what I’m aiming for, to try and save the environment.” – Participant CSEC3

• “[It was] my first time to do miniSASS and it was good, nice, I loved it. I loved it because I never noticed there were so many beautiful creatures living in the water. I never knew about stoneflies, I only knew about fish and sharks...I [learned] a lot of information about water and water pollution.” – Participant CSEC10

This aligns with findings from the literature, in which one of the most consistently cited advantages of citizen science is the development of a stewardship ethic amongst individuals and communities involved in citizen science work (Conrad & Daoust, 2008; Conrad & Hilchey, 2011; Cooper et al., 2007; Whitelaw et al., 2003). Environmental stewardship results from an overall increase in exposure (of community members) to the environment (Whitelaw et al., 2003), often due to participation by “environmentally motivated citizens” who contribute to informal learning processes within the community (Cooper et al., 2007, p. 445). Due to its participatory nature, citizen science is ideal for increasing public understanding of, and support for, both science and environmental stewardship (Dickinson et al., 2012). This is indicative of social learning and empowerment as it could be viewed as evidence that citizen scientists are gaining a more systemic understanding of water quality (discussed in further detail in proceeding sections).

The establishment of a stewardship ethic often translates into a desire to help educate other community members about water quality and the impacts that they in turn may be having on
water resources, this is an example of an instance in which the acquisition of knowledge at an individual-level can be scaled up to result in community-empowerment:

- “We must have more workshops and we must educate the people who are not in the Enviro Club. We must educate them, have a meeting, a community meeting… [tell] them not to pollute water…” – Participant CSEC6

- “…what inspires me? I would say it’s the love for the environment. I would say that I’m very, very passionate about the environment, and the education that I’ve got now allows me to work more with communities. I would say I’ve gained more knowledge and I can use that knowledge in helping others.” – Participant CSEC7

- “You know, when I started the miniSASS with our water, I was like ‘Oh people are dumping in the water. How can we change that, you see, who will listen to us?’ But there’s going to be a change. If we can teach them, there will be a change. If we can teach them.” – Participant CSEC10

- “…we need a lot of people, a lot of people, like a whole community…We need a whole community to be educated and to educate other people. Education is the key because there is nothing that we can do without education.” – Participation CSEC10

As such, it is not surprising that the occurrence of intergenerational learning is well acknowledged by many of those involved in citizen science in the uMngeni catchment area: “We are important because the future depends on us as a young people. And at home, our parents depend on us ‘cause they didn’t go to school.” (Participant CSEC4). Intergenerational learning occurs when informed individuals (often members of Enviro-Club) are willing to share their knowledge, experience, and wisdom with other members of the community, notably adults and...
community elders (so that they in turn might embark on their own journey of social learning through the U movement):

- “We have to stop [water pollution] because it started with elders, you see. When they go and dump at the water, then those little ones [children] will also go and dump at the water...they learn from their elders...so if those elders could stop and we could teach them not to do so, they will stop. But elders have problems. If you...tell...an elder to stop doing it, he or she won’t listen. But if you...tell a young person, they will say ‘Mom stop doing that’ and the mother will become shy and she will stop...she will listen to the little ones.” – Participant CSEC10

- “…parents they don’t go to meetings where they will be educated. If school kids can be educated at schools, then come back home and tell their parents, it will be easier... Maybe if we can teach the older generations, then there will be no need to teach the younger generations ‘cause they will see their leaders, then they will follow their leaders.” – Participant CSMS1

However, intergenerational learning occurs both ways with some adult citizen scientists playing an important role in educating the youth (role models): “…even my kids...when they come from school, they say ‘I’ve seen another manhole spilling’... even ...they [can] see that this is wrong because ‘Daddy always tells us this is not right’...They always tell me ‘we’ve told them that Daddy says we shouldn’t litter, after...we’ve eaten, we should use the dustbin.’” – Participant CSMS2
Leadership

Leadership, resulting from increased knowledge can be seen as another key indicator of empowerment.

- “She see[s] her[self] as a leader because…[she] give[s] other people information, so that together, we can do more things and make our environment clean and make our city clean.” - Participant CSMS6

- “He’s a leader ‘cause…the community, especially the neighbours…rely on him…[the] information he’s getting…[from] DUCT and other organizations, he’s trying to disseminate to…community members and…neighbours; [information relating to] what they need to put [in] the toilet, [and] what they need to [do to] care [for] the stream, so [in terms of] that, he’s a hero.” - Participant CSMS4.

Citizen scientists highlight both the importance of leadership and self-identify as leaders within their respective communities as a result of participating in one or more citizen science initiatives. Based on responses from the interview process, the following characteristics (Table 2) are identified by citizen scientists as being important qualities for strong leaders/leadership.
Table 2: Characteristics of Strong Leadership as identified by Citizen Scientists in the Greater uMgeni Catchment Area

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Significance</th>
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<tbody>
<tr>
<td>Knowledge</td>
<td>“It means you are a leader 'cause you are helping other people [understand.]” – Participant CSMS3</td>
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<td></td>
<td>“I’m still studying, I’m gaining knowledge as I’m working. I’m learning as I go...That’s what makes me think...one day I will be a leader.” – Participant CSW1</td>
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<td></td>
<td>“[Be]cause I love seeing the environment and I love knowing more about the environment, [to] have more knowledge and to teach others. [That’s why] I see myself as a leader” – Participant CSEC6</td>
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<tr>
<td></td>
<td>“Yes, I’m a leader because I also teach my little cousins and niece that ‘you know, one day, you must be like me.’ Be enthusiastic, what they say at school...do it, be involved in the environment, do things that some people don’t think you can do.” – Participant CSEC9</td>
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</table>

Leadership requires one to use knowledge gained through citizen science to teach other community members about water quality problems and to help them understand how their behaviours may negatively impact water quality.
Additionally, increased knowledge enables accountability, specifically, holding individuals accountable for detrimental behaviours and practices, after having educated them on the negative impact of such actions. The ability of a leader to increase education and awareness amongst the community is one of the most dominant leadership traits to emerge from the research. Consequently, the definition of leadership (within the context of this research) must account for, in large part, the education of community members.

| Dedication, hard work, & initiative | “I see myself as a leader because even here at school, people just dump everywhere they like. But when I see someone dumping I just go straight to her and tell her please pick up your paper and throw it in the dustbin because we want to live in a clean environment. There are dustbins, so we should pick the papers and throw them in the dustbin...[T]hey were laughing at us when...we were sweeping and they were laughing at us ...saying we are wasting our energy by cleaning...because tomorrow it will be dirty again. We said, ‘No, it doesn’t matter, we are going to clean there.’” – Participant CSEC10  
“Yes [I am a leader] ‘cause I’m enthusiastic and I love working hard. I love working hard.” – Participant CSEC4  
“It will take a lot [to overcome water quality challenges] and it’s a great challenge, but I believe that if people show their interest and work very hard - ‘cause to make a change, it is not easy...especially getting people to be
"interested...some...people don’t care, [so] it will take a lot of work, hard working, group working, team working...to...really make a change.” – Participant CSEC1

Respondents identify dedication and hard work as characteristics that make them (citizen scientists) leaders within their own communities. Participants note that dedication and the ability to take initiative are particularly pertinent in the face of adversity or struggle; the ability to understand the importance of water quality and to continue working towards improved water quality conditions, even if/when others do not understand, is an important characteristic of good leadership.

<table>
<thead>
<tr>
<th>Consideration &amp; respect</th>
<th>“I'd say I see myself as a leader because of the decisions that I've [made]... a leader doesn't make decisions for himself only, or herself only. He is considerate of others.” – Participant CSEC7</th>
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<tbody>
<tr>
<td></td>
<td>Being considerate of other community members and respectful of other ideas when decisions are made in/around the community is a key aspect of strong leadership (note: according to Participant CSEC5, this is especially pertinent given that some community members may not feel that they have a voice politically. It is reasonable to assume that this</td>
</tr>
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</table>
sentiment also manifests itself when identifying the barriers to citizen science, where citizen scientists identify lack of government support as a key obstacle to improving water quality). Evident in both consideration and respect, as characteristics of leadership, is the idea of community wellbeing and fostering a sense of community, both of which emerge as dominant themes throughout the interview process.

### Encouragement

“...we need different people with different skills” – Participant CSMS7

A good leader is able to encourage other individuals to contribute their strengths and skills towards water quality work/projects.

### Role-model

“...And the people should learn from me. I have to lead by example, actually” – Participant CSEC2

The ability to lead by example and to act as a positive role model (particularly for youth) is a key attribute of strong leaders within the community.
While the definition of leadership, as conceptualized by respondents, may not necessarily differ before and after participation in citizen science, the way in which citizen scientists implement the different characteristics of leadership (outlined above) may indeed differ. A notable example of this, which can be inferred from the findings, refers to the way in which citizen scientists view themselves as role models within the community, choosing to partake in more environmentally-positive actions, rather than continuing to perpetuate detrimental patterns of behaviour as a result of acquired knowledge and the development of an environmental ethic:

- “[Now] I view it that, [I] as a person... need to clean up when I see the litter near the streams or near the river, just clean it.” – Participant CSEC2
- “I’d like to make a big change [in my community]... ‘cause I don’t see people interested in nature in my community. So I would like to firstly change that part. Work hard and get people interested. I think that if I could also be an example, you know, to other people, then other people would also like to change.” – Participant CSEC1

Leadership as conceptualized by citizen scientists (Table 2) addresses education and awareness, an important barrier to leadership in the community as identified by citizen scientists and those involved in water quality related work (outside of citizen science). This is most evident in the relationship between knowledge and leadership, with knowledge being a key variable for enabling leadership. Many citizen scientists remark on this relationship, noting that in gaining knowledge about water quality, they have begun to view themselves as leaders when previously they would not.

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54 It is, however, plausible that citizen scientists have gained further insight into leadership as a result of citizen science, allowing them to identify characteristics of leadership that they might not previously have valued as being important. The findings of this research do not, however, provide concrete evidence of this.
This is further supported by the fact that participants commonly identify a lack of knowledge as being the key obstacle preventing them from becoming leaders within the community: “I think the more I learn, I should teach other people” (Participant CSEC2). This suggests that in order for citizen scientists to view themselves as leaders, they must first acquire the necessary education that enables them to assume a leadership role, or at least feel capable of assuming a leadership role. As a result, the appearance of a learning-leadership cycle (as depicted in Figure 8) emerges from the findings. The learning-leadership cycle represents the process, as described by numerous citizen scientists, through which they have progressed since participating in citizen science: “My vision is that the more I teach people and the more I gain information, I think me and the other people should work together as one big family. The more we work together the more the problems get solved.” – Participant CSEC2.

The cycle illustrates an increase in one’s own knowledge (as a prerequisite for becoming a leader) prior to educating others, and ultimately facilitating collaborative learning and contribution towards improved water quality. Specifically, the cycle begins with the acquisition of knowledge (step 1) which is used to teach other individuals and community members (step 2) who then collaborate in order to work on water quality together, contributing to the overall improvement of water quality conditions. Between steps 2 – 3, individuals experience a change in attitude and behaviour as a result of acquiring knowledge. The cycle of learning is continuous as depicted by the progression of step 3 to step 1, in which the original individual or educator (leader) continues to learn from the others in the group. This enables the leader to gain a more complete understanding of the situation and is useful when continuing to teach others.
The following excerpts serve as illustrations of each respective phase of the learning-leadership cycle. Step 1-2: the acquisition of knowledge in order to educate other community members and individuals:
• “...to work with the environment is nice because we get more information... so that we can teach other people about the importance of environment.” – Participant CSEC11

• “I got interested in knowing a lot about nature because I saw that there was a lot that I didn’t know. And during this process I learnt a lot and my interest...is just to educate people more about it.” – Participant CSEC1

Leading to changed attitudes and behaviours:

• “...it’s a challenge indeed. But I’m sure if we can give [community members] more knowledge, maybe some would [change their attitude], some wouldn’t. But those that have changed their attitude would have contribute[d] towards water conservation.” – Participant CSEC7

• “Well I just see myself making a change...Like making people get interested in nature... maybe if more people are interested, then less water will be polluted.” – Participant CSEC1

Step 3-4: Collaboration to improve water quality:

• “...my feelings have changed. I feel more confident that I can dream again that maybe the future will be brighter ‘cause at first I [thought] ‘Uh people don’t care about this.’ But as I see more people being connected and interested, it makes me feel glad and I think there’s hope.” – Participant CSEC1

4.2 Social Learning

• Affiliated research objective: to understand whether citizen science promotes social learning amongst participants
4.2.1 Theory U and the U Movement

The aims and objectives of Theory U as a social learning technology have been described elsewhere (Chapter 2). The focus of this section is not to provide an extensive overview of the U movement, but rather to analyze whether or not citizen scientists engage with Theory U, and more specifically the seven leadership capacities necessary for progressing through the U movement. Such analysis is useful in providing an indication as to whether or not citizen science is conducive to promoting social learning amongst participants and provides a tangible mechanism for helping to measure the impact of citizen science.

In understanding participants’ progression through the U movement, it is worthwhile to recall that social learning (in this case) is a gradual, long-term process that may take several iterations through the U. Each iteration results in a deeper understanding of the issue at hand. As such, changes within an individual may go largely unnoticed until a certain threshold is reached, at which point the change becomes apparent; the buildup to this threshold or tipping point may be largely indiscernible (M. Dent, personal communication, May 2013). As such, evidence of citizen scientists’ progression through the U movement may be subtle (M. Dent, personal communication, May 2013).

Nonetheless, the following findings suggest that there is evidence of social learning occurring amongst citizen scientists. However, it should be noted that the discussion presented here is a general overview of citizen scientists’ progression through the U movement based on the collective analysis of all interviewees. Not all individuals progress through the U at the same rate, and indeed, different participants experience and process change at different rates. Thus, the
focus of this section is to provide a general indication as to whether or not citizen scientists are engaging with Theory U, rather than a detailed analysis of the rate at which each individual citizen scientists might experience change in relation to social learning.

Progression through the U requires an open mind, heart, and will. The beginning phases of the U are based on “facilitating an opening process” (p. 9), which requires an individual to possess an open head, heart, and will (Scharmer, 2013). This phase of the U progression is focused on addressing “the resistance of thought, emotion, and will” (Scharmer, 2013, p. 11). In contrast, progression through the second half of the movement requires the intentional reintegration of “the intelligence of the head, the heart, and the hand” (p. 11) through practical applications (Scharmer, 2013). This is a key aspect of Theory U, requiring a connection between the mind, heart, and will “as an inseparable whole” (Scharmer, 2009, “Forward”, para. 13). When this occurs, “there is a profound shift in the nature of learning” (Scharmer, 2009, “Forward”, para. 14). This results when an individual opens themselves up to learning and integrates other ideas and mental models into their own understanding; this process may include a change in behaviour following the consideration of a new mental model that suggests that a previously-held idea or behaviour is negative or dysfunctional (e.g. no longer disposing of foreign objects into household toilets or manholes).

Based on the interview process and responses from citizen scientists, progression down the left side of the U does not appear to be problematic. Indeed, citizen scientists clearly demonstrate characteristics of an open mind, heart, and will. Citizen scientists are open-minded in that they are receptive to new/incoming ideas and mental models that suggest that the current water quality
situation is problematic. This is a mental model which may differ vastly from that which they held prior to participating in citizen science:

- “I didn’t know there was water pollution, I… only [know] now that there’s sewage [in] the river, that’s water pollution, something I didn’t know. And also people littering, I didn’t think it was a bad thing, didn’t think it was polluting the [water], I thought it was supposed to be done like that.” – Participant CSD3

- “Actually I didn’t know that litter can affect the streams and can make the animals die because litter is just around…I actually learned that litter can pollute the streams and the animals can’t survive there.” - Participant CSEC2

This finding is particularly significant given the strong cultural context – as evidenced in the quote – which acts as a catalyst for certain environmentally unsound behaviours and practices. It is important to recognize that being receptive to vastly different mental models is not necessarily easy when one is immersed in a specific cultural context that propagates such behaviours and practices. Being perceptive to new ideas, suggests a willingness to recognize and adopt a new mental model in which previously held beliefs and patterns of behaviour are recognized as being detrimental to a water system which is already in poor condition.

In addition, citizen scientists also demonstrate an opening of the heart, noting that their hearts play a key role in guiding their environmental and water-quality related work. Although abstract, opening the heart is not “a sentimentality or an emotionality,” it is a means of activating a deeper emotional perception that aids in the transition from ‘downloading’ to ‘seeing’, as previously discussed (Scharmer, 2009, “Opening the Heart”, para. 1). Overwhelming evidence (from the
interviews) suggests that by conducting citizen science, participants are following their hearts. Specifically, they are able to demonstrate their love for the environment and the work they are doing, and express a desire to connect with and make a difference in the lives of other community members (recall community empowerment through knowledge and leadership). Participants emphasize that their actions, along with participation in citizen science, is driven by a heartfelt desire to make a difference and includes sentiments such as:

- “When I’m working with the environment, nature, I feel happy, my heart feels happy.” – Participant CSEC1
- “…in order for you to be successful, you’ve got to work with your heart….you’ve got to listen to it.” – Participant CSEC3
- “I’d say my heart guides me because if it wasn’t for [my heart]… maybe I would have done something else, [gone] into a different field, but my heart is within the environmental sector.” – Participant CSEC7
- “…use your heart…People love you because your heart is open… I achieve my vision [with an] open… heart.” – Participant CSEC11

Lastly, citizen scientists demonstrate an open will by clearly indicating a desire to act on the new knowledge (ideas and mental models) that they have gained from citizen science, in order to bring about a change in relation to water quality, whether through altering personal behaviours or educating others within the community. However, based on the interview process and research findings, the journey back up the right side of the U is slightly more problematic.
While citizen scientists possess the will to act, this is made challenging by the presence of two prominent barriers: lack of education/awareness as well as an inability to work collaboratively with government officials in order to influence decision-making. Citizen scientists demonstrate the will to overcome lack of education as a barrier (e.g. recognition of the need to educate other community members), but the inability to work with government officials remains an obstacle for implementing large-scale environmental change, and hinders citizen scientists’ visions for an improved water future:

- “You know, my goal…is to see South African water clean, people drinking clean water…And... our streams [will be] protected, yes, and all the creatures which live in water...[won’t] die...the next generation [will] know that there [is a] thing called a leech, a stonefly.” - Participant CSEC10

- “OK, you see for me, the future I see it [being] different, very different, from the past. I see in the future, people being more interested [in] what God actually gave us [whereas]...in the past they were not interested...I see the animals being happy, our people participating in cleaning the water...and I see the plants growing beautifully. I just see the future being completely different from the past. And the future generations...telling them the story [of how] it used to be like this, making it hard for them to actually believe.” – Participant CSEC1

4.2.2 Leadership & Social Learning

Leadership requires a shift in the innermost place from which we operate (Scharmer, 2009). It is an integral part of Theory U and especially important under conditions of turbulent, systemic change (Scharmer, 2009). Because innovative change requires new ways of doing things,
leadership should not be limited to top-down directives\(^5\) (Scharmer, 2009). This type of leadership occurs when individuals let go of “established ideas, practices, and even identities” (Scharmer, 2009, “Forward”, para. 15). Consequently, leadership constitutes an important gauge for understanding whether and to what extent citizen scientists may be engaging with the U process and warrants further discussion in relation to citizen science, leadership, and the U journey.

The first half of this section – understanding citizen scientists’ progression through the U – requires an indirect assessment of whether or not citizen scientists are engaging with the seven leadership capacities required for Theory U, as outlined by Scharmer (2013). This discussion aims to compare leadership as conceptualized by Scharmer with that of citizen scientists (previously identified) in an effort to understand if aspects of Scharmer’s seven leadership capacities are present in the way leadership is currently conceptualized and enacted by citizen scientists (Table 3).

\(^{55}\) Indeed, a leader is someone who actively participates in creating change and shaping the future regardless of formal/institutional titles or positions (Scharmer, 2009).
Table 3: Characteristics of Leadership Required for Theory U as Compared to Leadership as Conceptualized by Citizen Scientists in the uMngeni Catchment Area

<table>
<thead>
<tr>
<th>The seven leadership capacities of Theory U as outlined by Scharmer (2013)</th>
<th>Leadership as conceptualized by citizen scientists in the uMngeni catchment area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Holding the Space: a leader must create a space that invites others to contribute, facilitating a co-construction of the problem(s) (Scharmer, 2013).</td>
<td>These sentiments are evident in citizen scientists’ emphasis on the need to be considerate of other community members and ideas, particularly during the decision-making process.</td>
</tr>
<tr>
<td>2. Observing: arresting judgment and observing with an open mind in order to “create a new space of inquiry and wonder” (Scharmer, 2013, p. 9).</td>
<td>Emphasis on community wellbeing and the need to foster a sense of community, as well as the desire to improve and conserve water quality for future generations align with cultivating the capacity to both love and appreciate. Additionally, having a “love for the environment” as</td>
</tr>
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cited by many respondents also contributes to the cultivation of love and appreciation.

4. Presencing: identifying and connecting with “the deepest source of your self and will” (p. 10) in order to begin to act; opening the heart allows one to “see the situation from the whole” (p. 10), while connecting with one’s will allows one to act from the whole (Scharmer, 2013).

Emphasis on knowledge and accountability as a result of educating other community members, as well as resultant changes in behaviour amongst individuals all relate to the idea that individuals are acquiring new mental models and a different understanding of the water quality context, and beginning to act accordingly.

5. Crystallizing: engaging with the ‘power of intent’ so as to realize (crystallize) the purpose or intent of the group; a committed group with a specific intent “begins to attract people, opportunities, and resources” in order to achieve their goal (Scharmer, 2013, p. 10).

The need for dedication, hard work and initiative amongst strong leaders (as outlined by citizen scientists) is resonant of crystallizing or focusing the intent or purpose (to improve water quality) of the group. In order to establish one’s purpose, and open oneself up to opportunities and resources in order to make that purpose a reality, dedication, hard work and initiative are all necessary attributes.

6. Prototyping: the intentional reintegration of the intelligence and

The intentional reintegration of the head, heart, and hand relate to the
lessons that have been learned in moving down the left side of the U (Scharmer, 2013). Specifically, prototyping involves the reintegration of “the head, the heart, and the hand in the context of practical applications” (Scharmer, 2013, p. 11).

<table>
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<tr>
<th>movement back up the right side of the U. Knowledge (as part of leadership) speaks to the importance of teaching others, which results in changed attitudes and behaviours. In this way, the knowledge aspect of leadership encompasses the entire movement through the U (which is required in order to implement change, or enact the knowledge that has been gained). Thus, citizen scientists recognize that at some point, reintegration of the head, heart, and hand is necessary for bringing about change or action, although they might not explicitly think about it or express the process in those terms.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Performing: the final leadership capacity involves performing, or putting together all that has been learned up until this point. It requires a leader who is able to assemble the right set of individuals, along with a social technology (such as Theory U) that enables a multi-stakeholder group to collaborate on the implementation of meaningful action (next A strong and positive role model as well as the ability to encourage others to contribute their strengths and skills is fundamental for convening the right people to co-create the problem.</td>
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steps) that have been co-constructed/co-created (Scharmer, 2013).
Comparing Scharmer’s definition of leadership with that of citizen scientists’, it appears that many aspects of the seven requisite leadership capacities are evident in the way that citizen scientists currently define leadership. While the exact order of citizen-science based leadership may not mimic the order of the seven step progression as put forth by Scharmer, the appearance of these characteristics is nonetheless significant as it suggests that citizen scientists have/are identifying specific characteristics and traits of leadership that are conducive to social learning and systemic change.

This is suggestive of the fact that citizen scientists are burgeoning into the types of leaders that are necessary for Theory U and the occurrence of social learning and systemic change. This is particularly significant as it reinforces the notion that barriers to social learning (as previously identified: lack of education and government support) are external as opposed to internal (which would require an individual-level shift); citizen scientists already possess the leadership qualities necessary for social learning. In this sense, the presence of external barriers to social learning may be a good thing as it is (arguably) harder to overcome internal barriers and evoke a personal shift (growth, learning) in individuals than it is to overcome external barriers. Indeed, many citizen scientists are already acting to overcome external barriers by increasing their knowledge, educating those around them, and viewing themselves as empowered individuals able to act on water quality issues despite the presence of government obstacles (e.g. lack of government support) (discussed in Section 4.5): “[Be]cause I love seeing the environment and I love knowing more about the environment. [To] have more knowledge and to teach others. So I see myself as a leader.” – Participant CSEC6.
4.2.3 Systemic Understanding

Systemic understanding is an important part of the U journey and deepening one’s understanding. The interviews suggest that many citizen scientists have gained a more systemic understanding of water and the subsequent need to improve water quality as a result of their participation in (and specifically knowledge/education gained from) citizen science:

- “I only knew that clean water comes from the tap… You use water from the tap, you don’t have to take care of water… which is in the streams…But come to think about it, the water… we use that comes from the tap is determined by the streams.” - Participant CSEC3

- “…sometimes it breaks my heart to see…water being polluted because when we’re doing… miniSASS, we always find the condition [to be] bad…And I always worry about the animals living there, the plants near there that are using the same water, and the people that…use that water. ‘Cause here in Howick…there are people…using the water, the river water…[that] comes from Midmar and Midmar is the place that is being polluted, you see… I…worry about the health of people, the health of animals, and everything.” – Participant CSEC1

Specifically, it appears that the establishment of an environmental ethic has enabled citizen scientists from MSEP/Enviro-Clubs to acknowledge the importance of water for survival, and emphasize a duty and responsibility to care for, and respect, water resources and the environment as a result of gaining an understanding of the importance of the environment. In light of this, it appears that many citizen scientists have adopted a more systemic view of water resources. Sentiments describing the need to stop behaviours that enable ongoing pollution because of the
impact they have on water - which is essential for our survival - suggest that citizen scientists have gained a better understanding of where they as individuals are located within the larger natural system and how their individual-level impacts affect the larger system at play.

This shift in perspective is also evident in the way that some (not all) citizen scientists emphasize systems thinking at the community-level. Participants identify and understand the greater influence that Mpophomeni has on other communities, most directly through the contamination of Midmar and subsequent impacts on other communities, cities, and towns. Additionally, some participants refer to the notion that what happens upstream has an influence on those downstream: “...what happens upstream has an effect downstream” (Participant CSEC7). Unlike this particular respondent, many citizen scientists don’t explicitly acknowledge this ‘upstream-downstream connection’ in reference to themselves or their work. However, it might be inferred from the way that citizen scientists discuss progress in Mpophomeni with regard to water quality and the importance of establishing connections with neighbouring communities/individuals so as to prevent unproductive actions downstream from counteracting improvement that occurs within Mpophomeni: “…because it’s...a stream...if we are cleaning the water here, but our next door neighbor up there is not, it will be of no use because the...[positive actions will be counteracted]. So I wish it could be a whole…” – Participant CSMS2.

4.3 Multi-Stakeholder Engagement

- Affiliated research objective: to understand if, and how, citizen science promotes multi-stakeholder connection, collaboration, and contribution to water quality-related work
From the interviews conducted with various citizen scientists, there is much evidence to suggest that citizen scientists acknowledge the importance of working together and connecting with other stakeholders. Indeed, the notion of working together (at different scales) is an idea that is emphasized by a significant portion of respondents. While the importance of connecting to others in order to overcome negative social constructs is outlined elsewhere (Section 4.4), the discussion presented here focuses primarily on the mechanics of working together, and the benefits that arise from such collaboration.

- “I think it’s…important when you’re working as a group because…when you work as a team…you [combine many]…minds and [come up with a lot of] new ideas. That can help a lot.” – Participant CSEC2

- “…we as people face different things and we think differently, but we have to try and [combine] our different thoughts. That’s [when] we come up with one strong [idea].” – Participant CSEC3

- “…it’s important to work as a group, ’cause if you work as a group you can do more things… You share the work and ideas…you bounce ideas off each other” - Participant CSEC6

- “It’s important when you work with the other people, not alone, because we can help each other. Like when we teach other people about the environment and [to] pick up all the papers…in our community.” – Participant CSEC8
More specifically, citizen scientists note the significance of being able to share ideas and resources\textsuperscript{56}, as well as draw inspiration from others when working together. In addition, respondents note that collaboration and the expansion of networks enables one to access, influence, and inspire more people; an observation that is particularly apt given the number of communities facing similar water quality challenges throughout SA, communities which may benefit from learning about the work that is being done in Mpophomeni: “...going to Mpophomeni and seeing what they’re doing there has really inspired me.” – Participant CSEC7.

4.3.1 Scale
Arguably, one of the most important aspects of working together is the ability to connect with individuals at various different scales, as outlined in Table 4. The opportunity to connect with others and share resources is closely related to Theory U; connecting with other stakeholders is required for progressing through the U, but also enables affected parties to develop potential mitigation strategies. In this sense, multi-stakeholder collaboration is important for enabling social learning and inviting others to join the movement in order to help co-construct the problem and ‘next steps’.

Table 4: The Advantages Associated with Multi-Stakeholder Connection at Various Scales

<table>
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<th>Scale</th>
<th>Advantage</th>
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\textsuperscript{56} This is particularly relevant within Mpophomeni (and similar communities/townships) in that resources (financial, supplies, academic/institutional knowledge) can be limited. Thus, collaboration with other interested and/or affected stakeholders can be invaluable in helping the community to implement positive environmental and water quality-related change.
Community-scale

The ability to learn from one another within the community by exhibiting good leadership qualities and leading by example (whether through individual-level action, or through a community project)

Local-scale

Increased opportunity to engage local government officials in a professional, rational, and compassionate capacity (rather than blaming Local and District government officials)

International-scale

The ability to connect with others via international environmental education and citizen science initiatives (e.g. Eco-Schools Programme, Orange-River Learning Box, and miniSASS)

4.4 Connections to Nature & Others

“...the reason we’re in such a mess environmentally is people have lost their connection with the Earth. They’ve lost the connection with their support system.”

-Participant CSD2

- Affiliated research objective: to understand whether or not citizen science provides a mechanism through which new connections with nature, the environment, and others might be established

Nature

Evidence of establishing [new] connections in nature is important as it provides some evidence of a shift in identity (e.g. the establishment of a stewardship ethic and the way that people view the environment and themselves in relation to the environment). Positive connections are particularly
important given the often-negative social context (e.g. social tensions, fractured relations) within SA. Thus, the establishment of new, positive connections can be seen as a way of challenging current social constructs, while also working to heal the fractured nature of many existing social relations.

Prior to examining the establishment of connections with nature, it is useful to provide a definition of ‘environment’ as conceptualized by citizen scientists. From the interviews and discussions, it was found that citizen scientists’ conceptualization of environment typically encompasses both anthropocentric and intrinsic sentiments:

- **Anthropocentric**: caring for the environment and working towards the conservation of water quality resources within the community, because we, as humans, rely on the environment and its resources (water). Community wellbeing is often cited in discussions where the environment is defined in an anthropocentric manner.

- **Intrinsic**: assigning intrinsic valuation to the environment, working towards the conservation of water quality resources within the community simply because water and the environment have an intrinsic and inherent worth that is separate to anthropocentric utility and value.

There is evidence to suggest that citizen scientists have experienced a shift in the way that they perceive and connect with the environment, regardless of whether or not the definition of ‘environment’ contains value-laden (anthropocentric valuation) characteristics. Some respondents identify intrinsic environmental worth as being a key incentive for participating in citizen science:
• “You know it hurts to see pollution in the water. Because there are creatures in the water, they live with water, water is their source of life...And if we pollute the water, they will die. They also deserve life just like us...they deserve to live in peace in their water, so we should not pollute the water.” – Participant CSEC10

• “What motivates me is that there are animals there that need to be taken care of. If us, we don’t take care of our environment, who is going to do that? The next generation won’t be able to see the environment if it keeps on [being] destroyed...” – Participant CSEC2

Whereas other participants tend towards an anthropocentric rationale for participating in citizen science, highlighting the need to conserve water quality for our own (human) needs. Sense of community wellbeing (including future generations) is often cited as a prominent characteristic in discussions where anthropocentric reliance on water is highlighted as a motivating factor for participation in citizen science:

• “…you’ve got to have time to think, ‘What if in a thousand years, this is all gone?’ the next generation won’t be able to see the beauty that I see right now. It will all be destroyed for the upcoming generation, just because I was [one] of the people who [was] destroying the environment. So you’ve got to be part of the people who are willing to fight for the environment, not destroy it.” – Participant CSEC3

• “…I care a lot because... some of the children love swimming, so I care for people, they swim in dirty water. And I care for some people that don’t have water. Some people don’t have water so they go and fetch it in the rivers. And if it’s polluted, there’s no water to drink...I care.” – Participant CSEC9
“I just want water pollution to be reduced, so that my family doesn’t get sick because I love my family. And as a world, we are also family, so I need to make water pollution clean.” – Participant CSEC10

“I just… want to achieve it for the next generation, so that they could drink our water, clean water, because if we do not achieve it, the water will always [be] a big issue.” – Participant CSEC10

While it might be argued that framing the environment in an anthropocentric manner can be counterproductive for sustainability and the conservation of water resources, emphasis on characteristics such as community and working with/for other South African citizens suggest that anthropocentric-related environmental connections may be equally important in helping to heal fractured relations and mitigate social tensions.

**Others**

“...I see myself as an Earth guardian...[a] person who was made to help people and to help environment issues, which is a big, important thing.” – Participant CSEC9

“...it seems like the environment is like a sub-culture that is being created and nurtured and that can be very powerful to also breaking down barriers in a social way whilst achieving environmental outcomes.” – Participant CSEC5

While the importance of multi-stakeholder engagement is outlined elsewhere, the focus here is on the importance of establishing new connections with others in light of a social context which can,
at times, be perceived as negative. Within the context of this research, environmental work and citizen science act to create a space where collaboration with others is possible in spite of the prevalence of social (gendered, racial, etc.) tensions in other sectors of society:

"I think that this process [citizen science] could eventually...[be a way of] opening up spaces in a town that was segregated before, and getting people from different parts of the South African community to collaborate on something in that town is potentially a very powerful way to break down barriers that still exist, and establish good power relationships: equality and mutual respect and cooperation. So to me the seeds are being sown for something really meaningful in other realms." – Participant CSEC5.

This is not to suggest that citizen science or environmental work is a solution for dealing with these longstanding, complex social tensions, but rather that engagement with such work affords participants an opportunity to connect, regardless of the presence of many social barriers in other aspects of society.

While there is no tangible evidence of this, it is plausible to suggest that many citizen scientists emphasize the need to work together and to collaborate on environmental issues as a result of having been given the opportunity (through citizen science) to experience the positive that can result from such racial/gender-neutral interaction:

57 As a result of SA’s complicated history, the legacy of apartheid is still prevalent in many aspects of South African society, resulting in high rates of crime and unemployment (as noted in Mpophomeni). In addition, due to the nature of Zulu culture, female-headed households are common, yet women are often faced with the threat of domestic violence and/or sexual assault. This is often exacerbated in townships where high rates of unemployment make it difficult for males to contribute in a positive manner to their families. Note: this is a broad generalization. While it is important to acknowledge the very real fear/threat of violence faced by countless females, it is equally important to emphasize that not all males within Zulu culture are violent or inclined to act in this manner.
...I used to believe that maybe male people... have [more] power... than female[s], but then again I see that male[s]... cannot do without female[s], female[s] cannot do without male[s], if we just put our different genders aside and work together we can make a difference.” – Participant CSEC1

...I don’t believe that girls belong alone and boys belong alone [separated]. Teamwork is important... because we don’t think in the same way, we think in different ways and that helps a lot. You can put your ideas [together] and come up with a big idea which can help a lot.” – Participant CSEC9

It is possible that this realization also contributes to the acquisition of leadership characteristics, amongst citizen scientists, necessary for engaging with social learning and Theory U. In other words, perhaps an understanding of the value of working together in order to overcome negative social constructs has contributed to citizen scientists’ ability to identify and define the characteristics required for good leadership.

In addition, understanding the power of overcoming negative social constructs may be a driving force behind participants’ desire to promote such leadership amongst individuals and the community at large (through education and empowerment). Understanding the power of connecting with others, despite the prevalence of negative social constructs in other aspects of society may be part of the reason that many citizen scientists already possess the characteristics necessary for progressing through the U.
4.5 Power Dynamics

- Affiliated research objective: to understand whether or not citizen science promotes a shift in power-dynamics with respect to how citizen scientists view themselves in relation to power and the power dynamics at play (notably, government-citizen relations)

Arguably, the most intuitive and noteworthy power relation, within the context of this research, is that which occurs between the government and citizens of SA. In this regard, citizen science has an important role to play in helping shift existing power dynamics, ultimately affording citizens greater agency over the decision-making process.

Such a shift in citizen agency and empowerment relates to concepts of citizenship and civic responsibility. Citizen science has the potential to support local sustainability initiatives (Pollock & Whitelaw, 2005), and encourage decentralized and more sustainable resource management (Bradshaw, 2003). Citizen science is rooted in specific locales with unique “political, cultural, environmental, and bio-geographical realities” (Carr, 2004, p. 845). As such, citizen science fosters an active citizenry whereby citizens/local agents who have the most impact on (and are greatly impacted by) local resources are given the agency to act on such resources (Carr, 2004). In this way, citizen science has the potential to challenge concepts of citizenship and “embrace a

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58 Local resource management is believed to be more sustainable because decision-makers are directly impacted by management decisions, site-specific solutions can be applied, and local management is better able to incorporate “superior local ecological knowledge and a vested interest in ensuring the survival of that place” (Bradshaw, 2003, p. 139). Furthermore, local citizens are well positioned to act on local issues, because they are more likely to possess “an ethic of care” and an underlying interest in maintaining their local environment (Carr, 2004, p. 842). Dickinson et al. (2012) also note the importance of place-based connections and experiences, resulting from citizen science.
more fluid, de-centred, and experience based- notion of both citizenship and expertise” (Leach & Scoones, 2003, p. iii).

In line with such concepts of citizenship and active citizenry is the concept that citizen science has the potential to help shift existing power dynamics between the government and citizens of SA by enabling participants (citizen scientists) to overcome ‘power roadblocks’. In other words, citizen science can be used as an alternate mechanism through which citizen scientists can overcome government obstacles to improving water quality. However, although the potential exists for citizen science to help shift existing power-dynamics to allow citizens to overcome government obstacles, my sense is that this shift is still in the process of occurring, and is more evident in some citizen scientists than others. As previously discussed, the process of social learning, is gradual and the build-up to the tipping point at which tangible change manifests itself may go largely unnoticed. The tipping point for overcoming current power dynamics has not yet been reached, as many citizen scientists emphasize the need for government intervention or support, citing that they felt ‘trapped’ (unable to implement large-scale change) without government support.

In other words, although some citizen scientists have experienced the empowerment necessary for overcoming government dependency, a greater number of ‘empowered’ citizen scientists are needed in order to reach this tipping point (in order to help shift the power balance in favour of citizens). Indeed, not all citizen scientists have undergone the necessary shift in identity that allows them to feel empowered enough to overcome the existing ‘government dependency syndrome’. This results in citizen scientists who rely solely on the government to address water
quality, with little confidence that other mitigation strategies might be used. Citizens do not yet feel as though they have agency to act on these issues.

Citizen scientists who identify government intervention/support as necessary for moving forward, tend to suggest that lack of government action is the barrier to improved water quality (hence, government dependency), whereas citizen scientists who have undergone this shift note that citizens and community members need to overcome government dependency ("...there’s a culture of treating themselves as a victims" - Participant CSMS9) to work alongside government in a mutually supportive and collaborative manner. The discrepancy between the two outlooks is subtle, but the latter suggests an increased confidence in the ability to act on water quality issues in the absence of government support and capacity, as well as an understanding of the importance of connecting with others and initiating multi-stakeholder action to address water quality concerns. In contrast, participants who have not undergone this shift state that in order to view themselves as empowered individuals capable of collaborating with government (rather than relying on government), they first need to further educate themselves.

Figure 9, which has been inferred and developed based on the interviews with citizen scientists, depicts the cycle through which participants progress as part of their social learning journey. The cycle illustrates the process through which citizen science allows for the acquisition of knowledge and ultimately empowerment amongst citizen scientists. Citizen science leads to increased knowledge, enabling participants to view themselves as both leaders and empowered individuals capable of collaborating with government in order to alleviate some (not all) government responsibility towards, and lack of capacity in relation to, water quality.
Individuals who tend to become trapped between the first two phases - Citizen Science and Increased Knowledge - do not feel that they have adequate knowledge to progress through the remaining phases of the cycle and thus do not feel capable of governmental collaboration. In these instances, the power balance remains skewed in favour of government. Consequently, individuals who are trapped at this phase of the progression tend to default directly to government, focusing on dependency rather than collaboration. In this way, they do not feel empowered enough to act on the problem in collaboration with government officials, but rather depend solely on the government to address and mitigate the degradation of water quality.

Figure 9: Citizen Science-Social Learning Progression.
The following interview excerpts provide evidence illustrate varying degrees of government dependency and individual-level empowerment:

- “No, [the situation] doesn’t improve because we haven’t told the municipality to come and fix the spilling manholes...I mean there are people who are clever who can fix [them], but I don’t think we can. I think the municipality can fix it...” – Participant CSEC9

- “…as young youth, as little people, working and being interested in nature and what is happening to Howick, I think that maybe... the government will see that if little people are interested, maybe we can also get other people, bigger people, interested...And maybe they will connect us out there and try to solve our problems.” – Participant CSEC1

- “…I would say that I have learned a lot from working with communities, the children, the general public like adults, I’ve learned...that sometimes you don’t need government to do things for you...” – Participant CSEC7

- “I think we still need [government]...’cause...what I actually want is...everybody to participate, do a part, you know, so...if everybody, the big people, the small people, could...combine, then we will make a change.” – Participant CSEC1

One notable obstacle associated with this research finding is the ability to engage with government officials. While citizen science can be used to supplement governmental water quality monitoring, it cannot and should not seek to replace government responsibility: “…what

59 This is supported by my experience as a researcher and aligns with the major limitation of this study: my inability to meet with or interview a representative from either uMngeni Local Municipality or UMDM.
is portrayed as ‘empowerment’ also can be interpreted as a shift of the burden of environmental monitoring to the citizen participant” (Lawrence, 2006, p.291). Thus, engaging with (not in place of) government officials is essential. Unfortunately, many citizen scientists and program facilitators emphasize the difficulty in engaging with government officials who are often unavailable to meet with, and listen to the concerns of, citizen scientists.60

Thus, a related and equally important aspect of using citizen science, as a mechanism to shift existing government-citizen power dynamics, is the potential for citizen derived data to influence the decision-making process, which can be an important and empowering process when government is unresponsive or unwilling to collaborate. Although some citizen scientists already view themselves as individuals with enough agency to collaborate with government, collaboration is reciprocal and requires government to be receptive to citizen input. Thus, an examination of whether or not citizen scientists and related data are currently influencing decision-making forms an important part of the research. Indeed, influence over the decision-making process is a very tangible way in which citizen science can help shift existing power relations.

Within the literature, an inability for citizen scientists to influence decision-making is identified as a key challenge. Thus, it is not surprising that my research findings and fieldwork experience suggest that data is not currently being used to influence the decision-making process, based on the current lack of government involvement in water quality. What remains unclear, however, is

60 While this inaccessibility makes it easy to blame the government for the seemingly apathetic disregard with which water quality concerns are met, it is prudent to remember that government officials are often constrained by their own set of challenges and institutional limitations (L. Taylor, personal communication, May 2013). While this remains an ongoing challenge, it provides additional support for the importance of collaborating with government (and other stakeholders) in order to implement large-scale systemic change in relation to water quality.
whether government has access to citizen-science collected data, but chooses not to use such data to inform decision-making, or if data simply aren’t making it to decision-makers in the first place. It is possible that aspects from each of these scenarios contribute to the degradation of water quality in the uMngeni catchment area. Nonetheless, influence over the decision-making process remains important as the potential for citizen science to shift the power from central to local agencies - by increasing community influence over resource management and environmental planning (Whitelaw, 2003; Conrad & Hilchey, 2011) - is a powerful tool in the hands of citizen scientists.

Although the use of citizen-derived data to influence decision-making may represent a challenge in the South African context, the ability of citizen science to promote agency, empowerment and active citizenry amongst individuals, is of utmost importance in helping sway existing government-citizen power dynamics; indeed, evidence of such empowerment has already been witnessed amongst some citizen scientists.

4.6 Feasibility of Citizen Science

MSEP and the Enviro-Club citizen science initiatives are the primary projects with which my research is affiliated, thus, the majority of my findings and conclusions are drawn from my fieldwork experience with the participants/coordinators of these two initiatives. As such, the discussion presented here is largely descriptive in nature, and aims to provide some reflection and insight into citizen science as a viable solution to contemporary water quality challenges in SA.

4.6.1 Local Impacts
Measuring quantitative change or improvement in water quality is a gradual, long-term process that is well beyond the scope of this research\textsuperscript{61}. Consequently, understanding whether and to what extent citizen science may prove to be a viable answer for long-term water quality improvement requires a qualitative examination of the impacts that citizen science has had on local citizens, communities, and resources thus far.

\subsection*{4.6.2 Education}

Arguably, the most tangible impact that citizen science has had on the local community is through the provision of education and awareness, a statement that appears to contradict previous discussions around education being a barrier to citizen science. Lack of education and awareness is a barrier to the outcome (improved water quality) that citizen science seeks to achieve, but this is not to say that citizen science as a practice does a poor job of providing education to its participants.

Indeed, citizen science fosters education; by default, implementing a citizen science project in the community increases awareness around water quality issues\textsuperscript{62}. Often, this occurs through intergenerational learning as youth (i.e. Enviro-Club participants) use the knowledge they have gained from participating in citizen science to educate their parents (and other family/community members) about water quality concerns. This is significant in light of the fact that indabas\textsuperscript{63} are

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\textsuperscript{61} Although many of the coordinators, facilitators, and other individuals involved in citizen science and environmental education acknowledge that water quality has continued to deteriorate over the course of their involvement in water-related work.  
\textsuperscript{62} Some citizen scientists became involved with various citizen science initiatives as a result of seeing other community members participating in citizen science.  
\textsuperscript{63} In Zulu culture, indaba refers to a community meeting.  
\end{flushright}
not well attended and subsequently, many of the adults in the community are not aware of current and ongoing water quality issues.

4.6.3 Government Capacity

In addition, citizen science – as a solution to water quality – helps address lack of government capacity. Citizen science contributes to the skill sector by addressing the lack of technical skill that often exists at the local level of government (WRC, 2013b) by building and strengthening environmental skills in citizen scientists, some of whom may go on to apply those skills in relevant government or environmental sectors, according to Participants CSW2 and CSW4. Citizen science helps to overcome the limitations associated with lack of government capacity/resources available for environmental monitoring. Citizen science increases the scope of monitoring efforts enabling water quality monitoring to extend well beyond provincial and even national borders (e.g. miniSASS and Orange River Learning Box are both water-quality related citizen science efforts that span national/international borders); after all, water doesn’t much care for political borders.

Additionally, Participant CSGT1 states that increasing monitoring networks allows for more efficient use of limited government resources by identifying hotspots and problem areas where limited resources can be used in a way that maximizes benefit. Indeed, several environmental protection and conservation agencies rely on data (including water quality data) collected by

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64 This point serves to emphasize the importance of youth, as they are most likely to pursue a career in a related [environmental/governmental] field and apply the skills they have gained through citizen science. This is promising given the fact that many youth are motivated to participate in environmental work because they view the environment as an opportunity to better themselves and to create a better life.
volunteers (i.e. citizen scientists) to target areas for protection (Bonney et al., 2014) and inform management strategies (Tulloch et al., 2013).

Moreover, citizen science has the capability to generate and improve both the availability and transparency of water quality data. Presently, as noted by Participant CSGT1, improving infrastructure and basic access to water is prioritized over environmental monitoring, thus government resources are allocated accordingly. In addition to educating participants, citizen science contributes to the generation and collection of water quality records, which have been somewhat neglected in the wake of municipalities’ focus on providing access to water according to Participant CSGT1. This has been greatly enhanced by the explosion of social media and various information technologies, all of which can be used to distribute and share information and findings with a variety of stakeholders, including government officials, even if they themselves are not able to participate in the collection of data according to Participant CSW4. Consequently, this has made citizen science an invaluable tool for generating and sharing water quality data.

Lastly, in relation to both education and lack of government capacity, communication of, and education on, the proper use of sanitation infrastructure is considered to be part of the governmental provision of basic sanitation services, government acknowledges that education is a key component of basic sanitation (SARVA, n.d.). Therefore, the provision of education is another mechanism by which citizen science is being used to fill a gap in government capacity by actively working to achieve an objective which the government identifies as being important, but has been (arguably) unable to effectively achieve.
4.6.4 Barriers to Citizen Science

While there are many benefits associated with citizen science as a solution to water quality, there are also a number of equally important challenges that warrant further discussion.

**Resources: Internet & Technology**

Access to Internet and technology comprises one of the greatest challenges relating to the implementation of citizen science in SA, the irony being that much of the citizen science literature credits the proliferation of the Internet as a key driver behind the rapid growth in citizen science. Nonetheless, citizen science is a useful tool for enhancing the availability and transparency of water quality data. Yet, lack of access to the necessary technologies, can act as a barrier to achieving this. However, limited access to resources has not stopped the implementation and success of current citizen science initiatives. Indeed, there are mechanisms for overcoming such barriers.

Access to computers/laptops and Internet within the community and schools is highly limited or nonexistent. However, many facilitators and coordinators have access to such resources and are willing and able to share such resources with citizen science participants, even though additional organization may be required in order to do so (e.g. meeting at an alternative location with Internet access). In addition, some citizen science initiatives (miniSASS) are experimenting with the idea of using cell phones and text messaging as the main system for data input, as noted by Participant CSGT1. Cell phone applications (e.g. iPhone applications) are becoming increasingly popular for citizen science based data collection (Silvertown et al., 2013), and a number of researchers acknowledge the growing importance/relevancy of the Internet, social networking.
and technological advances (e.g. customizable software) for citizen science (Triezenberg et al., 2012; Worthington et al., 2012).

While Internet access remains a challenge within the South African context, with the growing importance of technology, citizen science initiatives have, and will presumably continue to, find new ways of overcoming these obstacles.

**Financial Sustainability**

As outlined in the literature, the acquisition of funding and long-term financial sustainability of citizen science initiatives is an ongoing and well-noted challenge amongst current facilitators. This is especially pertinent given the strong correlation between funding, facilitators, and the success of citizen science.

Many of those involved in citizen science and environmental education in KZN note that having a champion facilitator who can implement the program is absolutely essential to the long-term success and sustainability of the initiative. In several instances, the loss of a champion or key facilitator has resulted in the diminishment of the program. This is reinforced by findings from Pollock & Whitelaw (2005), which reveal that the establishment of project champions (like the Enviro-Champs in Mpophomeni) is highly effective in building capacity, improving project coordination, and disseminating results and benefits to the community at large. It becomes clear that having adequate funding to hire a facilitator, who can oversee the program and drive the initiative forward, is of vital importance if citizen science is to be used for overcoming water quality challenges.
As such, the following provides some insight into the long-term financial sustainability of both the MSEP and Enviro-Club initiatives. Coordinators of both programs note that funding has been a notable barrier in the past, and will likely continue to be a barrier in the future. Presently, MSEP does not have funding to continue the program beyond February 2015 (L. Taylor, personal communication, June 2014) and Enviro-Clubs is run on a year-by-year approach (although this is not reflected in the design, approach, or mindset with which the program is operated) (L. Boothway, personal communication, June 2014).

Regardless of how advantageous each of these initiatives may be, the inability to acquire adequate funding would be detrimental to the programs:

“"There is great interest in the MSEP program, and lecturers at the universities, scientists, NGO’s, government officials and the general public do speak highly of the project and say it should be replicated elsewhere. But it does depend very much on funding...without funding it will definitely fail."” (L. Taylor, personal communication, June 2014).

Unfortunately, acquiring funding for programs with largely qualitative outcomes (social and educational outcomes that are not easily measured) has proven difficult, requiring “people with foresight to see the benefits of funding a human capacity project” (L. Taylor, personal communication, June 2014). While frustrating, this sentiment is echoed by Conrad & Hilchey (2011) who state that if government agencies were to have “the foresight to acknowledge the multiple benefits of CBM [citizen science] programs and want to link their efforts to enhanced environmental management, they can make funding for CBM a priority” (p. 282). This is particularly pertinent given that citizen science can, and is often, used to achieve social outcomes
The irony lies in the fact that a notable advantage of citizen science is its capacity to supplement government monitoring, but lack of recognition for such efforts on behalf of the government, hinders funding for citizen science.

While funding remains a challenge for citizen science, it has not hindered the implementation and establishment of either MSEP or Enviro-Clubs, nor has it prevented the emergence of the many advantages associated with each initiative. As outlined in the preceding discussion, the benefits that arise from participating in each of these programs are numerous. Acknowledging the challenges surrounding the implementation of citizen science is useful in better understanding mechanisms for overcoming such challenges in the future and should not prevent the continuation and growth of citizen science in the uMngeni catchment area, and more generally, within SA.

4.7 Citizen Science: Towards Improved Water Quality?

Having examined the specific objectives associated with this research, it is necessary to answer the broader, overarching research question: **How might citizen science contribute to (encourage and/or improve) the conservation of water quality in Mpophomeni Township (uMngeni catchment area), KwaZulu-Natal, South Africa?** The preceding discussion suggests that there is great potential for citizen science to encourage and improve the conservation of water quality, a fact that is all the more significant given that the current water conservation system is largely ineffective. In answering this overarching research question, it is helpful to examine each part of the question: how does citizen science encourage conservation, and how does citizen science improve conservation?
**Encouragement**

Enhanced knowledge and leadership skills as part of individual and community-level empowerment, resulting from citizen science, may well act as a tool for continuing to encourage individuals to participate in water-quality related conservation efforts. Similarly, the process of social learning that results from citizen science may encourage participants to continue working on water quality related initiatives as participants’ understanding of water quality deepens (through the U movement) and systemic connections are made (e.g. how am I located within the larger water system? What impacts do my actions and behaviours have on these resources?).

The challenge that arises with respect to citizen science as a mechanism for encouraging, specifically, the conservation of water quality in Mpophomeni and uMngeni, is that the benefits (empowerment and social learning) that are likely to motivate individuals, are only felt following participation in such work. In other words, it is necessary to participate in, and experience the benefits of, citizen science in order to be encouraged to continue. It cannot be expected that the act of implementing a citizen science project will result in the active encouragement of conservation efforts by passive bystanders. Because individuals need to experience the benefits that come from participating in such work, these benefits need to be discussed and shared widely. Through peer-peer interaction and the widespread distribution of the positive impacts of participating in citizen science, water quality conservation can be encouraged and sustained.

**Improvement**

Unlike encouragement, which aims to motivate or inspire people to become interested and involved in the conservation of water quality, improvement is more closely related to those
efforts that are already in effect. By fostering multi-stakeholder connections that enable multiple interested/affected parties to participate in the sustainable use and protection of shared water resources, citizen science can strengthen and improve existing and future conservation efforts. Inviting other individuals with alternate ideas, perspectives, and experiences to contribute to water quality can only serve to strengthen the work that is already being implemented.

Likewise, the establishment of new connections with nature (and other citizens) may well act as an additional mechanism through which existing and future conservation efforts can be improved. In establishing new relationships with the environment, citizen scientists demonstrate that they have gained a new perspective on our (human) reliance on the environment, and more specifically, the implications of our actions on water quality and subsequently, on other individuals also reliant on those resources.

Lastly, the ability to shift current power-dynamics has great potential to improve existing conservation efforts. Judging from the current situation, present-day power dynamics and government monitoring of water quality is ineffective. Using citizen science as a mechanism to sway existing power-dynamics in a direction that favours citizen contributions and values the effort and work that is currently being done by those directly affected by the current water quality conditions, could likely improve government’s current efforts to improve and conserve water quality.

The preceding sections have outlined and discussed specific and tangible results that occur from participating in citizen science. Examining these findings in a broader context suggests that in
addition to individual and community-level impacts, citizen science has the potential to both encourage and improve water conservation efforts more generally. While this thesis has examined the positive change that can occur through citizen science in a relatively small community, in a relatively small part of a larger catchment; the advantages have been significant. If similar changes were to occur in other individuals, communities, and catchments in SA, the collective impact would be momentous:

*Is it possible that citizen science will create ‘revolutionary science,’ that is, bring up enough anomalies to some current paradigm that it will create a new paradigm that subsumes the old results as well as new anomalous results into one new framework? Given the ability of citizen science to detect large-scale patterns of systems, it is possible for it to advance science in all these ways* (Cooper et al., 2012, p. 112-113).

4.8 Conclusion

The degradation of water quality is an ongoing and systemic challenge plaguing many communities throughout SA. As water scarcity increases, the conservation of water quality is increasingly important. As such, the aim of this study was to understand how citizen science might contribute to the improved conservation of water quality using Mpophomeni as a case study within the uMngeni catchment area.

The current system within uMngeni has been largely ineffective at mitigating or remedying water quality challenges to date, and the need to find alternate mechanisms of change and specifically systemic change, is essential. This research sought to explore the extent to which citizen science
participants engage with Theory U to enhance systemic understanding and action around water quality.

The research indicates that citizen science has great potential to help overcome significant institutional (governmental) and social (educational) barriers, currently hindering the improvement of water quality in uMngeni, and SA more generally. Ultimately, citizen science provides a platform through which social learning and systemic change, by way of Theory U, can occur.

Specific findings suggest that individual and community empowerment result in increased participant confidence and ability to exert agency over water quality issues, while participants’ conceptualization of leadership encourages the adoption of a more systemic understanding of water quality. In addition, citizen science promotes acknowledgement of the need to work collaboratively to implement large-scale, systemic water quality change, all the while nurturing the development of new connections with the environment (environmental ethic) and other individuals (dissolving the social tensions that are prominent in other sectors of society). Finally, the findings suggest that through citizen science, participants are able to challenge existing government-citizen power relations in order to garner widespread support and action (from government and other individuals) for improved water quality.

Although access to Internet and the acquisition of long-term funding are key challenges associated with citizen science in SA, the ability to overcome these challenges should be
encouraged and emphasized when implementing and continuing both ongoing and future citizen science efforts.

All in all, the research has demonstrated that the impact of citizen science on a relatively small subset of the population has been significant, and the possible benefits associated with expanding such efforts, are substantial: “I’d say you have to start small, focusing on community and then go up the hierarchy from, let’s say, community [to] a region, and then province, and then we can expand to the whole of South Africa” – Participant CSEC7.

Many of the benefits of citizen science, as identified through this particular research, relate to individual-level shifts in identity (e.g. viewing oneself as a leader, as an empowered individual with agency to act). The resultant potential from expanding citizen science efforts to include other individuals and communities throughout SA is arguably one of the most powerful tools in the fight to improve and conserve water quality: “…only if the local people know about citizen science, that’s…when water conservation [will] be [implemented]” – Participant CSEC7.
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Appendix A

Theoretical Interview Template

Interview objective: do citizen scientists engage with Theory U when promoting the conservation and/or improvement of water quality in the uMngeni catchment area?

Introduction

1. Can you please tell me about your work or experience with citizen science, or citizen-based action, and water pollution?

2. What type of work or project(s) are you involved in; what do you do as a part of that work/project?
   → Contextualization

Suspending and Redirecting

1. What is your experience with working in a group and with other people on water pollution challenges?
   → Indicative of whether or not participant is engaging leadership capacity 1: creating a space that invites others to contribute at the beginning of the U journey (Scharmer, 2013)

2. Have your ideas and/or knowledge about water pollution changed since you started this work?

3. How did you view the problem of water pollution before? How do you view it now?
   → Indication of suspending and redirecting thoughts/ideas/mental models; indication of opening up (open mind) and moving down the left side of the U

4. Why do you participate in citizen science, Enviro-Club, etc.? What motivates you to do this work? (What is your inspiration?)

5. What makes you care about these problems and this work?

6. Would you say that your heart guides the work that you do on water pollution? If so, how?
   → Indication of whether or not participant is engaging with leadership capacity 3: “connecting to deeper forces” (p. 9) of change through opening the heart as part of redirecting and letting-go (Scharmer, 2013).
→ Indication of systems thinking in that “…when it comes to seeing systems like the environment, empowerment starts with the instrument or organ of perception. You can’t just analyze such systems from the outside to get to the root causes of things-you have to feel them from within.” (Senge et al., 2004, p. 54)

Letting Go and Letting Come

1. Do you see yourself as a leader in environmental issues, such as water pollution? If yes, why/how do you see yourself as a leader? If no, why not? What would it take for you to be a leader?
   → Indicative of whether or not participant is engaging with leadership capacity 4 (presencing): connecting with one’s self and will to act from the whole as part of letting-go and letting-come (Scharmer, 2013)

2. How do you see yourself in the big picture of water pollution in uMngeni? In South Africa?
   → Indicative of whether participant is engaging with the bottom of the U (letting-go and letting-come) by maintaining an open mind, transforming self (identity) and will, being receptive to incoming ideas and concepts

3. Is it more important to focus on the smaller water pollution issues (in Mpophomeni for example), or on the big water issues in the whole of South Africa?

4. Do you think that this type of work has potential to improve water conservation on a national scale? Why and how?

5. How do you feel about water pollution? (E.g. do you feel helpless about the problem? Do you feel energized talking to others working on these problems? Do you feel hopeful that your work with citizen science can change the water pollution situation for the better?)

6. Have your feelings about the problem changed since you started working on water pollution? How did you feel at the beginning of your work? How do you feel now?

7. What do you think it will take for us to overcome the water quality challenges currently faced in Umgeni, KZN?

8. How do you think the future will need to be different from the past? How do you know this, or why do you feel this way?
   → Indicative of whether participant employs a systems approach in working on water-related challenges (i.e. do they see water pollution as a systemic challenge), or whether they are focused on the smaller parts that make up the bigger system.

9. What is your vision as a citizen scientist for water pollution? Where do you see yourself in 10 years?
10. How will you get there; what needs to happen in order for you to achieve that vision or goal?
   → Indicative of whether or not participant is engaging with bottom of the ‘U’ and whether or not participant is working with the end in sight, indicative of an understanding (of water as a wicked problem) and fact that the U journey is continuous: there is more to be learned, more steps to be taken to improve water quality (and enable systemic change)

11. Does your plan for achieving your vision or goal include others?
   → Indicative of whether participant employs a systems approach in working on water-related challenges (i.e. do they see water pollution as a systemic challenge), or whether they are focused on the smaller parts that make up the bigger system.

Crystallizing, Prototyping, and Institutionalizing

1. Have you learned new ideas and concepts about water pollution from others and from your work? Or has your experience reinforced what you already knew/thought about water pollution?
   → Indication of crystalizing, prototyping, & institutionalizing new thoughts/ideas/mental models; indication of “intentionally re-integrating the intelligence of the head, the heart, and the hand in the context of practical applications” while moving up R side of the U. (Scharmer, 2013, p. 11); and indicative of engagement with leadership capacities 5, 6, and 7 (crystallizing, prototyping, and performing, respectively).

Miscellaneous

1. What has been your experience with gender differences in relation to your work with citizen science and water pollution?

2. How important are the youth when it comes to this type of work on water pollution as well as other environmental problems?
   → Insight into context

Conclusion

1. Is there anything else you would like to add? Is there anyone you can recommend I interview? Thank you very much for taking the time to meet with me, I really appreciate it!
Appendix B

Organization Profiles

Both DUCT and WESSA are both environmental organizations active in uMgeni Municipality.

DUCT is a non-profit organization whose mission is focused on improving the environmental health of both the uMngeni and uMsunduzi (a key tributary of the uMngeni river) river systems (DUCT, 2014). Much of DUCT’s work is focused on establishing reciprocal relationships between communities and the river systems upon which they depend by encouraging community ownership of, and responsibility for, river health, in exchange for the sustained provision of ecological goods and services (DUCT, 2014).

WESSA is an environmental non-governmental organization (ENGO) focused on implementing “high impact environmental and conservation projects which promote public participation in caring for the Earth” (WESSA, 2011). WESSA has an extensive network throughout SA and often collaborates with government (local, provincial, national) and other environmental organizations on environmental projects (WESSA, 2011).

GroundTruth is an environmental consultancy that specializes in “assessing, monitoring, and managing environmental issues surrounding water resources” (GroundTruth, 2013d). This includes water quality monitoring (miniSASS), catchment management, and aquatic environmental assessments (GroundTruth, 2013d). GroundTruth has experience working in collaboration with industry, private developers, and government (notably, the DWS) (GroundTruth, 2013d).
Mathuba Schools and Citizens River Health Programme is a citizen-science initiative that works closely with individuals in various different organizations (including MSEP and Enviro-Clubs) with the aim of providing opportunities for participants to become interested and involved in “the health of local rivers…and the catchments to which they are connected” (Mathuba Schools and Citizens River Health Programme, 2013). Mathuba is affiliated with several organizations throughout SA (including WESSA, Eco-Schools, DUCT, and Umgeni Water) and aims to increase multi-stakeholder connection and collaboration - using Google Earth mapping - between individuals throughout SA (and internationally). In this way, like-minded individuals focused on water quality issues are able to connect, share their experiences and findings, and promote more systemic change in relation to the current water system in SA.