TOWARDS SOCIAL LEARNING IN WATER RELATED MULTI-STAKEHOLDER PROCESSES: INVESTIGATING THE VALUE OF INFORMATION SYSTEMS

by

THEMBEKA RACHEL MHLONGO
211510328

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Declaration

I declare that this dissertation is my own work, and that all sources utilised or quoted have been appropriately acknowledged and referenced. This dissertation is being submitted for the Degree of Master of Social Science at the University of KwaZulu- Natal, and has not been submitted for a degree or examination at any other university.

Thembeka Mhlongo

Signed

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Abstract

The challenge of behaving wisely concerning water constitutes itself as a wicked problem for humankind. This is particularly true for the management of the resource in South Africa. Wicked problems are termed such as they exist in social conditions of high complexity and uncertainty, amidst multiple perspectives where stakeholders are urgently attempting to solve the problems they see. Furthermore, wicked water-related problems become more challenging with climate change and uncertainty on the rise. All of the above holds for the uMngeni catchment in Kwazulu-Natal, South Africa, where environmental degradation and water stresses put additional pressure on the management of an increasingly scarce resource. In such contexts, a collective engagement approach by all stakeholders is essential for social learning and for fostering wise actions in complex dynamic stakeholder engagement spaces. Key studies indicate that information and knowledge co-generation within socio-scientific spaces is essential to feed the process of learning, and that this co-generation can be facilitated outside the typical physical space - in virtual hyperspaces of information systems. This study engaged with both the extent of social learning in the Umgeni catchment as well as the potential of ICTs to contribute to improve social learning in future. The aim of this research was thus to deepen understanding of the specific role of information systems, formed in virtual engagement spaces, for social learning. Practically, it also aimed to provide recommendations on the specific actions that can be taken to create a nourishing context for such social learning.

The broad framework that underpinned this exploratory research and its methods was the social learning theory, while methodologically the qualitative data were gathered in line with Theory-U- an action research approach to knowledge creation and social learning. Using the researcher's position as an embedded stakeholder, the study was grounded in the context of selected cases or multi-stakeholder groups in the upper uMngeni catchment. These cases are of three water-related multi-stakeholder groups in the uMngeni catchment.

Participatory observation (PO) and action research (AR) were utilised, which involved the researcher in bio-monitoring and other water-related fieldwork projects with multi-stakeholder groups, meetings and partnerships in the catchment. Lastly, two selected emerging integrated

information management systems - Mathuba web-based WIKI and the MIKE INFO desktop-based water management information system – were explored.

Using the pre-conditions of social learning as an analytical framework of the results it was found that the degree of social learning was highest in the small community, local level of stakeholder engagement. Social learning registered the least in the larger catchment size scale of stakeholder engagement as well as at an intermediate level in the sub-catchment scale of multi-stakeholder engagement. Key themes identified across the scales of engagement included: high stakeholder empowerment by self-identity change and stakeholder education; a lack of continuous participation and barriers to knowledge sharing hindering social learning; and a lack of participation and implementation of relevant actors for all the groups. It was also found that these barriers and prohibiting factors to social learning can be overcome through the use of integrated information systems that variously promote transparency of information, virtual inclusiveness in engagement of actors at the local scale and the enhancing of trust and relationships using virtual platform features such as online placed GIS-based maps, documentation and forums. Challenges of employing such information systems were concluded to be complexity, costs and the lack of suitable facilitators of the software and virtual engagement of actors. Of the two explored information systems: The Mathuba WIKI site seemed most plausible, yet this ideal kind of supporting information systems, may risk being too complicated and its use may not be sustainable in the future. It was thus concluded that in order for such information systems to be included in support of multi-stakeholder engagement in the future, they must be integrated, inclusive, co-created and truly transparent and should make good use of visual representations of water problem realities through maps, graphs and images that tell stories. Such information should also be piloted at the 3 main case study scales; the UEIP (large catchment management group), MCMF (sub-catchment management group) and LCPG (local community groups). This can be evaluated and the results published for future applications on the national scale.

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

Internationally, the past 30 years has witnessed a growing trend in the direction of multi-stakeholder engagement over environmental matters, of common concern. Within this trend, one of the strong strategic strands has been in the realm of water related issues, as water has steadily climbed the rankings of the World Economic Forums Global Risks Report, to be No. 1 Global Risk in 2015. Along with this trend has been rapid development in the information and communication technology (ICT) sphere, to the point where seamless integration between smartphones, satellite imagery (flag-shipped by Google Earth) and social media and banking platforms on mobile phones, have become a daily reality. These two megatrends have spawned another megatrend known as citizen science, which has not only dramatically improved citizen agency but also enhanced water resources management. The ability to communicate has been used by citizens globally to act on mega-challenges such as climate change, water and food security in poor urban settings and a myriad of other socio-environmental challenges facing human-kind.

South African NGOs, academics and parastatal research organisations have kept abreast of these trends both practically and intellectually. Their work provides a major part of the context for this research, which is an effort towards developing a deeper understanding of social learning in multi-stakeholder engaged, water resource management processes. More particularly, within these processes the research investigates the value of information systems formed in virtual engagement spaces. The introduction that follows will proceed from the international to the national and finally to the local context within which this research took place.

1.1 International context and developments

Over the past 15 years, it is evident from the work of Tippett et al., (2005); Allen et al., (2011) and Cornell et al., (2013) that there has been an observed global focus on multi-stakeholder engagement spaces as social platforms for supporting learning on subjects of interest such as sustainable development, as well as products of knowledge generation for managing the complexities of the environment. Mostert et al. (2007) have shown that the social learning imperative is based on the fact that no single stakeholder has all of the information or resources

required to manage the natural resource. Stakeholders need to collaborate where their collective action is supported by some type of organization or multi-stakeholder platform. Pahl-Wostl et al. (2008) argue that there is an increase in awareness of the need for adopting more integrated approaches that take on a holistic perspective not only in the bio-physical problems, but also focusing on the social aspects. According to Pahl-Wostl et al. (2008) this paradigm shift represents a change in culture characterised by increased awareness of the complexity of a system and the styles of leadership in multi-stakeholder processes that integrate multiple knowledge sources, that don't simply focus on expert advice. Thus, as de Loe et al. (2009) have put it, social learning, which, from this introduction, can be understood to be both a process and a product of stakeholder interaction, is critically reliant on the information from these multiple sources. de Loe et al., (2009) stress that social learning improves when diverse interests and knowledge from the catchment are integrated. These statements further enforce the themes that shape this research, namely, that changes in individual and organisational behaviour in managing highly threatened water resources requires multi-stakeholder interactions and that this is tightly connected to the aspect of information and knowledge produced and how it is managed.

Pahl-Wostl et al. (2008) and Ison *et al.*, (2004) claim that problems associated with water resource management, are increasing in complexity over time. These authors also find that the current approaches to management have not been enough to deal with complexity brought about by climatic and global uncertainties and the associated challenges. At the time of writing, the approaches or methods of managing water related issues have, according to Pahl-Wostl et. al (2008) and Ison et al (2004) often been characterised by what the authors refer to as calculated command and control measures. Ison *et al.*, (2004) and Pahl-Wostl et al. (2008) emphasise that in the face of climate change uncertainties, developing countries are slowly rejecting the narrative that solutions to water resource management problems can be solved from narrowly defined, expert advice guided purely from an economic, built infrastructure or environmental perspective. According to Pahl-Wostl *et al.*, (2008) there is a global interest in integrative approaches that are inclusive of lay persons contributing non-expert alternative knowledge, Thornton et al. (2013 believe, that these water related challenges constitute a wicked problem, a term first used over four decades ago by Rittel and Webber, (1973) and also thereafter by Ritchey (2013). A growing body of literature on post-normal science responses to wicked problems, is to be found in the work of

Frame and Brown (2008); Funtowicz and Ravetz (1993); Kastenhofer (2011); Valkering (2009) as reported by Dent (2014). There is also, according to Dent (2014), support by Reed et al. (2013); Von Korff et al. (2012); Bots et al, (2011); Valkering (2009); Haxeltine et al. (2008); Lotze-Campen, (2008); Matthews et al. (2007); Tabara et al. (2007); Guyot and Honiden (2006); Castella, et al. (2005) and Ramanath and Gilbert (2004) that participatory agent-based social simulation modelling responses are appropriate for wicked problems.

In many of the aforementioned papers the challenge of behaving wisely in relation to the management of water is described as a wicked problem. Picking up on the work of Rittel and Webber 1973 Irvine (2005) characterised a wicked problem as having multiple and conflicting definitions of solutions that can either make a situation better for others or worse, depending on how it is defined and subsequently approached. According to Ison *et al*. (2011), by framing complex issues in river basin management as wicked problems, it becomes more obvious of the complexity around climatic adaptation and water resources management. The idea of resilience (as framed by Yet, achieving resilience in the face of uncertainty presents itself as an aspiration and challenge of its own (Mukeheibir and Sparks 2003; Tompkins and Adger 2004).

A key message running through many of the aforementioned papers is that addressing problems in a system where some problems are characterised as being wicked in nature, requires a systems approach and more specifically, approaches that involve a collaboration of knowledge and learning between actors, who are interested in addressing the issues. According to Ison *et al*. (2004) this correlates with a definition of the process of adaptive management, which they contend is a normative model for a change in human behaviour, driven by ecosystem changes that are filled with 'surprises' leading to uncertainty and complexity of water management systems. One of the most fundamental documented relationship links between social learning and adaptive management is that the latter needs a collective learning by a body of actors in order for them to take concerted actions that encourage sustainable management of the ecosystem and ecological services (Van Bommel et al. 2009; Ison et al. 2004). In accordance with what Ison *et al*. (2004) and Mathur, Price and Austin (2008) wrote, social learning is a change in human behaviour and an interactive approach that has become an emerging option for the management of natural resources, where the actors involved :-

- Increase in awareness,
- Develop collective understanding and
- An improved ability to monitor and experiment

given a changing situation in their environment. Accordingly, authors such as Cheng and Mattor, (2010) and Romina (2014) present social learning in research as a change in processes that a person or individual undergoes due to being involved in some type of participatory activity with other people where perspectives and ideas are shared with the aim of reaching newer understandings of issues to help develop better strategies in management.

Pahl-Wostl and Craps (2007) and Dyball, Brown and Keen (2009) have specifically suggested that the forming of platforms for actors to develop these participative and critical learning systems is in accordance with the definition of social learning, is an institutionalization process that has a great bearing on supporting the resilience of a system. Hence, a key message behind these descriptions of social learning encapsulated well by Van Bommel *et al*. (2009) is that it is both a process and an outcome of interaction between a set of stakeholders where there is a convergence of ideas on strategies and means of dealing with problems, which in turn leads to collective and concerted action. These stakeholders according to Van Bommel *et al*. (2009) would have come to share a common purpose. Social learning requires actors to interact whether it be by engaging in discussion on issues, negotiating on issues and strategies or resolving conflicts between these multiple and interdependent stakeholders. Thus, based on the above introduction, one can conclusively state that a collective engagement leads to a collective type of learning where actors in the system demonstrate a change in behaviour that correlates with adaptive management in a highly complex system.

1.2 South African context and developments

At the national level perhaps one of the most important policy developments that is beginning to shape the context is the announcement of Principle 2 that was an outcome of a National Water Summit in 2014, led by the Department of Water and Sanitation (DWS) and the Water Research Commission (WRC). Principle 2 states "*Our decisions shall be informed by both the best available science, research and technology, as well as real-life, local experience"* (Naidoo, 2014; p11).

Numerous research programmes funded by the WRC and the Council for Scientific and Industrial Research (CSIR), are testimony to the enacting of the Principle 2 above. A variety of strategic partnerships have been formed inter alia between the WRC and GroundTruth; and between the Cape Peninsula University of Technology (CPUT); the University of Cape Town (UCT); Breede-Gouritz Catchment Management Agency (B-GCMA). Initiatives in Stellenbosch, Ceres, Pongola, Durban, Richards Bay, Pretoria, Cape Town and many other cities in which Universities, the CSIR, the Water Research Commission, Gesellschaft für Internationale Zusammenarbeit (GIZ- a German development agency headquartered in Bonn and Eschborn, it is focused on providing services in the field of international development international education work and cooperation), WWF (World Wide Fund for Nature), the Alliance for Water Stewardship (AWS), Wildlife and Environment Society of South Africa (WESSA), Eco-Schools, the Orange-Senqu River Commission (ORASECOM), private businesses, represented in the case of the uMhlathuze Water Stewardship Partnership, formed in 2016, by the National Business Initiative (NBI) and the Strategic Water Partners Network (SWPN). Apart from local government and parasternal funding for these initiatives, funding has also come from private sector Corporate Social Responsibility sources and international development agencies such as GIZ, the United Nations Development Programme (UNDP) through their Global Environment Facility (GEF); C40 Cities and the Rocker Fellow Funded 100 Resilient Cities Programme.

The success and spread of these endeavours has reached a point where the abovementioned partnerships; projects and programmes are being considered more seriously in conversations around the inclusive economy that seeks to bring in South Africa's huge unemployment challenges mainly in the youth and amongst women (Dent and Taylor, 2017). These strategic partners are also quite visible when it comes to water resource management.

1.3 Local Context and developments

The local context and the developments which spawned this research and which provided the context for the growth in this research as well as the recipient network for the products of this research consisted of engagement with a number of multi-stakeholder organisations. Whilst

navigating the research process through all afore mentioned groups, the researcher adopted the role of participant, stakeholder, researcher, observer and citizen at various times, as appropriate. Engagement by the researcher with several multi-stakeholder organisations formed the close and local component of this study. The researcher's interaction with the following organisations in particular will be described at various places in this dissertation.

The uMngeni Ecological Infrastructure Partnership (UEIP) is a 21 member organisation. The partnership's main objective is to build awareness, improve coordination and integration of stakeholders and conduct demonstration projects throughout the catchment as applied research in support of action learning. During the time of the research, this group met together twice a year to discuss research and studies occurring in the catchment, topics concerning how they engage ad how they can collectively tackle problems affecting the catchment. The uMsunduzi Catchment Management Forum (MCMF) on the other hand is one of scores of such forums, throughout South Africa, that are formed under the auspices of the Department of Water & Sanitation (DWS) in terms of the 1998 National Water Act. During the time period of the research, multiple actors from different organisations in the UMsunduzi sub-catchment met up four times a year to discuss water related issues and concerns in the catchment. The Ashdown and Mpophomeni local community projects groups (LCPG) are two examples of local municipal level stakeholder engagement projects within the uMngeni catchment management area, that form grassroots learning cases. These two local community project groups are in an essence made up of a combination of people who have been associated with the Mpophomeni Conservation Group monitoring project (MCGMP)[1], the Wildlife and Environment Society of South Africa (WESSA), Eco-schools and at times, the Expanded Public Works Programme (EPWP). They formed a major role in understanding the different ways stakeholders in multi-stakeholder engagement groups interacted in the interests of learning – some members of these groups will be interviewed for the purpose of this research[2].

[1] The MCGMP has since been funded by the Dusi uMngeni Conservation Trust (DUCT)

[2] This will be discussed further in the methods section.

1.4 Problem statement

Whilst there are many tangible signs of a widespread acceptance of the notion that collective action by multi-stakeholders is an important part of the solution, there is much to learn in this social space. It is widely recognised that whilst funding into this space is crucial for continued social learning, the sporadic nature and very small amounts of fixed term funding are problematic for the sustainability and growth of such efforts. A further problem is the high transaction costs of communication between stakeholders in this space and the difficulties associated with evaluating the benefits of stakeholder communication efforts. Added to this are the currently high transaction costs of monitoring and fairly rewarding these collective, multi-stakeholder efforts. There is also widespread and growing recognition that the wise use of information and communication technology (ICT) offers good potential for up scaling these activities and making them more effective and also rewarding them more fairly in cash, kind or recognition of all of the aforementioned contributions in stakeholder engagement, whilst at the same time bringing down the transaction costs of the aforementioned, significantly. Information systems are also growing in recognition as being useful technologies when applied in conjunction with citizen engagement for taking wise steps towards overcoming the effects of persistent water related problems that many the multi-stakeholder groups try to solve.

A lack of social learning leads to continuous struggles with stakeholder coordination, pushing actors further away from constructively handling problems associated with water resources and also from constructively involving valuable laypersons knowledge towards handling these problems. The problem of recognition by and involvement of the private sector in funding this space is one which is seen as pivotal to bringing the collective, multi-stakeholder, citizen action into the inclusive economy debate. Understanding the barriers and incentives to unlocking all of the above potential is a core part of the problem being addressed by this research especially in the ever changing and highly complex nature of water related problems in a catchment.

1.5 Aim and Objectives

The aim of this research was thus to employ methods that deepen an understanding of the role of information systems, formed in virtual engagement spaces, for the purpose of multi-stakeholder, water related, social learning. These methods are the learning models used as a framework for this research. The study was grounded in the context of selected cases in the upper uMngeni and uMsunduzi catchment and had the following objectives:

1. Understand the incentives and barriers to social learning in current spaces of stakeholder engagement.
2. Examine the potential for integrated information systems to be adopted to aid in multi-stakeholder social learning, in real and virtual spaces and
3. Provide recommendations on the specific actions to create a nurturing context for such social learning.

1.6 Methods

The researcher's journey in this work took place from 2015-2019 and assumed a number of roles and positionality from being an intern in a multi-stakeholder engagement group and an active participant to later being a researcher. In these roles the researcher engaged in fieldwork as a group member the , then later as a student mentor, teacher and leader in a variety of multi-stakeholder groups. Proficiency in the ICT aspects of this work was developed during this period. With the commencement of the intern role came academic reading of journal articles, media releases, policy documents and reports to gain a deeper understanding of social learning and particularly the role of the ICT applications that were being applied at the time.

The local context in which this work took place has been outlined briefly in Section 1.2 above and will be discussed more fully in the methods chapter three. The researcher engaged within these spaces energetically and with a keen mind for learning. Of particular interest, and what forms the backbone of the method was the progressive deepening of understanding by seeing the practical unfolding of the social learning theories reviewed in the literature review, chapter two. In essence, these theories are all forms of Scharmer's Theory U of learning which consists of many iterations of action and deep reflection. In this process of learning by doing numerous constructs were

reviewed and brought into the vocabulary and thinking of this research. These are reviewed in chapter two and form a key part of the analysis discussed in chapter four. One key point to note about the methods employed in this research is that reading, learning, reflection and action, both individual and multi-stakeholder, was a continuous interplay throughout the research period. One of the final pieces of work in the research method was to develop and then conduct and later analyse a survey amongst experts and other stakeholders in the broad space encompassed by the study. These were again stakeholders who also belonged to the identified three major scales or contexts of multi-stakeholder engagement: the large catchment management group identified by the UEIP, the sub-catchment management group identified by the MCMF and finally the much smaller local community groups identified as LCPGs in this research.

1.7 Thesis Outline and argument

The argument that governed this research was developed by looking at the constructs of learning and integrating these with social learning requirements, thereafter integrating these later on with the findings at local, sub-catchment and larger catchment scale to develop a measure of the barriers and incentives to social learning. Our goal is to ascertain what would constitute a nurturing context for social learning at the three scales, and to consider whether and in what ways actively using ICTs is able to support engagement.

Chapter two presents the theoretical context of the research by providing a comprehensive description of wicked problems and what effects they have on water resource security. A review of the constructs of social learning is then provided as well as the emerging ICTs in response to them.

Chapter three constitutes a review of how the research was carried out using the iterative process of learning as defined by Theory U. The researcher's different roles or positionalities in conducting the reach are also explained as well as the methods of data collection and analysis - including using semi-structured interviews and participatory observation.

Chapter four then goes on to present the results of the research addressing objective one; the state of social learning in the current multi-stakeholder arrangements in the upper uMngeni catchment using themes developed from literature- identified as constructs of social learning. A discussion on the current barriers and incentives for social learning in the uMngeni catchment is then presented based on the themes developed from literature.

Chapter five further presents the state of current efforts of reducing transactional costs in the different scales of multi-stakeholder engagement and the opinions of stakeholders by using ICTs. The themes of social learning constructs are then used to discuss how learning is improved or unimproved in the uMngeni catchment based on the effective use of ICT and information systems. The MIKE INFO and Mathuba emerging information technologies are then used to connect virtual multi-stakeholder engagement and the effectiveness of information systems in supporting learning through their use in the uMngeni catchment possibly in the future all the while providing recommendations in use for using ICTs for social learning.

Chapter six provides the final conclusion on all set objectives of the research and a summary of the work done. The dissertation ends by providing recommendations for future research on social learning and the use of ICTs and information systems in addressing water related problems.

Chapter 2: Literature Review

2.1 Literature review introduction

Understanding social learning in multi-stakeholder interaction processes in the water resource management context involves understanding the role of water managers, scientists and especially the users of the water resources who are key stakeholders. In addition, understanding the nature of water related problems that social learning will be required to engage with is essential and so too is understanding engagement that equips stakeholders for wise decision making through informed social learning. Reviewing the literature surrounding this topic is important because it guide and informs a better understanding of how stakeholders could be better aligned whilst at the same time encouraging social learning in their various platforms of engagement. The literature permits a more robust understanding of factors or elements of social learning or social interactions in complex multi-stakeholder arrangements can encourage social learning in their platforms (ie. meetings, workshops, implementation activities and other collaborative engagement sessions). Furthermore, as a potential solution, this literature review also shows how the audience can better use information communication technologies (ICTs) as shared information systems that will support processes of social learning and as tools for dealing with water related problems. The benefits hoped for through this review is to give a holistic presentation of how stakeholders can encourage social learning in their engagement processes in the short-term span of water resource management, in the medium term by unlearning unproductive methods of interacting with each other and in the long term, applying this knowledge in the uMngeni catchment in order to empower all kinds of stakeholders.

An important consideration is the functioning of current multi-stakeholder interaction processes and the potential value of shared on-line information systems in overcoming barriers associated with achieving social learning in such environments. The benefits of this review, is shedding some light on this topic.

This chapter thus aims to provide the theoretical framework concerning:

1. The nature of water related problems as reflected in the literature and the application of social learning to approaching such problems
2. How social learning within the context of shared on-line information systems has a direct bearing in dealing with wicked problems

The next few subsections present a scope of the above findings from literature by focusing on four key messages:

- The nature of water related problems that social learning can address;
- Why addressing such problems has been found to be important, over time, for water resource managers particularly in adopting post-normal science approaches;
- What the understanding of social learning in multi-stakeholder processes and the use of information communication technologies means to dealing with water related problems and to approaching them using the evolving post-normal science approach; and finally
- The benefits that social learning in multi-stakeholder engagement processes has for water resource managers and other expert stakeholders in the short, medium and long-term context of multi-stakeholder engagement.

Specifically, regarding the four key messages of this literature review, this section is thus divided into four sections that outline multi-stakeholder approaches and social learning:

- The nature of water related problems,
- A definition of social learning and social learning responses to uncertainties,
- Information and communication elements for social learning, and
- The use of information communication technologies and shared on-line information systems for learning.

2.2 Wicked Problems and Multi-stakeholder Engagement Processes

Water forms an integral part of all 17 UN-SDG's and this implies that a wide range of stakeholders have a strong interest in water matters (Sadoff et al. 2020). This interest is captured in. one of the

maxims to emerge from and then guide South Africa's transformation of policy, law and institutional arrangements in the realm of water since South Africa's democratic elections in 1994 which is "some for all, forever." One of the fundamental approaches to achieving this goal of effective water management has been the appreciation of multi-stakeholder collaborative approaches in the management of water resources- integrating input from various actors (UNU-INWE, ND).

As introduced in chapter one, uncertainty has been realised to be one of the issues with managing water resources. Many of the uncertainties have been the result of an increasing complexity of river basin management stemming from the constant change in stakeholder dynamics in river basins. (Gallagher et al. 2020). Government approaches have, over time been developed to create platforms for stakeholder engagement in adaptive governance to help address such uncertainty. (Cosens and Gunderson, 2021) Adaptive governance if adopted as a goal requires embracing diversity and multiple levels of management of water resources (Steelman, 2020). Developments such as adaptive governance have demonstrated public participation (i.e. inclusive of local knowledge and local actions taken), polycentricism as well as experimental approaches to management all of which are difficult to measure with regard to their effectiveness. Processes in support of adaptive governance such as decentralized governance and strong integrative properties in the vertical scale and cross levels of interactions between stakeholders have popularized over the years, not only in South Africa but globally (Pahl-Wostl and Kranz, 2010, Romano and Akhmouch, 2019, Akhmouch et al., 2020).

Literature findings (Grint, 2022; Niskanen et al., 2021; Termeer et al., 2019) have revealed that problems are becoming increasingly wicked in nature. Originally defined by Rittel and Webber (1973), wicked problems have been written about in different fields of interest and yet, universally they are described to having similar characteristics. The term wicked problems has been associated with various fields including politics, governance, agriculture, town planning and water resource management pertaining to managing pollution (Pryshlakivsky & Searcy, 2013; Thorton et al., 2013; Head and Alford, 2015; Termeer et al., 2015). To this end natural resource problems are no exception. They too have been described at times to be 'wicked' in nature and unsolvable, requiring collective rational discussions and wise decision making by a multiplicity of actors who

have a stake in the issue (Patterson et al., 2013; Innes & Booher et al., 2016; Markowska et al., 2020). Hence, the urgency of understanding better ways of managing water resources, particularly with the rise in external factors that further complicate water management itself such as climate change and climate change uncertainty over time. Wicked problems are also difficult to define, having no real solution to them, being complex and ambiguous, and requiring step by step actions and sometimes infinite actions towards approaching them due to their high complexity (Conklin 2005; Lönngren and Van Poeck, 2021; Rittel and Webber 1973; Wright, 2019). Wicked problems can also be described as problems that are inclusive of various stakeholders with competing priorities and values concerning the problem and having multiple perspectives towards the problem- thus being difficult to grasp in understanding (Rittel and Webber 1973; Conklin 2005; Dybal, Brown and Keen 2009; Forrester et al. 2018; Markowska et al. 2020). A key factor found in literature concerning this nature of problems in the realm of water associated with situations where there is accelerated change and growing complexities and related uncertainties is a way that such problems are handled.

Approaching wicked problems is a collaborative task requiring multi-stakeholder input and not a one sided approach (Maher, 2020; Salvia et al., 2021). In the uMngeni catchment, there are many stakeholder groups, initiatives and general multi-stakeholder platforms where stakeholders meet to discuss, collaborate or partner over the current state of catchment water resources with the aim of improving the state of the water resource that connect them all (Mazeka, et al., 2019; Sartas et al., 2019; Martel et al., 2021). The growing movement involves the studying and understanding of a number of *social involvement* processes in the context of problems affecting water resources and stakeholders as well as how these stakeholders choose to navigate their collective challenges (Finca et al., 2019; Rebelo and Methner, 2019).

The challenge for such collaborative learning in South Africa was articulated in the following way by the Water Research Commission (WRC), 2014 National Water Summit, Principle 2:

"Our Decisions shall be informed by both the best available science, research and technology, as well as real life local experiences."

This statement lead to questioning how can the best available science and technology be used to improve the decision making of stakeholders and how such technologies can be particularly used to integrate information supplied by these stakeholders. This especially includes information that may not be typically scientific, information by local stakeholders passing on real life experiences as knowledge. Hence the necessity to understanding the true nature of water related problems in a catchment that the best available technologies and local knowledge together can be used to approach (Colding et al., 2019). Generally, dealing with wicked problems in processes has been characterized by pursuing multi-stakeholder input and learning from the stakeholders. At times, this may mean learning from groups who possess important local knowledge where their participation aids in dealing with the issue or problem at hand (Paquet, 1999; Maidin, 2022).
Based on what is known in literature (Hopson et al., 2018; Forrester et al., 2018; Markowska et al., 2020) about the complex and multi-stakeholder approach required due to the wicked nature of problems, the necessity to review this concept in the context of catchments such as the uMngeni catchment becomes appropriate.

Managing wicked water problems such as water scarcity, water governance and water resource management all of which often require Integrated Water Resource Management (IWRM) approaches requires that multi-stakeholder engagements and collaborative processes take the wicked nature of water problems into consideration when the problems have no 'clear cut solution' to them (DeFries & Nagendra, 2017; Head, 2010; Quentin, 2017; Markowska et al. 2020). Increased coherence, dialog, shared understanding and collaboration between actors can all result in producing multi-perspectives that interact in a structured way in situations where modern problems facing society call for a robust approach of improved management (Roberts 2000; Conklin 2001; Conklin & Christensen 2009; Dentoni 2018). This is applicable as wicked problems have been described in literature to be highly fragmenting to projects. In such cases, intensive social interaction characterized by diverse multi-stakeholder engagement is needed in developing strategies that can spread the risk of wicked problems (Willis et al., 2018). Such multi-stakeholder engagement processes are believed to encourage cooperation and learning between actors which further leads to collective action (Irvin 2005; Willis et al., 2018).

The term wicked problems becomes even more relevant in the face of social learning as authors such as Pahl-Wostl (2007) who has stated that there is an increase in the awareness that the systems to be managed in the water context are complex and that management must be a process that is better served by learning, than by control (Pan, 2018; Marta, 2020). Pertaining to multi-stakeholder engagement processes and how to approach wicked problems strategically and with needed caution; collective learning of multi-stakeholders needs to be reintroduced and redefined from past experiences before any environmental management strategy is undertaken (Dyball, Brown and Keen 2009). For example, where an adaptive management approach concerning wicked problems in water is being sought after, literature shows that stakeholders are usually actively involved in some sort of open dialog exchange which helps them go through continuous social learning and understanding (Dent 2014, Tabara et al. 2007, Valkering 2009). This type of social learning has been known to increase insight on the local actions that need to be taken to address wicked water problems such as water pollution in multi-stakeholder spaces with competing values and multiple perceptions of cause and effect relationships (Lehtonen et al., 2020; Patterson et al., 2013).

While solving a wicked problem completely will not be possible because of their complex nature, open dialog of multi-stakeholders stakeholders, typically from an initial lack of knowledge sharing leads to more progressive ways of addressing long-term wicked problems, especially in the realm of water (Lund et al., 2012; Patterson et al., 2013). Hence overlooking the reality that most water problems have become wicked in nature, prevents multi-stakeholder processes that help stakeholders identify them for what they truly are- complex inter connected issues that require an intense and strategic methods of reflection that enhance learning and improve the general management of water resources for the future (Van der Wal et al., 2020).

The above mentioned introductory literature review shows that extensive integration of knowledge through dialog needs to take place between different knowledge sources and viewpoints. It should be a collaboration between those who identify as experts such as scientists and those that make part of the local community who are directly affected by the problem and government organisations who implement solutions (Dyball et al. 2009; Tabara et al. 2007; Valkering 2009; Weaver at al. 2019). The sharing of knowledge traditions by these groups must also be coupled by

a mutual respect between the members for each other's contributions (Dyball, Brown and Keen, 2009; Wehn, 2018). The term that has been adopted in literature to describe this change in the way multi-stakeholders engage with one another or approach problems; particularly those that exhibit characteristics of being wicked in nature for the benefit of advancing social learning is called post-normal science.

2.3 Social learning: approaching post-normal science

Social learning has been characterised by various elements that are essential for building the capacity of actors to address problems in a post-normal way (Craps and Maurel, 2003). Pursuing social learning in an essence requires refining how problems are approached by multiple stakeholders and post-normal science emphasizes the need for these stakeholders to learn together as part of an extended peer community (Allen, 2011; Lehtonen et al., 2020). In the realm of water and catchment management where problems are increasingly becoming wicked in nature, the key is understanding both the theory of social learning and why post-normal science approaches are better suited in dealing with complex wicked problems when social learning is in the horizon.

The social learning theory is based on the assumption that new behaviours can be adopted by actors when they imitate and observe each other in a social context either organically or through instruction (Scavarelli et al., 2021). It also refers to an increasing capacity for social actors in a catchment to perform tasks that they have in common (Craps & Maurel, 2003). Authors such as Ravertz (2003) have further expressed that social learning is attributed to both the layperson and the expert teaching each other and valuing their mutual learning. In such a situation all stakeholders can acquire understanding and develop mutual respect for each other's contribution which nurtures trust; an essential construct for building sustainability in evolving governance structures (Frame & Brown 2008, Raverts, 2003). The post-normal science approach comes into play as it also embraces actor interactions where knowledge sharing and learning takes place in problem solving strategies between citizen agencies, the public and private organizations - a task described to be difficult and a wicked problem in its own right (Frame & Brown, 2008; Allen et al., 2011).

Emerging as an approach to science in the 90's originally by Funtowicz and Ravetz, post-normal science has been defined as as being a method adopted in systems when:-

- Problems and issues arise where stakes are high;
- Decisions urgently need to be made and there is insufficient information on a problem
- Facts are surrounded by uncertainties, and
- Disputes between the stakeholders involves values.
- There is a limited time to solving the problem
- Social context and scientific practices of increasing uncertainty exist
- Turbulence in relations dominates in an environment

(Block, 2018; Funtowicz and Ravetz, 1994; Frame & Brown, 2008; Funtowicz & Ravetz, 2018; Meisch, 2018; Ravetz, 1999, Tainter et al., 2006)

Such conditions for adopting post-normal science approaches to problems are similar to those described when problems are considered wicked in nature and substantiates a relationship between the two.

Post-normal science approaches challenge wicked problems where traditional process of researching, setting a goal on outcomes of knowledge that is considered fact or truth do not apply and where the characteristics of approaching problems require only using a *normal* science approach. Post-normal science is able to transcend that in that it does not restrict certain types of information that may not be typically considered scientific or information that is obtained from scientific experts - thus the approach lends itself to catering non-traditional methods being more robust, focused on quality in the comprehensive sense (Ravetz 1999). Instead, methods have embraced social interaction, learning that aims to understand the true complexities of problems arising today and finding ways of engaging stakeholders in 'robust and healthy processes of learning that work against the fragmentation of knowledge caused by wicked problems (Conklin 2001).

Approaches to socio-ecological systems for example has been through increasing recognition to socio-ecological models of the complex system to represent human behaviour and the interaction of people in their environment and how they begin to have a change in mind set (Rounsevell,

Robinson and Murray-Rust, 2012). This particular example was focused on the use of agent-based modelling approaches. Other approaches such as environmental governance have moved away from central of governance and embraced multi-level systems that support participatory and collaborative governance (Newig and Fritsch, 2009). Political ecology approaches for research solving problems in third world countries has meant that researchers themselves have to adopt a political ecology perspective to research; keeping in mind that power relations between actors exerts a significant influence on 'human-environment interaction' (Bryant, 1997).

Again, the above mentioned conditions are similar to those that exist when a problem is considered wicked in nature. In light of the growing research on wicked problems and adaptive management strategies in mitigating their effects, the post-normal science approach has simultaneously been documented and has gained interest as a problem solving strategy (Ravertz, 1999). As early as 1999, Ravertz reported on the post-normal and science then, ever since, there has been a growing interest in the wicked nature of problems and unique ways of approaching them (Conklin, 2001; Daviter, 2017; Frame, 2008). Post-normal science as a strategy becomes particularly useful when doing research that deals with global environmental issues - where either or both uncertainty (what is not fully known or understood about a problem) and the decision stakes (referring to the commitment of each stakeholder involved to the problem) are usually high (Funtowicz and Ravetz, 1994). In the post-normal science strategy, the systems own uncertainties and high stakes of decision making are used in the analysis process - factors which are often ignored in traditional research of the pure or normal science approach (Frame & Brown, 2008; Ravertz, 1999, Funtowicz and Ravertz, 1994).

Post-normal science recognizes that problems usually have more than one answer to them, or at times having no answer to them at all (Ravertz, 1999). This is much like wicked problems where the biophysical factors, social factors and economic factors are in a constant state of change, affecting the certainty of problems and the ways of approaching them (Churchman, 1967, Funtowicz and Ravertz, 1994).

It is important to avoid the thinking that every problem in the water management context is wicked in nature or that it possibly requires a post-normal science approach in the manner to which

multiple actors engage with one another in order to go through social learning. Some problems have a clear cause-effect-solution relationship to which 'normal' scientific approaches embracing the pure sciences can be applied, but increasingly they have become more 'wicked' or 'messy' in characteristics and require embracing pre post-normal approached in multi-stakeholder interactions if social learning can be achieved (Block et al. 2019; Craig, 2020; Daviter, 2017; Frame & Brown, 2008; Grafton, 2017).

2.4 Information and Communication: fundamentals for Social Learning

One factor that connects social learning within the context of multi-stakeholder involvement consistent in literature is the communication of information between stakeholders (Biedenweg et al., 2013; Pahl-Wostl & Hare, 2004; Siddiki et al., 2013; Whalen et al., 2018). The role that shared information plays in social learning spans in social learning being both a process and an outcome of social involvement processes (Craps and Maurel, 2003). It has become necessary to understand social learning in multi-stakeholder processes and the use of information communication technologies (ICTs) in dealing with water related problems framed by post-normal science approaches.

There are various factors to understanding information communication extracted from the literature: understanding the theories of learning, understanding the traditional elements of social learning in multi-stakeholder arrangements and finally, understanding the general attributes or phenomena that have been connected to learning (Guechtouli et al., 2013; Siddiki et al., 2017; Wenger, 2009). With regard to the use of information communication technologies or ICTs to dealing with water related problems, it is important that the essence of social learning is understood first and within the context that social learning occurs or is being investigated (Craps & Maurel, 2003).

Social learning has also been found to be associated with various theories of learning, including Theory U (Scharmer,2009). It is also enabled by various social conditions or phenomena's for learning, some of these phenomena's or constructs of learning are affected by the shared use of information systems by stakeholders (Craps & Maurel, 2003).

2.4.1 Informed use of shared information systems for social learning

To adequately serve the cause of social learning, information contained and shared in information systems (eg. ICTs) must of necessity be diverse, embracing all kinds of information, not just the 'hard sciences' created by experts, but also the soft science-type information created by the layperson (Tabara and Chabay, 2013). This is in order to equip stakeholders to facing the accelerated uncertainty of problems and the new ways of understanding knowledge that it brings (De Bruin & Ensor, 2018; Mukhtarov et al., 2018; Tabara and Chabay, 2013). There are also various factors to understanding information communication, specifically:-

- One is understanding the theories of learning that are connected to information communication in general
- The second is the traditional elements of social learning in a multi-stakeholder engagement environment where information flows, and finally
- The third is what we characterise as the general attributes or phenomena's that have been associated with learning through the communication of information across these multiple stakeholders.

Stakeholder relationships that succeed in sharing information that lead to social learning have specific requirements referred to in literature often as elements of social learning, being met. These elements have collectively been responsible for the accumulation of knowledge in a system regarding a stake issue(s). These elements are all related in that they refer to as relational practices as stakeholders engage and all result, essentially from the social involvement of actors (Tippett et al., 2005) are:

- Mutual awareness of each other's goals and perspectives.
- Realization and understanding of stakeholder interdependency and system complexity.
- Building of trust and relationships between actors and,
- Ability to communicate effectively.

2.5 Communication: constructs of social learning

The above review has shown the fundamental process of stakeholder interaction for the modern day problems, and the growing appreciation for virtual spaces of engagement through ICTs. At the centre of these processes is information and the sharing of this information through communication which is fundamental for learning. Over the years, methods of communication have changed drastically; being facilitated by information communication technologies and the internet. These advancements have opened the door for communication in both virtual and physical landscapes, and the application of information systems as spaces for knowledge sharing. The subsections to follow give insight into the constructs as revealed in the literature associated with nurturing communication and learning in different methods of interacting with information in both the virtual and physical spaces.

2.5.1 Collective action spaces

Pahl-Wostl (2007) documented research that embraced the focus on studying communities of practice as examples of actor interaction within a group; creating actions that influence feedback of the social construction of the constantly changing spaces that the actors interact. These communities of practice where actions take place and are guided by the need for actor participation become a source of studying social learning (Wenger, 2000; Pahl-Wostl, 2007). Collective action spaces are exemplary social spaces where the importance of communication is one of the leading factors. Creating collective action spaces includes the use of ICT virtual spaces. Stimulating the co-generation of information and knowledge helps to foster the relatedness of such information and the collective understanding thereof. It follows therefore that such multi-stakeholder co-generation of information and knowledge is central to wise collective action in the water related space.

2.5.2 Recognising and understanding stigmergic processes

According to Allen *et al*. (2011), there is a growing need to replace old standard approaches that emphasize the selection of tools as solutions for problems with approaches that encourage the

participation of stakeholders as a process. A stigmergic process is the phenomenon that describes a group of interacting agents that continues to grow in adaptive intelligence as a result of being in self-organizing networks influenced by the actions of others (Heylighen, 2011). In essence, stigmergic processes are self-organizing systems for participation that make interested and affected individuals involved agents in a social engagement and modelling space which leads to significant actions being taken that benefit the system (Heylighen, ibid). In such a case, participatory modelling requires both stigmergic processes and self- organising systems.

The word stigmergic stems from the concept stigmergy which means to "mark the work" done (Heylighen, 2011, 2016). A good example used originally in literature is termites building a mound through what could be described as a social network of indirect coordination between agents or actions (Marsh & Onof, 2008). The coordinated behaviour of termites while building a mound has been described as display of collective intelligence of systems to forming collective mental maps (Dent, 2014 adapted from Heylighen, 2011). The termites begin to act as a single body by imitating and following through the actions of other termites in the colony. According to Heylighen (ibid), the natural system entirely uses signals which influence assumptions in the creatures that enables them to model their behaviour and act without having direct communication. The behaviour of picking mud pieces and placing it on the ground is spread as each termite copies the other until a complex structure such as a mound is built even if the first termite to set a pattern for the behaviour is no longer there (Heylighen, ibid). The process which is entirely based on signals creates a mental model that the insects begin to follow (Heylighen, ibid). Similarly, co-ordination can be accomplished to produce structures that are well designed and yet complex through self-organizing human systems (Heylighen, ibid; Marsden, 2013; Marsh & Onof, 2008). The self-organizing systems are actually self-organizing networks that have the potential to grow in adaptive intelligence and complexity as groups of interacting agents- hence the name stigmergic processes. It is also a process that results in deep and continuous learning as the awareness of those in the system, virtual or otherwise is constantly being fed.

Recognising and understanding stigmergic processes or stigmergy as processes that are self-sufficient, self-organising, online based virtual environments, supported by networks of social relationships are just some of the recent developments in literature expressed by authors such as

Thomas (2010). The formation of learning spaces and learning environments as the by-products of virtual self-organising and sufficient networks of actors who have similar set goals for a system (Marsden, 2013; Thomas, 2010) suggests that ICT supported information systems are also connected to social learning through stigmeric processes. Hence stigmergic processes not only exist in the physical sense, but also the virtual sense. Literature has revealed that the formation of learning spaces or learning environments is consistent with characteristics of the formation of stigmergic processes. Authors such as Dent (2014) have documented the link between stigmergic processes and learning with participation; specifically participatory agent based social simulation modelling (PABSSM). According to Dent (ibid), this link suggests that participatory agent based social simulation modelling is a stigmergic process where the work of others and their assumptions about a system is used to build on a model of the system. Thus each actor (modeller) figuratively 'picks up' information which is 'marked for others to see' and shares it to build on a model of the system[3]. As the research project progressed, the importance of applying stigmergic processes for collective intelligence and collective mental maps in multi-stakeholder engagement for social learning became more apparent.

2.5.3 Mental models

Recognising and articulating mental models can be considered an outcome of processes that feed the collective intelligence of a system such as in stigmergic processes. This is in part a result of what mental models is defined as. W. Forrester defined general mental models as:

"The image of the world around us, which we carry in our head, is just a model. Nobody in his head imagines all the world, government or country. He has only selected concepts, and relationships between them, and uses those to represent the real system" (Forrester, 1971). Ultimately, mental models have a bearing in understanding the processes of social learning and how these processes are formed as they are based on the pre-conceived understandings of a system that exists between actors in a multi-actor social space and are, essentially mental representations of information (Pahl-Wostl & Hare, 2004, 2007; Steger et al., 2021).

[3] The literature research does not reveal what kind of system this is, hence it is used in this research to refer to the water catchment system in its various aspects; biophysical social and others.

According to Pahl-Wostl (2007), developing methods for approaching complex management problems requires a learning paradigm to be adopted. This learning paradigm can enable stakeholders to analyse the origin of a particular management problem, how it is affected by the social constructed reality as well as what factors are impediments of change that enable the problem to exist (Pahl-Wostl, 2007). The mental models held by different actors can differ widely within complex engagement spaces such as those of water engagement (Fenemor et al., 2008).

The mental models and frames in which they are situated determines how information is observed and then processed to reach conclusions based on what is observed. The internal representation of reality, which is a mental model, is then shaped by the role of the actor, his or her experience in solving particular problems and thus their assumptions, expectations and cognitive biases and resulting behaviour towards it are formed. This is the selective processing of information and may prevent social learning as actors, most often, process information and determine appropriate actions based on their experiences. Such selective processing of information can also prevent individuals, organisations and groups from adapting to an ever changing and complex human-technology environment. If mental models are factually incorrect, they must be corrected through mutual actor agreement concerning the soundness of knowledge provided. This can be done through observation of actor interaction, the use of modelling exercises and empirical analyses using technical expert provided knowledge.

Mental models determine how knowledge is interpreted and embedded in a frame of reference. How knowledge is interpreted for mental models may be linked to preferences, normative assumptions and values (Den Haan and Van der Voort, 2018). When mental models are linked to normative assumptions, values and preferences embedded in a frame of reference; reflection and negotiation processes must take place (Den Haan and Van der Voort, 2018; Heylighen, 1999; Pahl-Wostl, 2007). This is possible when hard and soft system approaches are combined and the role of different types of learning in management processes is emphasised.

2.5.4 Surfacing assumptions

In the processes of multi-stakeholder engagement, it is vital to embrace techniques to enable the stakeholders to recognise and articulate their mental models which form the basis for their assumptions about and understanding of the water related complexities of the situation before them. The process of making implicit mental models or assumption explicit is often referred to as surfacing assumptions; that is bringing them to the surface of our consciousness so that they can be explicitly expressed and so that others can then contemplate or explore our assumptions (Thober et al., 2018).

Participatory agent-based social simulation models are both a process for and an outcome of such assumption surfacing for the purposes of building more wholistic mental models for multiple stakeholders to agree on and share as they collectively explore wise and sustainable ways forward (Schulze et al., 2017).
To create mental models of a problem or system, comes from appreciating that each stakeholder has a different view of the complex water situation and so wise, aligned and coordinated collective action is difficult to achieve unless the stakeholders have engaged in processes to deepen their common understanding of the information, mental models, assumptions and perspectives of fellow stakeholders

2.5.5 Socially robust knowledge

Understanding the concept of socially robust knowledge and how to develop it is imperative for effective collective actions by multiple stakeholders and for understanding why it can be closely associated with social learning in literature and in dealing with the wicked nature of problems in the water space.

Socially robust knowledge, sometimes referred to as actionable knowledge comes from surfacing mental models of an issue by mentally wresting with different perspectives. It stems from a strong collective trust that collective, aligned and generally wise actions are made possible. Within the context of natural resource management, social learning has been associated with socially robust knowledge creation in literature due to characteristics that are similar to social learning. In this context, it has been said that there is need for the development of new knowledge, skills, attitudes,

and behaviours for stakeholders to deal with issues constructively as well as to cope with uncertainty and to adapt to change. There exist a connection for dealing with the wicked nature of problems using a social learning as an approach and the creation of socially robust knowledge. The characteristics of moving towards socially robust knowledge is also similar to a shift towards post normal science approaches noted in the preceding subsections. It is a movement away from the limitations of what is considered to be 'reliable' information which is only restricted to the boundaries of the scientific peer community, to a recognition and interpretation of boundaries to extend science to a wider community (Gibbons, 1999; Kastenhofer, 2011). The reliability of this information cannot only be validated by the conventional scientific discipline norms (Gibbons, 1999). Under the lens of creating socially robust knowledge, the characteristics of wicked problems are recognised and so too is the approach of post-normal science regarding information. Two factors of scientific information exist: socially robust knowledge needs to be recognised by society to be both transparent in the way it is produced with its production being allowed for the participation of society (Gibbons, 1999; Ravetz, 2004; Weingart, 2017).

Considering socially robust knowledge also becomes appropriate in light of multi-stakeholder engagement in the water space as socially robust knowledge is created in a social space where science and the public meet- a symbolic space termed the 'agora (Gibbons, 1999; Nowotny, 1999). The 'agora' has also been documented in literature to not necessarily be a physical space for interaction; the activity of media and communication technologies in the agora or space have also been noted to have a significant role. True to socially robust knowledge, in the agora; scientific problems are framed and a contextualization of issues takes place but it does not belong to the public alone, and neither does it exclusively belong to private interties (Gibbons, 1999; Nowotny, 1999; Weingart, 2017). Rather, it is a domain where actors meet and negotiations of *possible* solutions to problems (Gibbons, 1999). In these types of negotiations, there is also room for experimentation between science and society; an important factor in socially robust knowledge being related to communication and social learning. Variety through processes of continuous experimentation feed creating socially robust knowledge, in turn, open interactions between science and society are responsible for creating this variety whether in scientific problems, institutional designs or colleagues or actors, as these stakeholders and groups attempt to respond to uncertainty and complexities of problems (Conklin, 2005; Funtowicz & Ravetz, 1994; Gibbons, 1999). When the lines of communication between the scientific community and the society at large

are more permeable following the need to co-creating socially robust information, there is better contextualization of problems as society's ability to speak up to science is increased.(Gibbons, 1999; Offermans, 2016).

A change in how scientist view themselves in the agora: with the production of socially robust knowledge, science does not automatically adopt legitimacy over other types of information, and non-expert information, instead conditions are created where society can speak back to science as part of the process of contextualization of science (Nowotny, 1999; Weingart, 2011). Instead, interacting to form socially robust knowledge would require repeated legitimization by entering into the agora and participating fully in the process of producing socially robust knowledge (Gibbons, 1999; Offermans, 2016). This heightens interest in research such as those of producing technologies that assist in the co-production of socially robust knowledge in dealing with wicked issues in the space of communication between stakeholders in the water space.

2.5.6 Whole system institutional virtual spaces

Recognising and using networks of actors in the virtual space of information communication technologies (ICTs) is a practical pathway to developing virtual spaces in which whole water related information and modelling systems can be constructed and in which virtual institutions can form to engage these systems. Virtual systems can also be characterized as being online self-organizing social systems - virtual learning spaces are sociable environments that help in the creation of a social space where networks of social relationships can emerge between members of a group (Thomas, 2010).

How the virtual system is designed, that is the landscape and the way data is represented is also important as it affects the way in which the environment is experienced and used by the actors. It is crucial that the design of the virtual system be considered, that is the virtual landscape and how it is represented as it affects the overall experience gained by the users and the way in which this environment is used (Churchill & Snowdon, 1998).

Stakeholders often engage in processes of collaboration in order to approach wicked problems in the water realm, however when collaborative work forms the centre of information sharing in communication between actor- collaborative virtual environments can give an opportunity for individuals and groups to share information through interactions with data representations (Allen et al., 2011; Churchill & Snowdon, 1998). These collaborative virtual environments by definition distributed virtual realities that offer digital landscapes, graphically realized with infinite potential. The actors who form these spaces can collectively determine the rules governing access and behaviours in these virtual spaces. The trust built in these spaces and the emergence of socially robust (also known as actionable) knowledge emanating from these spaces is a product of healthy social learning (Churchill and Snowden, 1998).

The application of whole system institutional virtual spaces becomes important with regard t the characteristics of the virtual spaces and whether or not information is accessible for interacting with or not. The next subheading briefly reviews the importance of transparency as an element of social learning in multi-stakeholder engagement.

2.5.7 Transparency and inclusiveness

Valuing and appreciating inclusiveness and transparency in the aforementioned virtual institutional space is imperative if the actors in such spaces wish to facilitate sustainable outcomes that contribute to the resilience of water related systems. Trust as well as holistic understanding can only be built on a base of transparency and inclusiveness.

2.5.8 Trust and relationship building

The scope and complexities of water related systems, both in the bio-physical and socio-economic sense are far too complex for any one actor or organisation or discipline to understand holistically. The metaphorical glue that holds the various components of the complex water web of components and relationships together is trust and shared information is a fundamental element of any trust formation. The above comes to light based in what is known about trust in multi-stakeholder engagement. It has been understood that organisational and social barriers as a result of the multi-stakeholder nature of most of the environmental issues, are the prime reasons why the much advocated collaborative learning approaches to managing natural resource issues have not been

taken up extensively worldwide and even in the south Africa context (Allen et al., 2011; Dana & Nelson, 2012). Specifically one of the social barriers is the deliberate exclusion of non-scientific forms of knowledge and institutional structures in the areas of research and policy and decision-making which effectively nulls the approaches to participate and inevitably fails to allow the processes that promote shared learning, understanding and development between the stakeholder diverse communities of practice (Allen et al., 2011; Tippett et al., 2005). While overcoming needs an inclusive space where multiple stakeholders can interact and engage in solving complex problems on equal terms needs to be facilitated, it can be a challenge to nurture this approach. This has been noted from literature to be particularly in building on an individual level and designing these multi-stakeholder engagement initiatives and relationships (Goldin, 2005).

Building trust and relationships relies on stakeholders trusting one another to share information whether the engagement is through collaboration, a partnership or another means to interact towards approaching issues or wicked problems. The ability to for building relationships through trust can also be based on how freely information flows from stakeholder to stakeholder: this can be described using another element that has been associated with learning; energy flows and tempo.

2.5.9 Energy flows and tempo in multi-stakeholder engagement

Any human engagement is characterised by flows of energy and the tempo of such energy flows is a key element in determining the vitality of such engagement. What can be defined as 'energy and tempo' can affect social learning indirectly by determining how quickly information moves from one person to the next and feeds the energy of growth of the knowledge space. Information can be limited in a group engaged in urgent matters pertaining to a river basin or catchment when information flows from one stakeholder to another, one stakeholder at a time (Churchill & Snowdon, 1998), rather than from one to many as with modern social media. On the other hand, when collaborative types of virtual environments are utilized to allow users to navigate easily in the system and communicate quickly and efficiently on activities in those virtual environments and many forms of communication are supported. These all act in harmony with deepening

awareness; a characteristic of social learning (Allen et al., 2011; Churchill & Snowdon, 1998; Cornell et al., 2013).

As a result, a group that only meets to communicate once every 3 to 6 months and has almost no communication in between, can hardly claim to display the energy flows and tempo required to match the complex dynamics of a multi-stakeholder catchment. The transaction costs of such multi-stakeholder engagement and the high frequency of engagement require the involvement of ICTs and information systems which can positively affect social learning. Energy flows and tempo (ie the speed to which knowledge is shared) contribute to the knowledge space where stakeholder are interacting on common issues. However, meaningful participation is also important in building a rich knowledge space for learning. The literature surrounding this phenomenon is presented in the succeeding subsection.

2.5.10 Meaningful participation

Inclusive participation by all relevant stakeholders is vital as discussed above. However, such participation must be meaningful and not simply a "head count" of presence at the proverbial table (Dent, 2019 pers communication; Valentina, 2017). Literature findings, for example from Valentina (2017) and Gustafson and Hertting (2017) show that it must be more than that. For participation to be meaningful for a stakeholder, the information exchanged must be understandable and accessible. Meaningful participation must also include the participation of citizens even if those stakeholders do not share institutional legitimacy with formal ones (Ison et al., 2004). In the case of cultivating meaningful participation, it must be stressed that the pathway to both understanding and accessibility, is very often through a network of trusted relationships and knowledge which help the stakeholder's understanding and facilitate access which opens pathways to deep learning.

Meaningful participation also affects how stakeholders view each other. Stakeholders who have embraced trust with other actors in a network are better able to transcend areas of *bounded rationality* and trust others to explain terms in a field they may not be well educated on and still be able to engage in meaningful participation based on the information they know in a multi-

stakeholder arrangement (Conklin, 2009; Funtowicz & Ravetz, 1994; Ison et al., 2004; Ostrom, 1994; Boadi et al., 2019). This becomes important as literature shows that meaningful participation is also related to the ability that a collective or collaborative group of stakeholders have in approaching complex and tricky water related issues (Cosens & Williams, 2012; Tippett et al., 2005; Ostrom, 1994). The value of meaningful participation can also be noted from citizen science - a phenomenon that has been associated with learning.

2.5.11 Citizen Science and citizen science monitoring

In social learning, dialogue between scientists and citizen science monitoring groups it is important in reframing and understanding wicked problems of processes. Citizen scientists engaged in citizen science monitoring as part of social learning become important in the reframing reality of the problem and initiate a reorientation of context of what is known (Paquet 1999). One of the social barriers to citizen science and their monitoring efforts is the deliberate exclusion of non-scientific forms of knowledge and institutional structures in the areas of research and policy and decision-making which effectively nulls the approaches to participate and inevitably fails to allow the processes that promote shared learning, understanding and development between the stakeholders in diverse communities of practice (Allen et al., 2011).

Typically social learning has been described in the literature as being built on dialogue between actors, mutual learning between both the scientists and the citizens and continuous reflection-action processes (Paquet 1999).

2.5.12 Self-identity and legitimacy

Wenger (2000) found that individuals engage in social learning pathways that are consistent with their self-identity. This means that if individuals engaged in citizen science activities see themselves as having a legitimate role in pursuing engagements which will lead to deeper understanding of the water related systems of their contexts and that their identity also includes being a curious learner in such systems then the stage is set for wise collective actions guided by continuous learning and improvement. The value of self-identity for legitimacy and efficacy comes

from the influence on connections and power, values, ways of engaging and feelings of legitimacy and efficacy it effects. Social learning results from a positive self-identity change, however, it can also lead to deeper social learning. Within a group as already revealed above; the shape of the identity of an individual changes as a result of the social learning of an individual in their social surrounding (Pahl-Wostl, 2007). The value of self-identity for legitimacy and efficacy comes from the influence on connections and power, values, ways of engaging and feelings of legitimacy and efficacy it effects (Dent, 2012; Pahl-Wostl, 2007).

2.5.13 Transactional costs of engagement

If the transaction costs of engagement, sharing information and learning are low such engagement is bound to be more inclusive and continuous. Because of the complexity of solving problems, solving problems has been described as expensive, having higher costs due to the increased need of information becoming more organised while the costs of processing large volumes of information increase (Tainter et al., 2006). In a typical multi-stakeholder arrangement, ICTs and other ways to lower transaction costs in multi-stakeholder engagement has an influence on the abilities of the actors to learn, even if they do not invest costs into engaging face to face often . For instance, the use of online tools and virtual engagement spaces have been documented to be effective in assisting integrated stakeholder engagement as an approach to catchment management (Allen et al., 2011). The use of ICTs and online virtual spaces of engagement can give opportunity for a holistic natural resource management approach as the stakeholders interested in the affairs of the catchment could be involved even if they were from different disciplines (Allen et al., 2011; de Loë et al., 2009). Many of the constructs discussed already aid in the processes of lowering transaction costs of multi-stakeholder engagement.

2.5.14 Transcendence of intellectual and organisational barriers

It is a very frequent lament in the multi-stakeholder water related space that many actors and organisations are “operating in silos” and that stepping out of them through post-normal science approaches in the face of wicked problems has become prioritized in the realm of water (Dent, 2012; Frame & Brown, 2008; Ward, 2016). Such fragmentation is a recipe for duplication, re-

inventing the wheel, non-aligned activities which pull in opposite and often unwise directions, high costs, reduced trust, lessened appreciation of inter-dependencies and synergies (section 2.5.14); lack of critical mass and economies of scale to tackle challenges, solutions that themselves cause more problems, a general lack of progress and heightened potential for conflict (de Loë et al., 2009).

It is therefore imperative that stakeholders develop the leadership skills to *transcend intellectual and organisational barriers* to productive engagement. Meeting in cyberspace on virtual organisational platforms that are becoming more and more prevalent in the realms of citizen science related collective actions are a wise way forward. Some of these pathways were researched and are discussed in this dissertation.

2.5.15 Appreciative inquiry

According to Bushe (2013), appreciative inquiry encourages collective inquiry where stakeholders feed off each other's contributions in order to collectively design a desired type of future state that does not require the actors to be coerced or persuaded to act on behalf of planned change. Such spaces of dialog exchange where information is shared equally between stakeholders facilitates open sharing and receiving of views and opinions between stakeholders in a spirit of democracy. This further leads to enhanced learning, mutual recognition of others opinions and views as legitimate and sharing of the same needs and values (Mathur et al., 2008). It is argued that the development of skills in appreciative inquiry will assist in multi-stakeholder collective action in which citizen science and citizen agency development have the potential to play a significant role, particularly in allowing citizen science to be communicated on in virtual spaces and inquired further regarding contributions made the knowledge space and subsequently social learning. This gave rise to reviewing another phenomenon that can be associated with social learning; that is practice architectures and safe places to experiment which is discussed in the next subheading.

2.5.16 Practice architectures and safe places to experiment

Creating practice architectures (Kemmis & Mutton , 2012; Wilkinson and Bristol, 2018) and safe places to experiment is imperative for the kinds of trial and error required to develop all the skills needed to pursue the constructs mentioned above and below. The virtual organisational space offered by online engagement platforms and information and modelling systems where scenarios can be run through models, assumptions made explicit and tested in modelling systems where "failure" has almost no cost and experimentation is encouraged; assumptions are surfaced and test in the modelling systems and stigmergic processes abound.

According to Kemmis and Mutton (2012) a nourishing space of a practice can be formed even if many stakeholders are involved in different activities in a management area or site. However, all of them can be interlinked in a web of activities. In the context of water management in a system, the idea of having an interconnection of activities such as this one is desired in the ace of wicked issues. Kemmis and Mutton (2012) also described a system in which the activity of one actor contributes or builds on the task of another actor. This the authors term an ecology of practices or 'webs of human social activities' that are necessary to sustain a practice as one of a particular complexity and type carry the overall purpose of the project.

Dent (2012) suggested that collective spaces of stakeholder engagement in South Africa such as the Catchment Management Agencies (CMA's) have demonstrated efforts for deliberation where enormous in-kind contributions are generated as stakeholder engage with one another and with information. It is for this reason that such collective action spaces are called 'practice architectures' – they have the potential to be places where information could be tested and modelled from collective contributions of information (Valkering, 2009).

2.5.17 Models as metaphors to assist public participation

Models can be thought of as metaphors of the actual catchment. It is widely accepted in scientific and business circles that multi-stakeholder modeling processes provide "safe spaces" for stakeholders to experiment with ideas and perform "what if" scenario analyses to stimulated both strategic and operational conversations (Allen et al., 2011).

The models provide one of the ways to encourage discussions so that people can come up with different ways of sharing perspectives (Allen et al., 2011; de Loë et al., 2009). Multiple stakeholders can mentally practice future scenarios or share ideas and experiment with ideas about future possibilities; such modeling practices can encourage continuous learning and deepen understanding about the catchment. Such processes are entirely consisted with Theory U Scharmer (2009) for social learning in complex multi-stakeholder contexts. The participation process of actors sharing a common stake such as water management is of outmost importance particularly as it comes to involving actors in discussion of scenarios about the future of water resources, The next subheading reviews the importance of what is known as participatory agent based social simulation modelling.

2.5.18 Participatory agent based social simulation modelling (PABSSM)

Arguably at the advanced end of the range of social learning processes in the water space, is the practice of participatory agent based social simulation modelling (PABSSM)[4]. As the name suggests it is a participatory process involving the agents of the various stakeholder groups in a social process of posing scenarios to a consensus based modelling system that is co-constructed in the midst of an inclusive, transparent multi-stakeholder process. PABSSM is one of the emerging processes of complex and large multi-stakeholder engagements aiming to share water resource benefits equitably (Pahl-Wostl, 2002). For PABSSM to succeed, a good use of practices and practice architectures needs to be taken (Kemmis & Mutton, 2012). As stakeholders view themselves as agents of change and continue to participate virtually, this construct leads to deeper learning (Tabara et al., 2007).

Many of the above mentioned constructs of social learning can be tracked indirectly or directly to the core requirements of social learning. This is reviewed in the next subheading.

[4] This is a practice that combines almost all the elements of Sections 5.2 to Section 5.15 and Scharmer's Theory U as well as the ICT systems discussed in this study.

2.6 Building capacity for social learning

Social learning in which the change in behaviour of individuals is as a result of being influenced by other actors, is a concept and phenomenon in the literature linked to social interactions and relationships. The relationship dynamics to which communication of information between actors and learning occurs is dependent on specific requirements referred to in literature often as elements of social learning. These elements of social learning have collectively been responsible for the accumulation of knowledge in a system regarding a stake issue or issues. These elements are all related in that they refer to as relational practices that exist as stakeholders engage and all result, essentially from the social involvement of stakeholders (Tippett et al. 2005; Pahl-Wostl and Hare 2004a). In accordance with communication being an essential part of encompassing the elements or constructs of social learning, the following requirements from literature were reviewed for the purpose of this research and social learning.

1. Mutual awareness of each other's goals and perspectives
2. Realization of stakeholder interdependency and systems complexity
3. Building of trust and relationships between actors
4. Shared role definition and fact finding
5. Combined Planning and implementation

2.6.1 Mutual awareness of each other's goals and perspectives

In environmental issues, mutual awareness of stakeholder views, knowledge and perspectives becomes important in achieving the tasks in a multi-stakeholder arrangement.

Literature shows that the idea of achieving mutual awareness of each other's goals and perspectives has been closely associated with knowledge shared: where knowledge must be multi-sourced bother from formally trained experts such as scientists, natural resource managers, policy makers and users of natural resources. The focus in gaining this multi-sourced information is to build a system that is integrated or that is system-orientated and holistic. Such an approach in literature

pertaining to natural resource management results in non-expert or state actors, otherwise known as citizens are not only recipients of knowledge contributed to the system but also co-creators of this knowledge (de Loë et al., 2009; Rich et al., 1995).

In South Africa, and more specifically in the uMngeni catchment that this research looks at, groups such as the uMngeni Ecological Infrastructural Partnership (UEIP) have documented their objectives to be centred on awareness. In describing the objectives of the UEIP, the necessity of raising awareness with regard to water security problems has been revealed to be a key component in achieving real collaborative governance (UEIP collaboration meeting, 2016). Additionally, literature supports the view that an awareness of the mutual interdependency between actors in showing a problem in particular issues, even if these actors are divergent on views and perspectives is essential (Dyball et al., 2009). Such awareness moves actors towards negotiations and the building of consciousness on particular problems or issues. This mutual awareness as observed in the body of literature has been documented to be based on mutual interdependency in solving or dealing with particular problematic water based problems and where desirable outcomes are possible when stakeholders stick together than if they were working in silo's (Dyball et al., 2009). In fact, such literature suggests it is worth developing or aspiring towards mutual interdependent in a group even when actors are heterogeneous in their roles and perspectives. At times this mutual dependency is enough to develop if actors are far apart both figuratively and sometimes physically due to stakeholders existing in the virtual age (Dyball et al., 2009)where information communication technologies are used to raise mutual awareness of stakeholder views and perspectives with the sole purpose of attaining a holistic understanding of problems or issues. Such development in the way actors move towards social learning has lead to investments into the ways technologies in the form of virtual environments and realities achieve ways of integrating knowledge information communities in the same way they would face to face.

Literature findings also reveal an association between collaborative virtual environments and stakeholder awareness. Collaborative virtual environments using IT technologies have been documented in application as tools (Toderi et al., 2004) that help actors become aware of each other's activities and thus providing a shared context between them.

2.6.2 Realization of stakeholder interdependency

The realization and understanding of interdependency between actors is primitive to generating social learning through the sharing of information. However information that is shared between stakeholders comes about through the realization that stakeholders are interdependent of one another and that their views, perspectives and goals are important to one another in order to solving a particular issues or problem (Pahl-Wostl, 2002; Van Bommel et al., 2009). Moreover, when information is made transparent between actors and is shared openly it is assign that stakeholders realize their interdependency and understand the necessary to make information easily accessible to one another (Cornell et al., 2013). This has been deemed important in understanding social learning potential in multi-stakeholder arrangement.

Simply adopting blue-print, standard procedures of planning and implementation approaches to problems in the natural environment is now insufficient because approaching problems requires that multiple stakeholder views and perspectives are consolidated and used in the decision making process due to the problems being either highly complex or in some cases being wicked in nature (Conklin, 2009; Dyball et al., 2009).

2.6.3 Building of trust and relationships between actors

Creating social capital includes trust and relationship improvements, where intellectual capital is created with mutual understanding and shared frameworks of problems and agreements on data (Cornell et al., 2013; Mathur et al., 2008). This has been linked to social learning as an integration different frames and views of the river basin by stakeholders- that is different perspectives on issues, functionality, views of one another and different solutions to river basin management their relationship is improved and a mutual trust develops (Mathur et al., 2008; Mostert et al., 2007). Trust and legitimacy are build when stakeholders ensure accountability with one another also ensures accountability as stakeholders which is important for processes of deliberation and inclusion (Cornell et al., 2013; Goldin, 2010). Mutual respect and trust are the key ingredients to communication and are at the core of building social capital and collective learning between stakeholders and in building their abilities to make decisions (Allen et al., 2011; Tippett et al., 2005).

2.6.4 Shared role definition and fact finding

When it comes to social learning, there is a strong emphasis on stakeholder engagement where the roles of stakeholders involved needs to be clearly defined based on clear decision on what they are by the stakeholders in in not to order to inhibit social learning (Mostert et al., 2007). Even if initially stakeholder enter the 'space' having different roles in their organisations, research shows that through multi-stakeholder engagement, stakeholders get closer towards social learning by sharing a common role in the multi-stakeholder group. To overcome situations where learning does not occur because processes that allow shared learning are disrupted or not initiated, an inclusive space where multiple stakeholders can interact, engage in solving complex problems on equal terms needs to be facilitated (Allen et al., 2011; Wehn et al., 2018). However nurturing this approach has been noted to be a challenge in its own terms as it is linked to some core social constructs that have been reviewed above such as building trust and mutual respect which are essential for communication (Allen et al., 2011; de Loë et al., 2009; Reed, 2010).

2.6.5 Combined Planning and implementation

The quality of the interrelationship between the actors is what will determine the social learning outcome. This social interrelationship is formed under what is called events of stakeholder interaction - whether formal or informal (Craps & Maurel, 2003). The ability for stakeholders to plan and implement is also related to communicate such as having free transfer of knowledge and information between actors. The meeting of social learning requirements in multi-actor arrangements means social learning is being applied practically to as situation (Van Bommel et al., 2009). The ability for stakeholders to communicate is important for creating opportunities for open dialog exchange and recognising the interdependency that exist, but more important, the ability for this information to be targeted towards planning and implementation.

Combined planning and implementation encompasses all the above mentioned requirements since in some cases even excessing over the actors interdepended can still be achieved since making other rethink their goals and perspectives (Craps & Maurel, 2003; Van Bommel et al., 2009). Thus

other social learning requirements such at independency are not only prerequisites of social leaning but outcomes of stakeholder interactions,

Emerging models for social learning describe why social learning is an approach that supports the interaction of stakeholders to lead towards process as an outcome of deep learning.

2.7 Emerging models for social learning

There are many models and frameworks that have been used to describe different types of learning. However, in this research those that are related most to the core essentials for building capacity for social learning by connecting the phenomena's or constructs for learning as already described above are reviewed above are focused on. One particular theory of interest includes Theory U by Scharmer (2009). According to Scharmer (2009), collective learning in an organization and institution can be limited. When the same kind of actions are often opted for by an organization or group in situations where some kind of disturbance to the system occurs, it becomes indicative of the groups going through repeated active learning. When groups or organizations undergo a change in circumstance or when new issues arise; groups often look for the best way of reacting to the circumstances that they face and a form of reactive learning occurs (Peschl, 2022; Scharmer, 2009). This can be linked to how pure science is often used instead of post-normal science in approaching consistent wicked problems in the water management realm (Paquet, 1999; Ravetz, 2004).

The type of action resulting from reactive learning described by Scharmer (2009) is governed by the acts of 'downloading' old habits of thinking that influence one to see the world in an idea that they are comfortable in and that they are used to. This way of thinking simply reinforces older beliefs as the groups and individuals act in a way that they have always acted in- reacting to a situation or problem, disregarding the fact that they may be facing unique problems with unique characteristics. It also goes against creatively working towards innovative methods of approaching arising problems (Iversen, and Pedersen, 2017; Scharmer, 2018). Figure 2.1 taken from Scharmer Stakeholders in a process of reactive learning adopt their older views and methods, reinforcing their mental models that have been predetermined (de Loë et al., 2009; Schamer, 2009). This

reactive learning is illustrated to be cyclic and governed by the typical factors of learning: thinking and doing. In reactive learning, the act of *thinking* is governed by predefined mental models and *doing* governed by 'established habits of action.

Figure 2.1 Two paths to approaching problems- abscencing that reinforces old habits and presencing that encourages deep learning, increasing awareness and letting go of old habits. Reprinted [or adapted] from Peace Valley. A virtual Sanctuary, by O. Scharmer, 2009, https://peacevalleyau.org/info/theory%20u/theory-u. Copyright [2014-2021]

Scharmer (2009) has described the quest for a different type of learning which has, in recent years lead researchers to developing a new model of learning that not only interacts components of action and learning as the previous one, it increases the 'depth awareness' and the source of action. This type of deep learning encourages reflection by individuals and organisations as they connect issues

back to the source and explore new ways of approaching problems by letting go of preconceived notions if understanding (as seen in the yellow 'U' arrow in figure 2.1). This type of learning goes in deeper and penetrates what the writer terms 'wholes' of the system, that is 'what it is' and the respective connection of the individual to it- hence the 'U', a turning point for individuals who are part of groups or work alone in understanding complex issues.

Such deep seeing by Theory U is also nurtured by an increasing awareness which has a profound effect on understanding, an individual having a sense of who they are and their place in the world- this is the turning point. This too is well illustrated in Figure 2.1 where the act of thinking resulting in 'increasing awareness of the whole' in the system, contributes to actions that increasingly, with deepening of awareness becomes better to equip to 'serve the whole'. The consideration of this model by Scharmer (2009) for learning supports views of self- identity change, which has been associated with social learning.[5] The conditions that will lead to deepening awareness moving away from downloading old habits to prototyping and performing from a wholistic perspective on the wicked nature of problems is sought after and further warrants understanding the phenomena of learning that can support this transformation by individuals in research and by organizations and groups tackling wicked problems in a catchment. An iterative process of deep learning process as one cuts further down in a 'U' pattern shows what could result as stakeholders arrive to a new state of awareness of the system they are engaging in. This iterative process of going through the 'U' is worth investigating and applying in research (Fitch & O'Fallon, 2014).

[5] Refer to 2.5.12 above.

Chapter 3: Methods

The purpose of this chapter is to describe the research methods that are supported by applying selected learning theories. It situates the researcher, geographically speaking, in the case study area and describes how the researcher's positionality as a participant and observer shifts and interchanges throughout the research process. These interchanges are designed to effect the best methods for achieving the aims of the research.

3.1 Research process outline

Initially the method involved the researcher immersing herself in selected tasks, designed to help create an integrated information management and modelling system which would facilitate coordination in water related multi-stakeholder engagement processes. This work was part of a Green Fund sponsored uMngeni Ecological Infrastructure Partnership Project in the year 2014-2015. One of the processes in pursuit of the above goals was for the researcher to expose herself to various other multi-stakeholder group activities. Of particular relevance, the researcher began to immerse herself in citizen science fieldwork with existing, active volunteer groups, led by Non-Governmental Organisations (NGOs), in the upper uMngeni and Msunduzi catchments of KwaZulu-Natal. She also simultaneously engaged in using and bringing about small modifications to a range of practical information technology applications to enhance inter-personal and inter-organisational communication capabilities.

In parallel to the abovementioned processes the researcher studied the relevant literature as reviewed in Chapter 2. The literature review was primarily to gain an understanding of the key constructs of social learning governing the engagement processes she was observing in the catchments. An outcome of the literature review was a decision to employ the learning theories of Mintzberg (2004; p267); Nonaka (2004); Pahl-Wostl (2007) and embrace these in the Theory U framework of Scharmer (2009). The primary purpose of this approach was to form an inclusive dynamic, iterative process of action and reflection to facilitate the growing learning, in the complex socio-dynamic space. As a result, the leading question: 'how is social learning of stakeholders in

water resource management affected by multi-stakeholder processes in the uMngeni catchment and what role can information systems play in the outcomes of social learning?' can be answered by following the research methods. Answering the research question in a dynamic and complex space was essentially navigating in a wicked problem space.[6]

In this research, the objectives were formed through reflection on experiences of engaging in multi-stakeholder engagement groups in the uMngeni catchment. Hence, a significant part of this process was engaging in Participatory Action Research (PAR) and Participatory Observational Research (POR).

The outcome of the initial participatory engagement process lead to comparing what is known about multi-stakeholder engagement in the uMngeni catchment with what was known from literature. During this time, the researcher was also practically exploring the value of the information technology aspects which in essence support inter-personal and inter-organisational communications. As a result, the focus was on helping progress work on an Integrated Information Management and Modelling System (IIMMS) in support of the initial objective of the research based internship[7]. Finally when the researcher had built the above knowledge base through PAR and POR, she embarked on an extensive literature research to 'make sense' of what she was observing and practically engaging in herself. In addition, the self-inquiry and reflection by the researcher on her, by then, 18 months of field experiences was synthesised to:

• Establish an understanding of the incentives and barriers to social learning in current spaces of stakeholder engagement;
• Examine views on the potential for integrated information systems to be adopted to aid in multi-stakeholder social learning, in real and virtual spaces, and
• Formulate recommendations on the specific actions to create a nourishing context for appropriate social learning in the multi-stakeholder water related space.

[6] Refer to Chapter 2, Section 2.2 for a description of what wicked problems are.

[7] For further insight on the positionality of the researcher during this internship and details of the internship, find Section 3 below.

The information gained from the literature search was further supported with an inquiry of selected stakeholders from the multi-stakeholder engagement groups in one on one interviews. In these interviews their thoughts on the engagement and the prospect of using ICTs for creating information systems was explored. The interviews were guided by the constructs learned by the researcher in her ongoing literature research and were designed to address the research objectives as stated in Section *1.5*. In essence, the researcher sought to establish if experienced practitioners in the realm of multi-stakeholder social learning in water resources management had a similar understanding of the "value of information systems formed in virtual engagement spaces" facilitated by ICTs and furthermore, if and how does such virtual spaces compliment real or physical spaces of engagement?

The broad overarching theoretical framework that underpinned the research methods was Theory U (Scharmer, 2009). The following sub-sections of this chapter are created to provide a more detailed account of the research process that ensured that the researcher went through her own learning, primarily through the processes of Theory U, as she immersed herself in the interspaces of engagement. This research was guided by a theoretical approach. The four main learning models were Theory U which is illustrated in Figures 3.1, and within this the learning theories of Mintzberg (2004; p267); Figure 3.2; Pahl-Wostl (2007) in Figure 3.3 and Nonaka (2004), Figure 3.4. These were integrated to form Figure 3.5, which in essence provides the theoretical framework that guided the research.

3.1.1 Theory

As stated above, the broad overarching theoretical framework that underpinned the research methods was Theory U (Scharmer, 2009). Theory U was introduced in Chapter 2 as a theory, a framework and a phenomena. In this research it is considered particularly suited to providing guidance into a deeper understanding of the complex and dynamic systems[8] that characterise the

[8] Refer to Section 2.7 for a review on Theory U.

spaces of multi-stakeholder engagement in the uMngeni catchment. To achieve this learning, the researcher was engaged in *action learning* over a period of 3 years. This was inclusive of a 12 month internship and a total of 24 months of master's research. Throughout this period the researcher was guided in the macro-sense by the principle understanding of Theory U and the methods of deep learning that it entails. As the researcher immersed herself in various activities and applied the concepts of Theory U, she learnt more and engaged more in various participatory activities. These activities have included gaining access and being a stakeholder in multi-stakeholder groups, attending their meetings, engaging in their group projects, exploring participation contributions to support their engagement and presenting this work into the stakeholders (ie. POR and PAR). Once a basic understanding of some of the catchments activities and how stakeholders engaged was achieved, the researcher was able to move the research in the direction in which the three objectives identified in Chapter 1 would be able to be addressed.

After establishing that the process of research required in generating feedback knowledge from the experience of engaging in participatory observation in the different spaces of stakeholder engagement, it was realised that a deep process of reflection was required from this emersion. This is why Theory U by Scharmer (2009)[9] was considered to be most suitable for this process in this research. Moreover, Kearns (2005) states that "believable observation is the outcome of more than simply seeing: it requires cognisance of the full sensory experience of being in place through immersion in the situation" (2005, p. 205). Therefore Theory U, which according to Scharmer, is essentially about sensing and responding, is appropriate for adoption as a research framework for deepening understanding of social learning.

The meaning behind understanding Theory U for this research was to understand that each piece of information gathered is important in building up the picture of the 'whole', in which the researcher is immersed. For the researcher to answer the research questions set, she had to go much deeper in understanding. The process of going through the U can be illustrated by Figure 3.1 adapted from Scharmer (2009) and Senge *et al*. (2005) on the process of presencing. A

[9] Although reference is made to this particular publication, there are various other publications by Otter Scharmer that describe the Theory U process of deep learning.

combination of these diagrams is able to adequately illustrate the initial research framework according to Theory U that the researcher followed to govern her methodology.

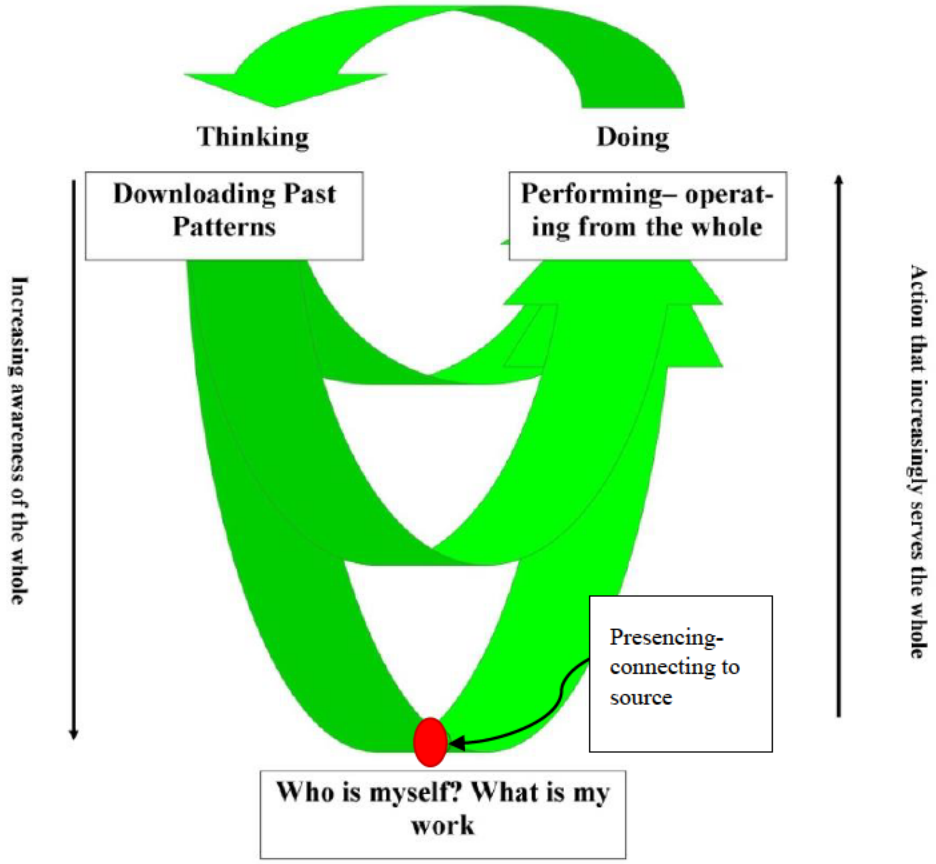


Figure 3.1 Theoretical approach of Theory U taken by the researcher where iterative processes of deep learning, increased awareness and moved actions taken to understand the research and the changing 'roles' of the researcher to connect to the source. Combined and adapted from Scharmer (2009) and Senge *et al.* (2005).

As illustrated in Figure 3.1, deep learning increases awareness of the 'whole' or of the system at work. The deeper the learning, the more the future actions taken by a group or individual evolve as thinking and doing takes place and so too were the researchers methods changing from the beginning of the research until the end.

For instance, the researcher made efforts to avoid 'downloading old patterns of understanding' and adopting predetermined notions of what supports coordination and learning in multi-stakeholder groups in the uMngeni[10] catchment, by extending her knowledge base to other spaces of engagement. This happened during the first 12 months of the study when it was realised that there are likely differences between different engagement groups in the uMngeni catchment. The researcher thus extended herself to more spaces for participatory observation research and observed the interaction processes between the different groups and how they were addressing wicked problems[11].

Figure 3.1 also shows a pivotal point of transformation that requires an individual to question who they are and what their purpose is. Since it is known from theory U that the transformative process towards learning occurs as the individual operates towards the whole, who the individual is also evolves as a more complete picture of the 'problem' forms. Likewise, a significant factor in the methodology was the researcher also changing her positionality multiple times in the research process, questioning who she was and what her purpose was in the research as depicted in the 'turning points' of the U in Figure 3.1. The researcher thus refined the aim of the study, the objectives and appropriate methods to employ.

By actively participating in multi-stakeholder groups in the catchment, the researcher underwent learning by reflection from the successes and challenges faced by the stakeholders she observed. This deepened understanding in the challenges faced in achieving social learning with and without the proper use of information systems. As a result of this action; the researcher went through processes of reflection as multi-stakeholder engagement took place. The reflection process meant 'going down' (seen as the left side of the 'U' in the diagram) and 'coming back up' (seen as the right side of the 'U' in the diagram) repeatedly as new ideas that increased understanding of the

[10] This was the external purpose of the research brought to the researcher through an active research internship. The objectives of this internship fit into the realm of creating a virtual Integrated Information Management and Modelling System through the uMngeni Ecological Infrastructure Partnership (UEIP). The details of the research process are described in the succeeding subsection.

[11] The researcher found that the problems being addressed by these stakeholders are common and that most of these problems were wicked in nature. However, it is worth noting that not all problems existing in the catchment whether revealed by the researcher were wicked in nature. These findings are described in Chapter 4.

'whole' picture of multi-stakeholder engagement emerged. This deep learning governed the methods of data sourcing until it increasingly served her understanding of the whole.

All methods adopted as guided by Theory U ensured that the researcher underwent the complete 'presencing' process where she finally connected to the source, the theoretical method of learning through the entire U by Scharmer (2009)[12] .

Through these methods themes were shaped, the researcher referred to these as the constructs of learning, explored in Chapter 2. This was also considered the initial stage of the 'coding' process and it applies at varies places within the research and influenced the *iterative* processes of learning, reflection and doing.

3.1.1.1 Adult Social Learning Theory

An important step in the research methodology is realising that iterative processes of learning and reflection govern the steps to take in data collection, analysis, research and understanding the 'whole' as described in the preceding subsection. This allowed for the mental application of the model of adult learning by Mintzberg (2014) in this research. Since the aim of this research was to deepen understanding on the role of information systems formed in virtual engagement spaces, for the purpose of multi-stakeholder, water related, social learning, the researcher immersed herself into that multi-stakeholder space to give herself an opportunity to undergo deeper learning. This was in accordance with the above mentioned Theory U. As a result, the research process and the analysis and reflection follows the auto-ethnography form of qualitative research (Anderson, 2012).

The researcher's experience as a participant often followed what is described in Dane (1990) as a *complete participant* where the 'researchers' positionality was not realised by both the researcher and the actors in the spaces she was engaging in until later on. In accordance with the Mintzberg

[12] A detailed explanation of presencing and Theory U is provided in Chapter 2.

(2004) model of learning illustrated in Figure 3.2, the researcher had to be conscious of the different roles she took on in the research and the effect they would have in accomplishing the research objectives. Clearly understanding the roles that needed to be played in the research also lead to an extensive literature review into social learning models including Mintzberg (2004) and the constructs or attributes that are related to learning as seen in process A of Figure 3.2[13]. However, arriving at this realisation also included initial exposure of the researcher to multi-stakeholder engagement processes in the uMngeni catchment. This was the *participatory observation research* (POR) aspect: process B in Figure 3.2 which shows how in accordance with Minztberg's theory of learning, information concerning what the different multi-stakeholder engagement groups in the uMngeni were and what their objectives were was collected by doing focused observation of the members engaging. Upon gathering such data through observation, this part of the research methodology also involved the researcher taking in another role where she was a *participant action researcher* in the development of an Integrated Information Management and Modelling System (IIMMS) - process C in the diagram. Such a method initially occurred while the researcher was an intern before clear objectives and methodology of the research were identified. The objective of engaging in the active use of ICTs in creating an IIMMS as defined in the UEIP project in the year 2015 was to complement the ongoing engagement in the uMngeni catchment and to support collective action by stakeholders as well as social learning. Additionally, the stages of the research project started to evolve and became refined through identifying clear methodology, objectives by reflecting the past experiences with ICTs and participatory observation research and what is known from literature (process D)[14].

[13] Many of these social learning attributes are detailed in Chapter 2.

[14] This meant being further involved gaining a basic understanding of the social learning constructs and phenomena at play as reflected in literature

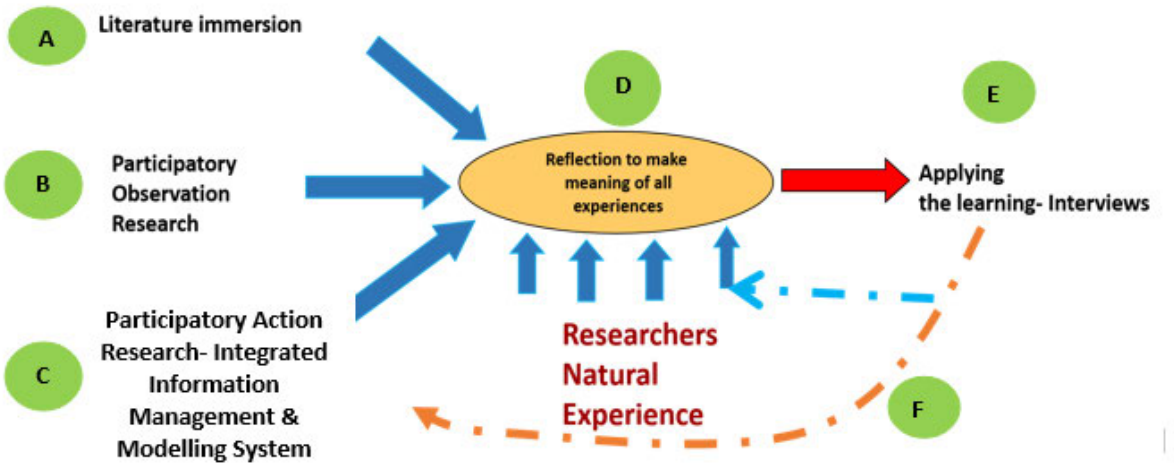


Figure 3.2 A model of adult social learning process after Mintzberg, (2005:267) labelled specifically for this research topic

The researcher shaped the themes for the sampling process of the field research aspect using information that was gathered from the above mentioned experiences and her growing understanding of literature on the subject. The researcher used these themes through iterative reflection in process D. Iterative processes of reflection led to the formation of the research objectives and later, the semi-structured interviews used as seen in Process E.

All these methods enhanced the researcher's natural learning experience (Process F, Figure 3.2) and fed into the reflection the researcher was able to make, even before a detailed analysis of the interviews commenced. The continued processes of reflection (process D) nurtured the process of deep learning in accordance to Theory U by sharpening the understanding of how integrated information management and modelling systems could specifically serve the purpose of supporting social learning in multi-stakeholder engagement groups in the uMngeni catchment (Process C). The researcher's natural learning experience through the stakeholder interviews (Process E) also fed back (Process F) into participatory Action Research (Process C). Based on the responses gathered from applying the learning through interviews (process E), the information systems were used as tools by the researcher to understand how information could be communicated across to

address the concerns in multi-stakeholder engagement which further fed into the researchers reflection. The continued process of reflection also informed the researcher on how stakeholders may respond to integrated information management and modelling systems being used as means of communicating across information within their multi-stakeholder groups (process B) and how knowledge from literature could explain these phenomena's (process A). This cycle of learning continued through the research methodology until the objectives were achieved.

3.1.1.2 Building a Participatory Group Model

The two theories that have been described for individual learning are linked to each other; Scharmer's (2009)[15] Theory U model describing the purpose of the research process, followed by Mintzberg (2005) describing how and what kind of explorative research was followed for deep learning. The next model that was introduced into the methods was that of Pahl-Wostl (2007). This model for learning shows two types of knowledge- soft knowledge which is formed from perceptions and hard knowledge, which is formed from more factual types of knowledge. Using this understanding- part of the methodology was for the researcher to understand and explain the different types of qualitative data she was collecting and its bearing on the soft and hard knowledge interchange happening between stakeholders in the uMngeni catchment. To illustrate this interchange of 'hard' and 'soft' information and of perceptions and known 'facts' which will be used in this research, the Figure 3.3 based on the learning model by Pahl-Wostl (2007) has been provided.

[15] Inclusive of Senge *et al.* (2005) for deep learning

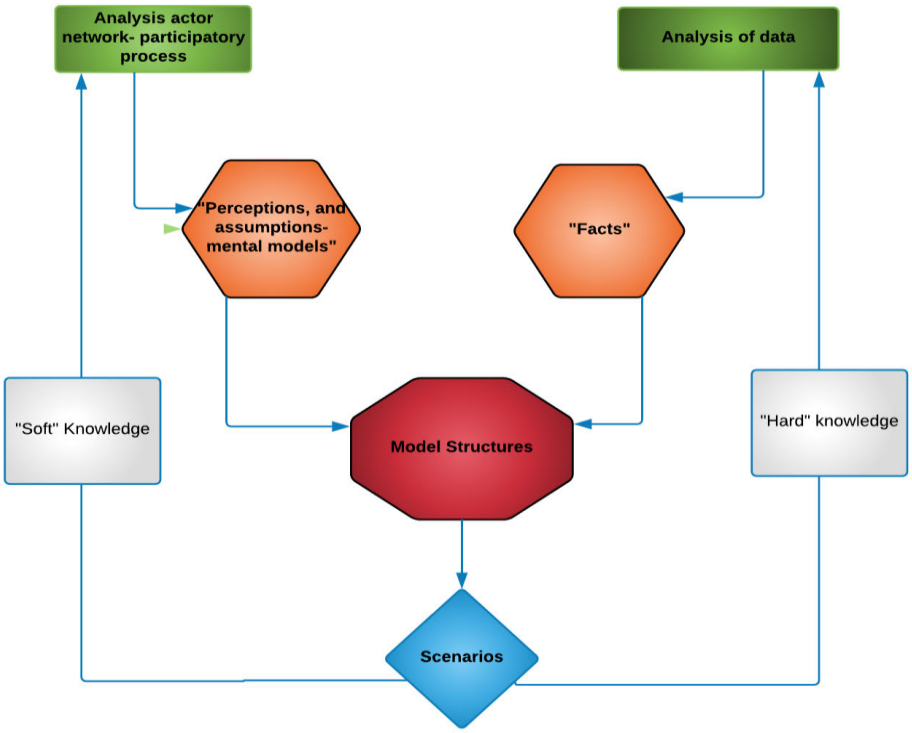


Figure 3.3 The overall approach of combining 'soft' subjective perceptions and 'hard' factual knowledge in a participatory group model building process (after Pahl-Wostl (2007: 564)

Figure 3.3 from the top, left hand side, shows how the researcher had to *analyse the networks* of multi-stakeholder engagement groups that are in the uMngeni catchment. This analysis involved being part of a participatory process as a participant observer. Information gathered from the participatory process lead to perceptions and assumptions being drawn about the multi-stakeholder engagement groups in the uMngeni catchment. These perceptions and implicit assumptions were used to guide the researcher forward and further formed *model structures* that could be supported by what was known from literature. As seen from Figure 3.3, perceptions and assumptions to form mental models of understanding on the *current* spaces of multi-stakeholder engagement are taken into consideration through analysing the actor network using the participatory observation and participatory action research approaches. On the right hand side of the diagram, *facts* of knowledge are formed from analysing the information communication technologies (ICTs) or information systems that were existing and being used in the uMngeni catchment as well as the ones that were emerging as IIMMSs. *Facts* also referred to what was already known about the multi-stakeholder

engagement groups being looked at in this research and what can be interpreted directly from the stakeholders, including interviews all of which lead to an analysis possible *model structures*.

The results that come from *model structures* which are a combination of *facts* about multi-stakeholder engagement relationships in the uMngeni catchment with and without the use of ICTs, as well as the perceptions and assumptions that could be made on how social learning can be improved in multi-stakeholder engagement processes lead to *scenarios* being formed. The interpreted *scenarios* from *model structures*, according to Pahl-Wostl (2007), form both soft knowledge and hard knowledge as seen on the outer left and right hand sides of Figure 3.3. The future scenarios on the trajectory of multi-stakeholder engagement and social learning were imagined for this kind of research. Since these scenarios would be guided by themes developed from the literature they could be applied to gain more information about the uMngeni catchment-*soft knowledge* emerging to analyse how the social involvement of stakeholders could be improved to support social learning and *hard knowledge* emerging to analyse the role that ICT and information systems could play in supporting the objectives of social learning.

As seen on the left, going up, *soft knowledge* generation lead to more *analysis of actor network* through *participatory processes by the researcher* and *hard knowledge*, as seen on the right hand side, going up, lead back to the *analysis of data* through participatory action and the cycle continued until the objectives of the research were reached.[16]

The methodology followed in building a participatory group model as illustrated by Pahl-Wostl (2007) in Figure 3.3 followed integrating different types of knowledge and appreciating different information sources, both those that created *soft* and *hard* knowledge. Since what is known from Pahl-Wostl (2007) as in Figure 3.3 is that the distinction between soft and hard elements of knowledge is of a gradual nature with a blurred interface, all types of information gathered from the research process were considered valuable. This meant that information from documents such as minutes of meetings, information from interviewing experts, information from interviewing non

[16] The iterative process of learning using themes developed form literature was described already under 'Adult Social Learning Theory' Section 3.1.1

experts who were still stakeholders, experience from first hand use of information systems, and the factual information collected from experience on the capabilities of emerging the information systems and any other important information[17] was taken into consideration. This somewhat post-normal science approach[18] was considered valuable in answering the research objectives and in refining the mental models of understanding.

3.1.1.3 The Dynamic Theory of Organisational Knowledge

Thus far, the above models guiding the research methodology adopted support social learning through iterative processes and identifying and valuing knowledge types. However, knowledge itself also changes depending on the spaces it is taken from. The Dynamic Theory of Organisational Knowledge by Nonaka (2004) is best used to define how the research case was divided.

Nonaka's (2004) depiction of an evolving interplay between knowledge that is explicit and knowledge that is tacit and the socialization process of learning is useful in showing how in the model, implicit or tacit knowledge becomes more explicit as perspective widens. The researcher, through her various engagements before and during this research, had accumulated an implicit knowledge of the system which she had not yet expressed as explicit knowledge. As she reflects on her experiences and shares her knowledge of her individual perspectives with other persons, groups and organisations during meetings and sharing her perspectives, another learning model is applied.

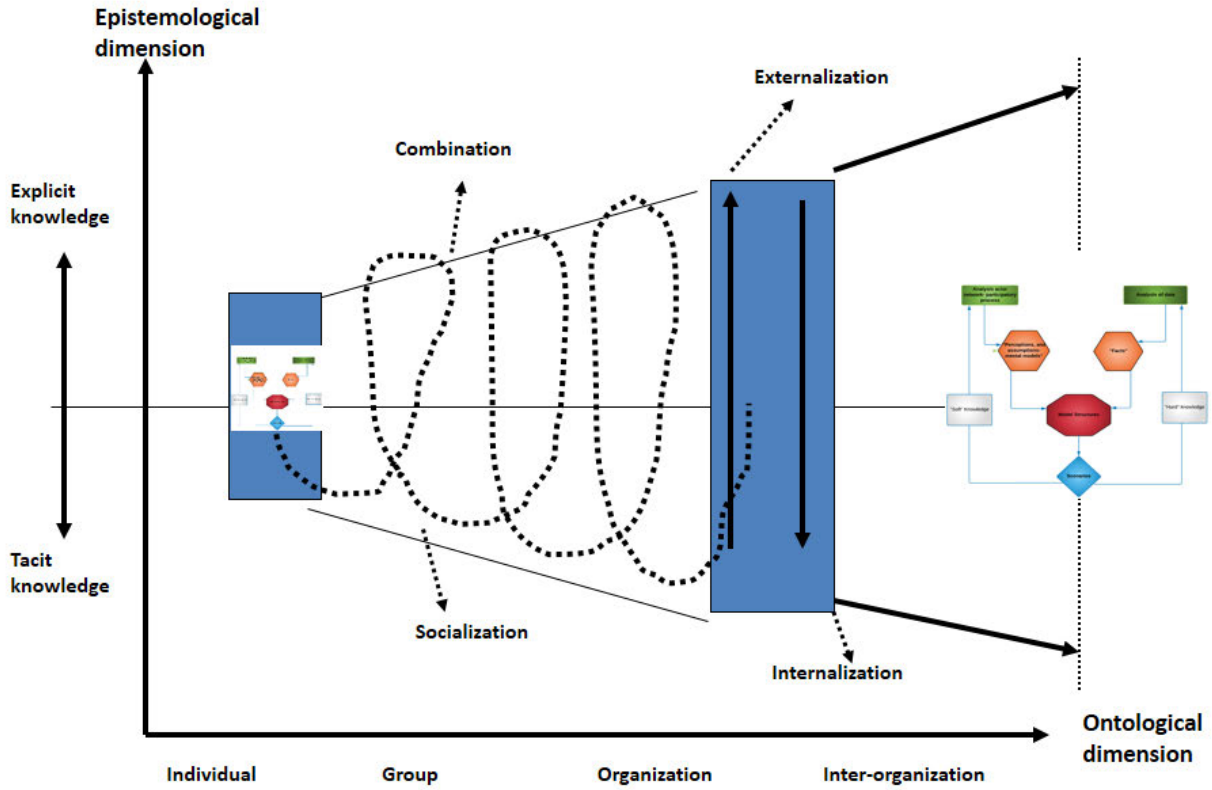
The growth of the learning space in the uMngeni catchment was necessary for expanding the researchers understanding. It is what expanded POR from simply observing Local Community

[17] By doing the above appreciation of knowledge types, 'soft' and 'hard' the researcher shows an appreciation for Post-normal Science; suitable for approaching wicked problems. For a detailed explanation of PNS, refer to the Section in Chapter 2.

[18] Chapter 2 Section 2.3.1 provides a review on what a 'post-normal science' (PNS) approach to problems and research involves.

Project Group (LCPG) groups to engaging with them. Engagement also expanded to stakeholders at the sub-catchment scale in the Msunduzi Catchment Management Forum (MCMF), and finally to stakeholders at the large catchment scale, in groups such as the UEIP. Figure 3.4 adapted from Nonaka (2004) illustrates this growth in learning. The diagram depicts a combination of the integration of knowledge from Figure 3.3 and the expansion of this knowledge as the learning space is also expanded: more stakeholders are observed at bigger multi-stakeholder spaces, moving from an individual perspective to group, organisation and even inter organisation spaces.

The researcher also applied this model in approaching the research methodology to expanding 'hard knowledge' about ICTs. While initially the researcher worked with and observed what common ICTs are used by stakeholders in the uMngeni catchment, she also expanded in this knowledge space as the learning space expanded with time by exploring the emerging technologies such as MIKE INFO and the Mathuba WIKI. These carried the potential to serve the purpose of social learning in accordance with what is known from literature and had to be investigated as well. To achieve this using the Nonaka (2004) model for learning, the researcher also applied an *exploratory type of approach*. Figure 3.4 is designed to illustrate the above mentioned points.



Epistemology :- the theory of knowledge
Ontology :- the science that investigates the nature of pure being, its essential properties and the relation one universal bears to another. *(the socialization dimension)*

Figure 3.4 Showing deepening processes of learning across learning spaces that increase in scale from an individual perspective, to a group, organisational and finally to an inter-organisational perspective. (adapted from Nonaka (2004)).

As seen from the adapted diagram by Nonaka (2004), by moving to larger spaces of engagement and as she made implicit assumptions more explicit, the researcher ensured the creation of a better space to learn, one that was to help the researcher attain the 'whole' as described by Theory U (Sharmer, 2009). However, to create a holistic picture of the whole, one that accurately described the research process and gave knowledge on the research objectives on social learning and the role of information systems as virtual spaces of engagement, the application of the model by Scharmer (2009), Senge *et at*. (2005), Pahl-wostl and Hare (2004) and Nonaka (2004), had to be used

together. All these learning models that describe the method are in support of creating *iterative and deep processes of learning* of the researcher which is at the core of Theory U.

3.1.1.4 Combining all 4 models

Figure 3.5 is a combination of these learning theories. From this diagram it can be noted that consistent with Pahl-Wostl and Hare (2004), the researcher goes through iterative processes of learning about the socio-ecological dynamics of the catchment. These processes produce 'soft perceptions' as knowledge gained from POR and 'hard' factual knowledge from exploring and applying the ICT systems.

The new mental models formed by these processes can be refined as described in detail in the discussion about Figure 3.3. However, this mental model becomes refined by expanding the knowledge space as much as possible. This is characterised by moving from observing single multi-stakeholder groups to participating and observing bigger spaces of stakeholder engagement groups. As the researcher attempts to enter into productive "*thinking*" and "*doing*" processes, she undergoes iterative processes of deep learning. When the iterative processes of learning through the U are expanded over a period of time, as in this research, the researcher's understanding deepens with time as she explores wider spaces of engagement as a participant or stakeholder. During this process, an individual perspective based on personal experience is refined through the researchers own social learning process. In a practical sense the researcher engaged and learned from a community-scale *group* project that is through a LCPG such as the Mpophomeni Enviro-champions[19]. The researcher then further engaged at greater organisational level where two main organisations became the focal point: the MCMF at the sub-catchment scale of stakeholder engagement and the UEIP at a catchment scale water related multi-stakeholder engagement process. As this immersion by the researcher was not restricted to the upper uMngeni catchment, she used lessons learnt to engage with other groups that were in other parts of the uMngeni through

[19] A description of the activities the researcher was involved in is listed in the next subsection.

workshops, learning exchange programs and other local community project meetings,[20] thus expanding and deepening her learning to an inter-organisational perspective. All such processes were motivated by a desire to understand what kind of system can accommodate the objectives of various kinds of multi-stakeholder engagement groups residing within the catchment.

With the aim of transforming tacit or implicit knowledge to explicit knowledge, such engagement also involved presenting work and sharing views with such groups, thus embracing participation in such groups (ie. getting involved in their projects and using ICTs if possible). This embraces understanding of the whole and supports 'action that increasingly serves the whole', in this case, the creation of an IIMMS which is ICT system that is to serve water relate engagement. In this research, methods are modified as new information surfaces due to the iterative deep learning that spreads out and evolves over time. All such actions increasingly become part of creating alternative outcomes or futures that give insight into the bigger picture or the 'whole' which is addressing the aim of this research as illustrated in Figure 3.5.

[20] This specifically refers to the Ashdown Peace Valley product coordinated by DUCT. The researcher used lessons from engaging in the main LCPG (Mpophomeni Enviro-champions) to make observations and learn about water related multi-stakeholder engagement in this local project.

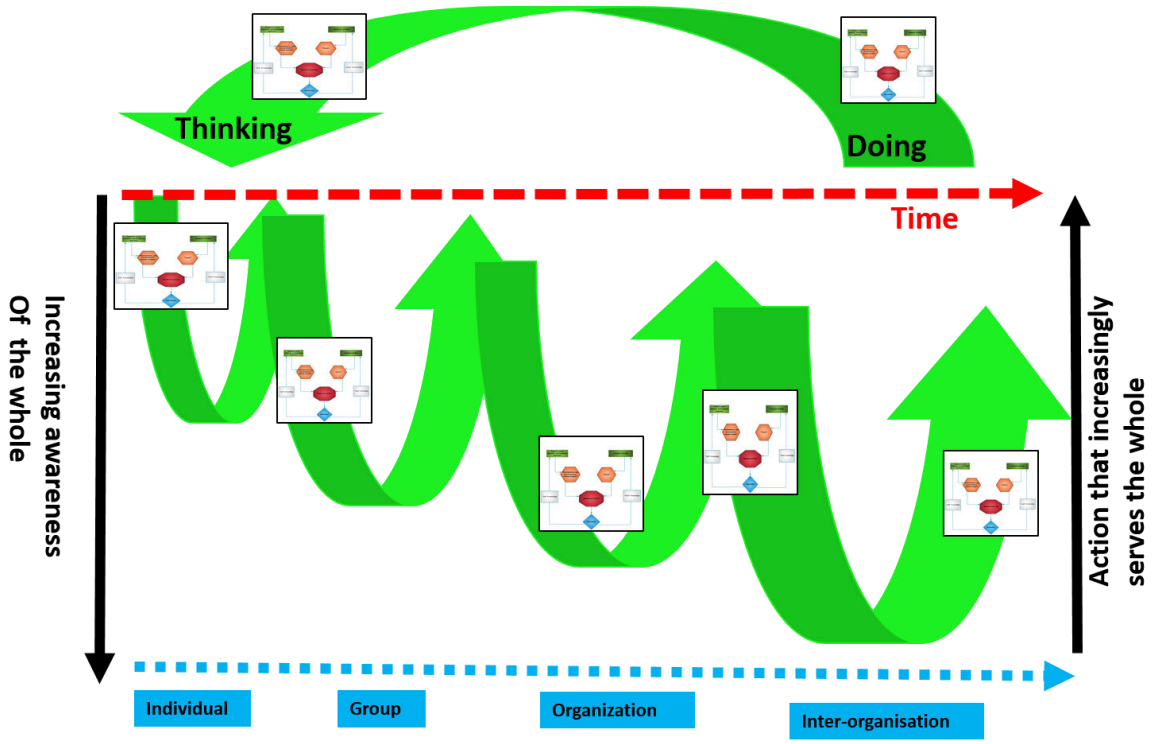


Figure 3.5 A combination of Scharmer (2009), Nonaka (2004) and Pahl-Wostl and Hare (2004) describing the entire research process. There is increasing awareness, deepening and expanding knowledge with time.

Successive iterations of reflection and actions, were conducted over a period of almost two years (18 months), each time the researcher alternated her positionalities or roles which allowed learning to deepen. Thus the actions embraced:

- Bio-monitoring eg. MiniSASS (with LCPG)
- Alien invasive clearing (LCPG)
- Sewage pipe system monitoring (LCPG)
- Potable water leak monitoring (LCPG)
- River clean-ups to remove solid waste (LCPG)
- Educational and awareness events (UEIP,LCPG)
- Training and other water related fieldwork, with a range of community groups and scientists (LCPG, UEIP, MCMF)

- Acting as a mentor to citizen science groups and individuals (LCPG)
- Conference and workshop presentations and or attendance (UEIP)
- Participation in community and large partners meetings and forums (LCPG, UEIP, MCMF)
- Conducting semi-structured interviews (LCPG, UEIP, MCMF)

Integral to this field work was the facilitation and observation of data capturing and information generation processes using *inter alia* social media and computer-based applications including Google Earth, smart phone and Google based wiki technology, outlined in Chapter 5. Specifically, this involved two main type of information systems; the Mathuba online WIKI and the Desktop Based Integrated Water Resources based MIKE INFO. [21]

The diagrams in Figures 3.1, Figure 3.2, Figure 3.3, Figure 3.4 and the combined Figure 3.5 have been used to describe the social learning models and the step-by-step research processes followed by the researcher and the spaces into which she immersed herself. In the sections which follow, the researcher will use the above outline of the research process to elaborate on the explored research spaces and describe the positionality and recruitment strategy followed; that is the mapping technique.

3.2 Engagement with multi-stakeholder organisations

Following the auto-ethnography as the type of qualitative aspect in the methodology and later in the analysis in this study, the researcher engages with some multi-stakeholder groups in order to reflect on her own experience, observations and learning in the spaces (Anderson, 2012). Before and during the period of the study, the activities of the NGOs mentioned earlier were being conducted in a problem space in which several formal networks, forums and partnerships were operating to varying degrees of both activity and success. These organisational forms (listed below) and the researcher's relationship to them are described further.

[21] The functioning of these main information systems is described in the succeeding Chapter 5.

- uMngeni Ecological Infrastructure Partnership (UEIP)
- uMsunduzi Catchment Management Forum (MCMF)
- Ashdown[22] and Mpophomeni local community project groups (LCPG)

The notion and practice of enhancing ecological infrastructure[23] to complement hard infrastructure[24] and catchment ability to provide water resources is also being pursued in the uMngeni drainage basin by a combination of approximately 20 organizations. They are signatories to a memorandum of understanding and call themselves the uMngeni Ecological Infrastructure Partnership (UEIP). The UEIP's main objective is to build awareness, improve coordination and integration of stakeholders, and conduct demonstration projects throughout the catchment as applied research in support of action learning. As a multi-stakeholder partnership, it provided the researcher with an opportunity for studying the engagement of stakeholders who are also part of other collective participation initiatives in the catchment such as various Catchment Management Forums (CMF's). The UEIP also held a number of meetings of its own throughout the year; these amounted to four that the researcher attended in 2015 and several others attended in 2016 and 2017.[25]

The uMsunduzi Catchment Management Forum (MCMF) is one such forum, throughout South Africa, that are formed under the auspices of the Department of Water & Sanitation (DWS) in terms of the 1998 National Water Act. These fora are chaired by a stakeholder representative or by a DWS person, depending on the circumstances. They are, as the name suggests forums for stakeholders to come together to discuss common issues related to water in the sub-catchment. Their membership is voluntary and attendance at meetings generally fluctuates and often attendance is by different persons from time to time. They take non-binding decisions and are

[22] This is the uMsunduzi Green Corridor waste management pilot project (MGCP) specifically

[23] Ecological infrastructure – in reference to the health of the natural system (that is plants/ natural vegetation in a catchment including as well as healthy waters and streams and biota).

[24] Meaning any manmade infrastructure in a catchment (eg. concrete roads and surfaces, bridges, buildings ect)

[25] Invitations to these meetings and my participation can be noted from the email conversations

perceived by many as “talk shops.” They are generally not well attended by the private sector and have no formal financial support from the DWS for projects. Complaints noted at these fora are sometimes taken up by the DWS and acted on. They do however offer a platform for collective action, if they can be mobilised. The uMsunduzi River forms one of the major tributaries of the uMngeni River and has its own forum.

The Ashdown and Mpophomeni local community projects are two examples of local Municipal level stakeholder engagement projects within the uMngeni catchment management area. These local projects formed grassroots learning cases. The researcher’s involvement at this level focused on these two specific projects. Firstly, the Ward 23 Ashdown, Peace Valley 2 Green Hub project otherwise known as the Msunduzi Green Corridor waste management pilot project (MGCP). Secondly, the Mpophomeni Conservation Group monitoring project (MCGMP) which has since been funded by the Dusi uMngeni Conservation Trust (DUCT), the Wildlife and Environment Society of South Africa (WESSA) and at times by the EPWP.

As an observer, at times and other times a participant, in these different community scale projects, the similarities of the barrier and incentives to social learning in them became evident and the opportunities for social learning in these arrangements became clearer. A fundamental connecting aspects of engaging through all these spaces was the presence of NGO’s. Because some of these NGO’s were found engaging in all three of the main groups investigated, it is essential to identify the key ones that had played a role and that the researcher had much interaction with.

3.3 Engagement with specific NGO’s

Engaging with LCPG would have not been possible if it were not for the connections formed with some NGOs who also form part of the UEIP and MCMF. The activities of the Dusi-uMngeni Conservation Trust (DUCT), the Wildlife and Environment Society of South Africa (WESSA) and Eco Schools are the NGO activities that the researcher engaged with, predominantly. These were to gain field experiences which form the crucibles of ongoing learning in this research. As a participant and actor, this engagement method was mainly as a volunteer working under the auspices of the abovementioned NGO’s. As a result, the researcher was afforded the opportunity

to engage in the uMsunduzi Green Corridor waste management pilot project (MGCP) and the Mpophomeni Conservation Group monitoring project (MCGMP) that form part of the LCPG.

3.4 Positionality of the researcher

Whilst navigating the research process through the mentioned multi-stakeholder groups of section 3.3, the researcher adopted the role of participant, stakeholder, researcher, observer and citizen at various times, as appropriate. Ison *et al.* (2004) report conducting social learning research from a similar range of positionalities. The researcher's position in this research was dynamic, alternating between fulfilling all these roles, which influenced levels of exposure, the relationships formation and the associated knowledge and understanding gained about the system of stakeholder engagement and the catchment. Similar influences were reported by Mansvelt and Berg (2005: 249). Such exposure is also critical in terms of Theory U, in which reflection on new experiences, if allowed to "*come in*" (see Figure 3.2), alters one's perspectives in varying ways and degrees. One then acts on these new insights, for example, by looking for more experiences, more field work, wider audiences, bigger audiences, as it was done with the MCMF and the UEIP. This part of the research is thus also appropriately described in the proceeding Section 3.1.1, Figure 3.2 as process A- literature immersion which guides the researcher through participatory observation processes. In these processes one finds generic needs and insights as found in literature, discussed in Chapter 2, for example:-

- Application of post normal science (Section 2.3.1)
- Creating collective action spaces (Section 2.5.1)
- Recognising and understanding stigmergic processes (Section 2.5.2)
- Application of mental models (Section 2.5.3)
- Surfacing of assumptions (Section 2.5.4)
- Pursuing socially robust knowledge (Section 2.5.5)
- Using and creating whole system institutional virtual spaces (Section 2.5.6)
- Valuing and appreciating inclusiveness & transparency as imperative facilitators of resilience (Section 2.5.7)

- Valuing of trust and how to build trust (Section 2.5.8)
- Using energy flows and tempo in stakeholder relationships (Section 2.5.9)
- Cultivating meaningful participation (Section 2.5.10)
- Using the power of citizen science and citizen agency (Section 2.5.11)
- Understanding the value of building self-identity for legitimacy and efficacy (Section 2.5.12)
- Applying methods to lower the transaction costs in multi-stakeholder engagement (Section 2.5.13)
- Transcendending of intellectual and organisational barriers (Section 2.5.14)
- Developing appreciative inquiry (Section 2.5.15)
- Creating practice architectures and safe places to experiment (Section 2.5.16)
- Utilising models as metaphors to assist public participation (Section 2.5.17)
- Developing absorptive capacity to engage participatory agent based social simulation modelling. (Section 2.5.18)

In the writing of Babb (2006:50) the researcher found support for the understanding that, the manner in which the researcher engaged the subjects, influenced the data collection processes. Thus, evidence for multiple perspectives being revealed as the researcher engaged in the different research spaces is pervasive in this dissertation. For example, in Section 3.4.1 and in Section 3.4.2 and in Section 3.4.3, positionality changes are broken down.

With an academic background in the natural science field of hydrology and soil science, the researcher's knowledge on the biophysical conditions and the effect that they have on the provision of ecological goods and services has mainly been rooted in so called hard sciences. However, the researcher's positionality as a part-time mentor of the Mathuba program (described in Chapter 5) enlightened the researcher to the value of using a soft systems approach in understanding the socio-ecological issues linked to maintaining the ecological infrastructure of the catchment. Social learning forms the overarching theme of the web based virtual platform known as, Mathuba programe which by design allows citizens to contribute to the growing body of citizen science (Mathuba, 2016).

Examples of the different roles assumed by the researcher are described in the sections which follow.

3.4.1 Participant

The task of the UEIP project on which the researcher worked as a minor team participant, at the beginning of the research process for this dissertation, was to assist with the creation of an Integrated Information Management and Modelling System (IIMMS) that will facilitate the co-creation and organisation of catchment related information and lead to more coordinated behaviour in the management by stakeholders. The researcher was a participant in a number of stream clean-up and bio-monitoring learning events as a volunteer. The researcher participated in a number of workshops and conferences as a presenter which afforded opportunities for sharing her knowledge and networking. The ecological infrastructure catchment partnership learning exchange program between the UEIP and uMzimvubu Catchment Partnership Program (UCPP) was an opportunity to participate and observe the engagement process between stakeholders in catchments. Organised by the Critical Ecosystem Partnership Fund (CEPF), the South African National Biodiversity Institute (SANBI) and Wildlands Conservation Trust; the learning exchange was created to give an opportunity for these partnership programmes to share lessons and grow in knowledge of each other's successes and challenges in their respective catchments. The researcher used her positionality as a participant by exchanging experiences with others and learning from the engagements and experiences shared.

3.4.2 Stakeholder

During 24 months of the research, the researcher continued to attend the uMsunduzi Catchment Management Forum (MCMF) meetings as a recognised stakeholder and contributor. She was able to prove this positionality by using the platform to share her experiences and ideas on using an IIMMS or ICT type of system in facilitating the engagement of stakeholders within the forum. The researcher also used these meetings and the time between them as an opportunity to network with other stakeholders, sharing her knowledge and skills of virtual information systems. These

information systems whom she refers to as IIMMS's due to the internship opportunity at a previous time included the Mathuba WIKI system[26] as well as DHI's MIKE INFO data management software powered by GIS. [27] This positionality taken by the researcher affirmed her other vital role in the accomplishing the objectives of the research; such as being a networker.

3.4.3 Networker

In addition to using multi-stakeholder meetings as an opportunity to network and learn from other stakeholders, the researcher used the networking opportunities outside the meetings with a wide range of NGO's and their events in the catchment. These activities or events have included clean-ups, bio-monitoring, community scale meetings participation in local projects, such as the ones in Mpophomeni and Ashdown. Often times these engagements meant continuing to engage in various citizen science-based activities with the community environmental activist groups long after the completion of the initial event or activity.[28]

3.4.4 Learner

The researcher was also fortunate to receive expert tuition, both formal and informal,[29] from the software and consulting company DHI-SA as well as by attending an international training event for water practitioners in Gabarone for Integrated Water Resource Management. These tuition sessions and certified training had the further benefit of introducing the researcher to DHI's integrated hydrological models and other modelling related data and information management systems. The researcher focused attention on the MIKE INFO information management system and the MIKE customised software of DHI and experimented with ways that it could be populated with information from the uMngeni catchment, as imagined by the IIMMS mentioned above.

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[26] With all its related components;, notably smartphone connections to Google Earth Outreach; wiki technology

[27] Findings from using these are described in detail in Chapter 5 this dissertation

[28] Evidently for this research it has meant engaging with groups such as the Mpophomeni environmental champions and stakeholders of the Ashdown Peace Valley project which included members of the NGO, DUCT and community members.

[29] It is worth noting that the researcher attended an IWRM course by DHI in Gabarone Botswana.

Results of which are noted in Chapter 5. The purpose of engaging in the aforementioned was to gain some understanding of the suitability of these IT systems to serve the purpose of facilitating multi-stakeholder engagement processes, which are inclusive of citizen science based information (ie. soft knowledge type), thus encouraging citizen agency and empowerment in a software space that accommodated hard science information. The second purpose of engaging in the aforementioned information system was to learn how the systems could be managed to provide an inclusive and integrated database of biophysical, geographical and other types of information of the catchment related to water and the environment.

In the role of a participatory action researcher, it was possible for the researcher to continuously act and reflect on these information systems to be used in virtual space, how they were used to support soft science information, improved and applied to contribute as aids for efficient engagement of stakeholders. All to foster or encourage social learning from virtual spaces. In the above-mentioned aspects of the research the researcher noted strong similarities to the Participation Action and Observation Research as described by Kearns, (2005) and Kindon (2005) which further supported the exploratory approach chosen for the research.

3.4.5 Facilitator of socially robust knowledge creation

The researcher also took positionality as a facilitator of what could appropriately be described as the creation of socially robust knowledge, a term that is used often in this research to describe knowledge that that stimulates the implementation of collective action. It is evident from the already mentioned roles of being a researcher, a learner and mentor that the researcher's choice of research topic is also influenced by a deep personal desire to study the conditions that favour the *resilience* of stakeholders in the catchment and how they are able to behave in a more coordinated manner in their ongoing engagement processes.[30] As socially robust knowledge (Section 2.3.) creation is one of the main requirements for enabling such resilience, the explorative use of ICTs housed virtual spaces (ie. information systems) is not meant to remain experimental, in the sense

[30] In Chapter 1, the introduction, the researcher justifies the research using this understanding.

of being purely an academic exercise, for the uMngeni catchment. It is to perpetuate towards an *understanding* on how these spaces can be better nourished to create socially robust knowledge and social learning as a goal. To do this, the researcher creates or uses existing cases or scenarios within the catchment management spaces to test and explore how the information systems could be used to archive certain objectives of information management in the multi-stakeholder arrangement.[31] Thus, as the researcher studies whether and in what ways these information systems can adequately be adopted to increase stakeholder engagement, she unconsciously becomes a facilitator of the creation of socially robust knowledge. The results of this exploratory use of the information systems is documented in different chapters as part of themes collected in Chapter 5. Critical to this the researcher also studied and inquired into the adoption of these engagement processes for civil society and citizen sciences on a wider scale than the selected catchments and groups mentioned above.[32]

3.4.6 Mentor

While the above description of the researcher's methods followed as a facilitator of social robust knowledge creation within the 3 main types of groups of multi-stakeholder engagement (ie. UEIP, MCMF and LCPG), the researcher's positionality as a mentor very much depended on the networks she formed through these groups.

From her engagement with LCPGs such as DUCT associated MEC, the researcher spent a significant amount of time in the field engaging in citizen science mentoring activities with the Mpophomeni Enviro-champions of the Howick Secondary School and environmental clubs of uMsilinga Primary School to name just a few. In addition to miniSASS bio monitoring activities as citizen science activities, the researcher's mentoring included helping learners in their water related science research projects. In this situation the researcher was able to use her knowledge of

[31] The researcher uses three many cases from the UEIP, MCMF and LCPGs to demonstrate the capabilities of the information systems I assisting stakeholders approach their problems. Although there are evidently various explored opportunities, the researcher will focus on just three. These are documented in Chapter 5, Section 5.3.

[32] Chapter 1, the introduction documented how principal 2 from the WRC summit report applies to this research.

mental modelling and social learning to assist learners in building up an understanding on river and environmental problems in their local streams.[33] These mentoring tasks using citizen science, provided good opportunities to gain insights into the apparent positive self-identity changes which the learners underwent as a result of engagement in these activities and gave much needed insight into how LCPGs work.

In addition to mentoring leaners the researcher was also able to demonstrate to individuals in organisations such as the Msunduzi Municipality, Department of Environmental Affairs, the functioning of Google Earth based programs to manage environmental data as useful ICT tools. During this time, the researcher was able also to chaperone and mentor post graduate exchange students from Germany on many of these visits as they set up and engaged in their mini-projects.

3.4.7 Summary of positionality

Figure 3.6, illustrates the interlinked positionalities of the researcher. As explained above, the initial positionality of the researcher as an *observer* evolved to being a *participant observer* in the different multi-stakeholder groups. However, because of the internship position initially adopted, the researcher who was initially a *de facto* participant, observing the interactions of the stakeholders around her she realised having a stake in the problem and became stakeholder in the UEIP project even though she had not yet immersed herself extensively in other multi-stakeholder groups. As she received information or feedback from the engagement, she continued to be a participant observer of the engagement spaces, the aim of the research was defined and she acknowledged herself fully as a researcher. Then, using her knowledge of the information systems being investigated, she expanded the scope of her involvement and became a participant actor in other groups as well. While sharing her perspectives as an actor or participant, knowledge of the information systems as well as her experiences she became a mentor, a facilitator and networker of all the spaces she participated in and or researched. As a result, the entire research process

[33] The task of building a mental model of what is observed in the catchment such as point pollution can be done using the Ice-berg model (detailed in Section 5.2, Chapter 5). It is this Ice-berg model that is taught to learners as well as basic research skills concerning the problems they observed and the information they could deduce by building their own mental models of pollution problems observed in their local streams.

adequately complimented Theory U as seen in the centre of the intersecting positionalities- as action increased so did reflection on the findings, awareness and learning. Thus at the centre of all these roles, the researcher is a learner, actor and actor in entire process. As an iterative process of learning (Theory U), these positions continued to overlap, and alternate throughout the research process. In relation to Figure 3.1 of Theory U it can be deduced that all of this was important for the researcher to have a wholistic understanding of the 'whole'

Figure 3.6 the interconnected positionality of the researcher in the catchment; a stakeholder, a mentor, learner, participant and networker. Interconnecting all positions, the researcher is a co-learner, actor and reflector

3.5 Exploring information communication technologies

As an action-research based project, the objective of understanding the potential of selected ICTs was to provide virtual cyberspaces or platforms to facilitate social learning in stakeholder engagement processes. As previously reviewed in Chapter 2, the system being supported by engagement of stakeholders is a real one and has been seen to be illustrated relatively well by a cloud depicting a mash of connections between stakeholders and respective organisations.[34] This was done in two ways; first by reflecting on past application in citizen agency and citizen science skills development and secondly by allowing stakeholders to develop an institutional memory of data relating to the catchment. The developing systems was thus there to help them reflect and direct action where it may be required based on lessons thus supporting coordinated decision making learnt. This application critically delves into the researchers past experiences in the field of information communication technology or ICTs to develop or improve on use information systems that not only can assist multi-stakeholder engagement processes, but can develop citizen agency and skills across a range of local actors in the uMngeni catchment, not just for expert stakeholders.

3.5.1 Developments in the ICTs

Developments in the ICTs or information systems included the two main information systems already introduced in preceding subsections; Google supported Mathuba WIKI and MIKE INFO developed by DHI. Two of the developments which the researcher added to the Mathuba WIKI were linkages to the miniSASS system developed by GroundTruth and the incorporation of the weekly reports on water quality sampling at 12 sites in the Msunduzi, supplied by uMngeni Water scientists to the MCMF stakeholders. In so doing the IIMMS facilitated better information sharing and opened the potential for a more holistic knowledge, amongst stakeholders, of this aspect of selected streams in the upper uMngeni the catchment.

Using knowledge derived from the continuous review of the literature reported in Chapter 2 the constructs of social learning processes were applied to the researcher's reflections on the MIKE INFO software system of DHI. As both systems embraced GIS in its presentations of data, the same principles that were used to shape the Mathuba WIKI system are same principles applied to the MIKE INFO data management system with the limitations of system capabilities and limitations.[35] Additionally information from what was already available from what stakeholders in the UEIP, MCMF and LCPG provided was used in these information systems.

The MIKE INFO system formed an important technology piece in this research and evaluated to gain a sense of its utility for multi-stakeholder water related engagement. For the researcher the studying of integrated information systems as facilitators of social learning was a continuous process of skill development in ICT. As the researcher engaged with the software and applied the lessons she learnt in helping stakeholders approach some water related problems in the catchment, feedback was generated and used to learn and or improve on the ICT software use. In cognisance with Theory U, this learning process was continuous and the researcher made use of various opportunities to gain feedback on the 'value of the information systems in supporting social learning.'[36] This iterative process of acting and reflecting to deepen understanding is in keeping with Theory U (Scharmer, 2018). In this ongoing process feedback was gained from the following:-

- Engaging in educational workshop conferences or meetings- using feedback from experiences shared with attendees.
- Noting and documenting her own challenges of using the ICTs.
- Comparing experiences of using the ICTs with other similar systems available.

[35] A detailed description of the findings of this exploratory application of the information systems that is the experience in using then information systems as well as the relative outcomes is described fully in chapter 5.

[36] In support of answering the second objective of the study.

In all cases the researcher simultaneously used the opportunity to engage with different types of stakeholders; whether it be to consult on the challenges she faced in using the software or to make use of advice given by other stakeholders for the applicability of the ICTs. The capabilities of the software (ie. Mathuba WIKI and MIKE INFO) were presented by the researcher to those stakeholders present and their verbal responses to the systems were noted. These responses were reflected on against a mental backdrop of the selected social learning constructs reviewed in Chapter 2. During these processes the interview questions relating to the barriers and fostering mechanisms to social learning using information systems began to emerge and form the basis for the survey questions presented in Appendix A and described briefly in Section 3. 6 below.

3.6 Interview data collection

This research also makes use of oral research using semi-structured interviews (Appendix A) to give insight on systems thinking and mental models formed by stakeholders within the catchment. These interviews were developed and conducted with selected stakeholders of the UEIP, MCMF, NGOs and the local community level citizen science projects in the catchment (ie LCPG). The formulation of questions was influenced by the constructs of social learning and were designed to reveal information that would serve the objectives of the research, namely:-

- To establish an understanding of the incentives and barriers to social learning in current spaces of stakeholder engagement;
- To examine views on the potential for integrated information systems to be adopted to aid in multi-stakeholder social learning, in real and virtual spaces, and
- To formulate recommendations on the specific actions to create a nourishing context for appropriate social learning in the multi-stakeholder water related space.

Furthermore, sampling respondents from the catchment was influenced by the situation of the researcher within the research; that is her positionality and role as a researcher and facilitator of social learning through the exploratory use of ICTs. The succeeding subheading will detail how the interview templates were formed.

3.6.1 Developing interviews

As Craps and Maurel (2003) have shown, developing questions to assess the social learning process is a self-exerting task which involves the researcher undergoing a process of social learning herself. In this research, there was no exception. Having been exposed to different types of engagements with stakeholders as noted already as a *participant*, the researcher sought to understand more deeply by inquiring directly with those in engagement spaces of the study. The researcher first made use of the constructs of learning as described in Chapter 2 to form probing questions that give an indication of what knowledge the informants shared on the construct in question as reflected by their responses on the engagement process they have gone through or are aware if in the uMngeni catchment[37]. These types of questions were designed to deepen the researcher's understanding of the role of information systems in supporting various types of engagement in three ways:

- Firstly, by getting experiences of the possible barriers and incentives to productive engagement[38]
- Secondly, by forming questions to appeal to the specifics of the types of information systems and their positionality in the current spaces of engagement in the catchment.
- Thirdly, by helping the researcher get a better understanding and any possible recommendations on the design of virtual spaces through these information systems that create a nourishing context for learning.

The essence of these three different categories of questions was to help answer the three different objectives of the study.

[37] Refer to the appendix for an interview template example.

[38] In this research, productive engagement is characterised by learning as characterised by the manifestation of the key constructs to learning. Details of this are found in the analysis and discussion Section of this dissertation that is in chapter 4 and briefly in Chapter 3.

The researcher's internship with the UEIP exposed her to interacting with a wide variety of stakeholder types both lay persons and experts. This exposure led to an understanding of the need to develop an understanding of the experiences of different stakeholders within the uMngeni catchment and study the manifestation of various constructs affecting learning. The interview questions were developed to differ slightly to accommodate different kinds of stakeholders engaging in multi-stakeholder group arrangements, both the lay persons and the experts. Selected individuals and most likely contexts they fell into included:

- Community level citizen scientists (LCPG)
- Government level decision makers, (MCMF, UEIP)
- Academics and (UEIP)
- Non-government organisation leaders *inter alia* in environmental education and water related sciences. (LCPG, UEIP, MCMF)

Selecting the above mentioned stakeholders included a purposeful kind of sampling. The next subheading describes the recruitment strategy process from the uMngeni catchment. It will reveal what sampling design was followed, the sampling method, and what determined the sample size.

3.6.2 Sampling design

The participant-observer positionality taken in this research enabled the researcher to select the survey interviewees as someone who is knowledgeable about the processes to be observed (Dane 1990). As noted in Section 3.4.1 the researcher was a participant in three types of stakeholder arrangements, namely local community scale (LCPG), open catchment management scale (MCMF) and research-based catchment partnerships at a larger catchment scale (UEIP). These put the researcher in an ideal situation to observe, reflect and recall the engagement processes that take place as well as to conduct interviews. Figure 3.7 is a schematic diagram of these socio-geographic research spaces and how they overlap and relate to one another, the UEIP being the space that overreaches most of the catchment area, the MCMF being at a smaller sub-catchment level of interaction and lastly the LCPG of community and NGO projects being the smallest of the three. Several key individuals who were interviewed, spanned all three spaces in terms of their involvement and experience.

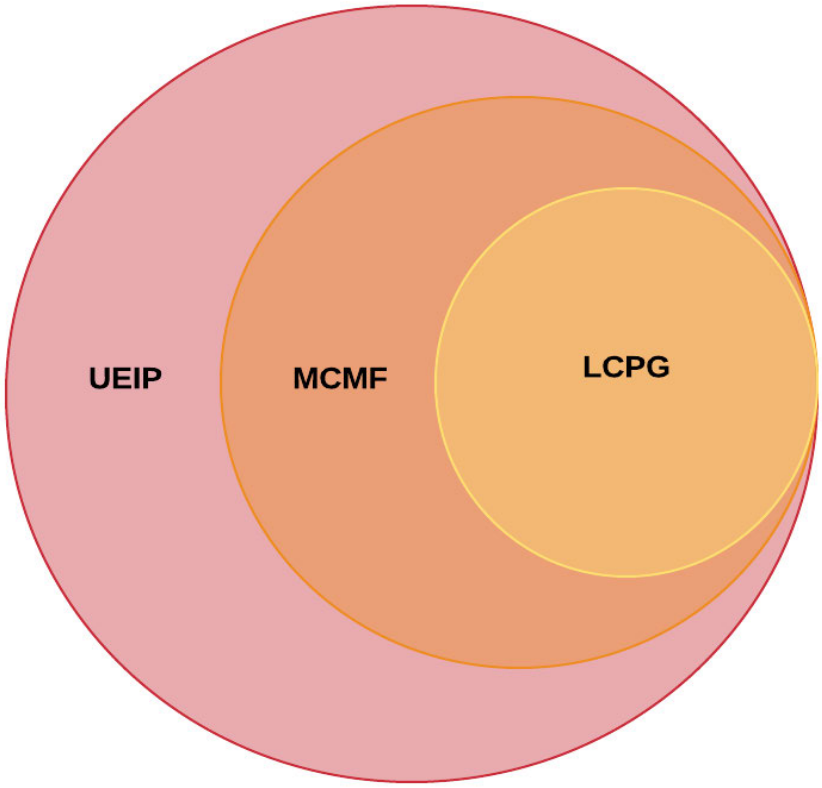

Figure 3.7 Spaces of engagement the researcher was immersed in in the uMngeni catchment: UEIP is catchment scale, MCMF (uMsunduzi Catchment Management Forum) at open sub catchment management scale and LCPG (Local community project groups) at local community scale.

3.6.3 Sampling Method

Developing and administering semi-structured interviews formed an important method of deepening understanding in this research. The sampling process was inclusive of both the formal and informal actors and their relationship with one another. This method was considered based on what was known from reviewing research by Craps and Maurel (2003). Research questions were formed based on the different types of actors (ie. institutional, informal and individual actors) involved in river basin management as well as the social relationships that were being researched. Hence, the choice of three different stakeholder engagement spaces; that is the public participation encouraging MCMF, the researchers consisting of stakeholders of the UEIP and the private and public community engaging informants of LCPG namely the Enviro-Champions of Mpophomeni.

3.6.4 Sample Size

The sample size was determined by the potential interviewees suggested by initial interviewees in a snowball sampling technique employed by the researcher. This process was consistent with Theory U which requires action and reflection to progress the process, in this case interviewee's selection. This contrasts with the positivist approaches to research, in which it is important to get a statistically significant number to prove a conclusion. However, using the Theory U approach of learning; every new piece of evidence from any source is a source of deeper insight. The issues are so complex, dynamic and uncertain that one is not looking for proof but for *understanding*. Hence in line with following Theory U and the other theories combined[39], the researcher seeks enough stakeholders to give an understanding of the number of the opinions and perspectives of different types of stakeholders regarding multi-stakeholder engagement in the catchment and the application of ICTs (Isaias et al., 2013).

The number of people to sample depended on the information and knowledge enrichment achieved in the process of the study; this includes the number informants suggested by other key informants. Initially, the goal was to interview 4 key participants from each of the three major stakeholder engagement groups (ie. MCMF, UEIP and the LCPGs) and use snowball sampling to gain a further 10 individuals to enrich the initial interview set. However, following the exploratory nature set out for the methods, interviews continued with other stakeholders, some suggested by the key informants.

It is worth noting that the application of Theory U as a research method in support of the framework in the research also applied in determining the number of people to use as participants in the interview process. Theory U whose concepts show that it requires *action, thinking* and *reflection* processes to take place gives reason to conclude that these processes will ultimately determine if the amount of participant is enough to form a conclusion of the study. Thus, going through an

[39] Refer to figure 3.5 in Section 3.1.1

iterative process of learning was symbolic of going through the 'U' and is to be expected to reach completion in this research only when a satisfaction with the results gained as answering the original objectives of the study set. In Theory U and in social learning every new piece of evidence from any source is seen as a source of deeper insight so when combined with observed data, action based data and reflections, 12 participants were sufficient in answering the questions and supporting what was known about the research case.

The next sub-heading describes how information was analysed- a combination of oral research obtained data, reflection and observations as well as action learning techniques through information systems.

3.7 Data analysis

To complement the results with the approach of Theory U, the researcher will narrate the findings according to how they were collected. This is from themes gathered during participatory observation of the multi-stakeholder engagement processes, to findings from a reflective learning process of the application of the information systems in question and finally through interviews. According to Holliday (2002) themes are formed very early in the research, often growing in the mind of the researcher during the entire research process even before any formal analysis. For this reason, the researcher felt it necessary to apply theoretical approaches such as Theory U where general understanding is not limited; it grows and deepens as information grows. Hence the necessity of the analysis at the very beginning from known observations then by using these to shape interviews, the use of information systems and reflection as supported by what became known form literature. However, since this research embraces the teachings of Scharmer (2009) with regard to continuous processes of learning through Theory U, these findings are analysed simultaneously to shape the understanding- an expression of the inter-connectedness of the data[40].

[40] Refer to Mintzberg's adult learning diagram (Figure 3.2) above that depicts the interconnectedness of the research process itself.

Analysing the data began in the data collection process. Interviews were specially designed to obtain the opinions of the stakeholders regarding their engagement experience and their thoughts on virtual engagement spaces. Using observations made as a participant, the researcher shaped her understanding to form common themes and compares these to literature. As already described above, these themes are formed from an understanding of social constructs or attributes connected to multi-stakeholder learning environments, this is the initial step followed in analyses[41] and was used to propel the research forward towards oral research using interviews.

Findings from these interviews were used to analyse what responses responded to which constructs of social learning. The questions were also divided in parts in order to answer the first and the second objectives of the study. Appendix A, has the two templates of the interviews that are used in this research. Understanding or application of a construct in the multi-stakeholder group type is given a grade from 1-5: the lower it is, the more it becomes a potential barrier, the higher it is, the better understood the construct is by stakeholders and the higher the likelihood of using it as an incentive for social learning.[42]

The final step of the analysis process groups constructs to social learning as identified in the literature and places them at different places in the 'loop' of Theory U for social learning; some are barriers and some incentives (objective 1). These together with combined findings observing and exploratory experimental use of information systems as virtual systems[43] and the effect these have on learning, helps explain from literature the links between the two (objective 2). This, through conclusive reflection is also used to explain the probable type of environment that can support social learning by multi-stakeholder engagement with the use of information systems in

[41] Refer to 3.4.4 for the detailed description of the interviewing process and the appendix for these research questions. Also refer to Figure 3.2 for the iterative research learning process followed which is a combination of data collection, reflection and analysis and additional data collection.

[42] While this rule is used as a generalisation, the researcher explains the findings to support her understanding of the engagement processes and as described by the interviewed informants as barriers and incentives. This is made clear at the onset of the results (specific to theme or propositions made, refer to Chapter 4).

[43] These refer to MIKE INFO and Mathuba. For a detailed explanation of these information systems refer to sections 3.5 above.

the uMngeni catchment (objective 3)[44], and how these can properly support citizen action in the long run[45].

3.8 Conceptual framework: ideologies and constraints

Having described the researcher's positionality in the research process, it is important to make explicit as possible research biases formed as they continuously change in support of the Theory U approach and affect the ideological position of the researcher and the impacts this has on the research setting (Holliday, 2002).

Given the complex nature of the research and the wickedness of the problem of successfully applying information systems in water resource management groups, the researcher attempts to make the research as wholistic as possible[46]. This introduced a new bias by the researcher in which she had to seek and discern which participants could give her the information she needs to form the picture of the possible barriers and incentives to learning existing in the catchment.

Furthermore, navigating through this bias, the researcher uses snowballing as a sampling technique while searching for interview candidates, here she hoped that her perspective on who is best to obtain the information from could be sharpened by external input from experienced persons who already engage in the different group scales. However, since the area of research chosen in this study is not vastly known particularly when considering the studying of information systems for learning (i.e. objective 2), the information from the candidates cannot be viewed as the ultimate decider on who to interview. This introduces another bias where it cannot fully be known who has *all* the information the researcher needs to help answer all the objectives as most stakeholders

[44] This final part of analyzing data is represented in writing in Chapter 5.

[45] The statement originally stated in Chapter 1, Section 1.4 supports the direction towards this direction of analysis in the methodology.

[46] The iterative process of Theory U and its application in the research conceptual framework is described above.

already engage in silo's.[47] This other bias is out of the researchers control and is accepted to be a wicked problem in itself where 'the problem is filled with so much uncertainty that it cannot be solved' but improved upon by insight gained. The researcher thus simplifies this complexity by limiting the research to stakeholders who have engaged in three multi-stakeholders spaces the UEIP, the MCMF and the LCPGs in the catchment and not all multi-stakeholder groups existing within the uMngeni catchment.

The above mentioned considerations also warrant the necessity for the researcher navigating through various roles in the data collection process, she has had to put on different hats or roles to obtain this information[48]- whether through observations, interviews or applying the information systems themselves. Data was collected using mainly interviews, an interactive observation through workshops, meetings and multi-stakeholder learning exchange programs for feedback mechanisms of social learning and active use of 'current technologies or information systems. It is also important to note in this process of using the ICTs and while the researcher attempts to give a holistic understanding of the processes and the variety of stakeholders, the catchment is highly diverse in terms of the stakeholders involved and three types of engagement spaces are a not a representative of all types of engagement spaces existing in the catchment and neither are the two information systems chosen. These chosen areas of investigating the case study thus become a guide for further application as piloted projects, deepening the learning process in alignment with Theory U.

3.9 Summary of the research methods

A detailed description of theoretical framework used to guide the research methods has been presented. Four world class and widely used social learning models were used as a basis for the theoretical framework, which itself was framed by one of the models namely Theory U. The three levels of socio-geographic spaces in which the research took place were described along with the

[47] Such findings affecting the existing barriers to social learning in the uMngeni catchment are described in Chapter 4, and in chapter 5 when information systems are considered.

[48] In this chapter these roles are termed 'positionalities'

reasons for selecting these socio-geographic spaces, namely; the UEIP, MCMF and the LCPG. The positionalities adopted by the researcher, namely researcher, mentor, learner, stakeholder, participant and observer, in each of these spaces was also discussed. The researcher also engages with two information systems; Mathuba WIKI and MIKE INFO to populate and adapt the systems for integrate management of water related information of the uMngeni catchment. Chapter 3 ends with critical step of the analytical and reflection process; that is that of developing semi-structured interviews to be conducted with selected key stakeholders of the engagement process how all these methods adopted affect ideologies and biases.

Chapter 4 Discussion of Results

This chapter presents findings reached in the three scales used in the study; the local level, sub-catchment level and the larger catchment scale of engagement, in line with Theory U for learning by Scharmer (2009) and the framework of methods of this research presented in Chapter 3. The results presented here show the pathway of learning taken by the researcher with regard to the state of social learning within multi-stakeholder groups. The most prominent mechanism for learning in the catchment as originally introduced by Ward (2016) is accessing, generating and using information. Accessing, generating and using information was found to be affected by the different ways that the stakeholders interacted with one another. This interaction varied from group scale to group scale but has a common theme running through all three group sizes and that is the communication enabled by the processes of their interaction. From the methods pursued in Chapter 3 and Chapter 4 it is clear that the multi-stakeholder processes studied in this research did produce social learning. This chapter discusses how some examples of stakeholder engagement increase the potential to undergo social learning by fulfilling the requirements needed and by being closely related to the constructs that facilitate and stimulate social learning.

When Theory U by Scharmer (2008) is considered; the research shows that the more efficient communication is between stakeholders, the greater their awareness with regard to going through processes of social learning is. This can be connected to the fact that deeper learning allows barriers for learning to be overcome, and the incentives to be readily pursued in a multi-stakeholder group. Social learning potential was the most evident in the smallest group scale of engagement; the local community project group (LCPG), less evident in the uMngeni Catchment Management Forum (MCMF) and the least evident in the uMngeni Ecological Infrastructure Partnership (UEIP). Chapter 4 and 5 should be seen as being connected through a common analytical approach that enables the reader to go through deep learning and increased awareness of the multi-stakeholder engagement processes that can support social learning in the catchment and the role that information systems can play in this learning (see also Chapter 3, section 3.5).

4.1 Overview of findings

The analysis first *describes* the characteristics of the processes of stakeholder interaction and the degree to which outcomes of these processes supported the requirements for social learning. Here, the researcher characterises the main processes of stakeholder engagement at all three scales affecting social learning in the study area. Where large scale groups like the UEIP faced challenges in incorporating local knowledge concerning the environment from the civil society in their own organisations. While smaller scale engagement groups like the LGPG's faced the challenge of working vertically with expert stakeholders and expert role players not originating from the communities. With regards to the structure, the thoughts developed between this chapter and the next can be represented using an analytical framework adapted from Tippet *et al*. (2005). An adapted framework for conceptual social learning in natural resource management documented by Pahl-Wostl and Hare (2004) and again by Tippett et al.(2005), is presented in this section as figure 4.1 and was used to present the results of the study. Figure 4.1 does not necessarily refer to the exact name of the headings in the sections depicted in the brackets. It refers to the content of the sections and how they relate to the analytical framework of research taken as depicted in the adapted framework by Tippet et al. (2005).

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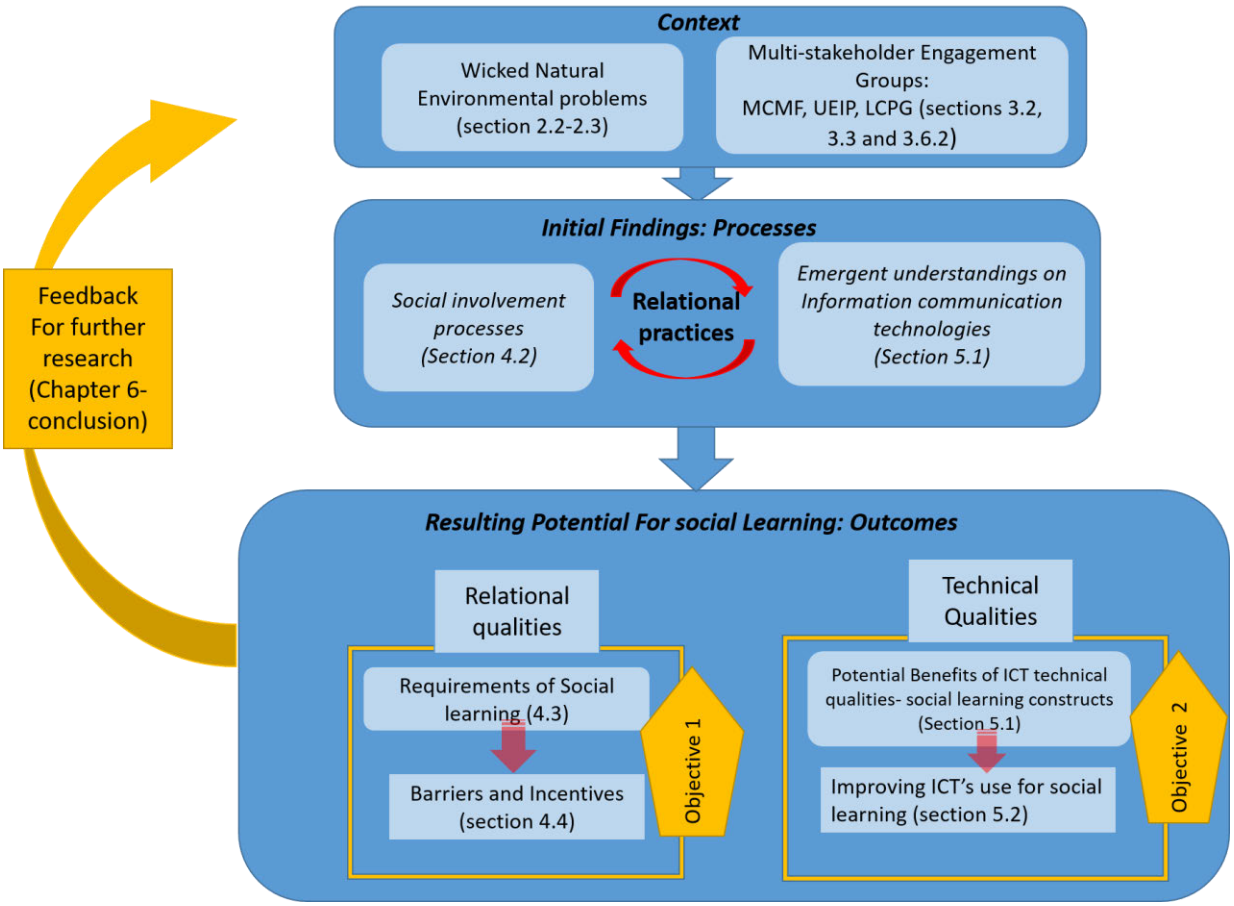

Figure 4.1 Holistic analytical framework for the research (Adapted from Tippett et al. (2005)).

From the processes and their outcomes described in Section 4.1; Section 4.2 then evaluates the requirements for social learning that were met with regard to the group of constructs that were manifested in varying degrees in the three scales of engagement evaluated. This is done using a scoring system that is based on analysing semi-structured interviews. Leading up to this, in Section 4.2 an evaluation of the stakeholder processes at all scales of engagement is provided. This was done by assessing the expression and satisfaction of the seven criteria for meeting social learning. From this comparative evaluation it was found that not all requirements for social learning were observed in the uMngeni catchment within the time the researcher was involved as a participant observer. The requirements for meeting social learning varied depending on the type of multi-stakeholder group and the engagement processes they were involved in as shown from some case

examples. Furthermore, the results of looking through the lens of multi-stakeholder group scale showed stakeholders were more interdependent to one another even when they engaged at different levels of expertise in uMngeni catchment. This result was supported by more characteristics after doing a cross examination of the processes and responses of stakeholders within the uMngeni catchment.

Lastly, in Section 4.3 the researcher makes definitive statements with regard to the barriers and incentives to social learning in multi-stakeholder engagements groups in the uMngeni catchment (section 4.3). Here the first research objective is addressed and the more subtle enabling and inhibiting factors to social learning are revealed. These contrast with the previously assumed rigid barriers and incentives to social learning. These factors are discussed as conditions that can be met when certain processes of stakeholder engagement are enacted.

Overall, the case study in the uMngeni catchment indicates that the main issues with stakeholder engagement processes relate to collaboration; specifically with the presence of effective collaboration and also its absence. Multi-stakeholder engagement processes were connected to the issue of assessing, generating and using information described by Ward (2016). It was found that all three scales of stakeholder interactions in working towards addressing water related issues investigated in this study, have platforms for collaborative engagement in common. While the narrative of achieving collaboration was often discussed in the larger catchment management group (the UEIP), it was also a goal in the MCMF. The necessity of achieving collaborative engagement of stakeholders was evident in the way stakeholders in the larger catchment management group, mainly the UEIP dealt with commonly shared issues by forming collaborative projects where the expertise of stakeholders belonging to different organisations were used to help address the issues at hand. However, the matter of accessing, generating and using information (Ward, 2016) was still a problematic issue; a subject often discussed during periodic meetings such as the collaboration meeting held twice a year. When it comes to the subject of collaboration and multi-stakeholder engagement processes, the observed experience described in this research differed for the MCMF and the LCPG scales.

For the smaller local groups, MCMF and the LCPG (ie. The Mpophomeni Enviro-champions); the formation of collaborative projects was used to define problems and determine implementation techniques at a finer local scale. In this research, actions of multi-stakeholder engagement are discussed and issues relating the accessing, generating and using information for the benefit of overcoming common wicked problems is also discussed. The findings to be presented in this chapter show that effective collaboration was most prevalent for social learning in the LCPG, and least observed for the UEIP, while the MCMF falls in the intermediate

While there were significant enabling factors to social learning, these were few when compared to the observed inhibiting factors because of the currently underutilized opportunities to engage in social learning constructs that support learning in the uMngeni catchment. This was found to be true across all scales of multi-stakeholder engagement, but more so at the larger catchment management scale group, the UEIP and the sub-catchment management group the MCMF.

Stakeholders of the UEIP were found to have limited social learning when it came to accessing, generating and using information in a group, which is the most prominent mechanism to facilitate social learning as documented by Ward (2016). This was largely due to infrequent times of stakeholder engagement and the sustaining of discussions reflected upon by the greater manifestation of inhibiting factors than enabling factors in the processes of engagement. On the other hand, stakeholders of the local community groups, particularly groups such as the Mphophomeni Enviro-champions, were found to have potentially undergone the most social learning characterised by a change in behaviour supported by regular meetings and interaction between the members.

The enabling factors of social learning for the civil society involved the empowerment of these groups, the establishment of strong networks of communication across stakeholders, increasing awareness of common wicked problems, increasing trust and stronger relationships, easing access to and centralising of information about the catchment. Some skilled key stakeholders in the LCPGs who are associated with non-government organisations working in the communities have been able to initiate and drive such enabling factors for social learning. On the other hand, factors inhibiting social learning included reduced transparency and integration of knowledge, lack of

sustained energy of engagement, lack of trust, poor recognition of the complexity of the system, physical and or geographical distance related barriers to engagement and socio-relational barriers to engagement. The section below elaborates on these findings by giving a comprehensive presentation of the processes of stakeholder engagement supporting social learning observed in this research. These findings are the outcomes of the researcher's role or position as a participant observer in the uMngeni catchment.

4.2 Discussion of social involvement processes

This section covers the processes of stakeholder engagement in the uMngeni catchment that are closely related to communication and the accessing, generating and using of information (Ward, 2016). As part of the researcher's reflection process, it includes a summary of four themes observed of stakeholder engagement and participation processes. These themes cover the general processes marking social learning, investigated by Ward (2016). These are:-

- The engagement of local actors.
- The creation and establishment of relationships
- Networking and cross-sectional awareness.
- Innovative use of information communication tools.

The results are important in analysing the signs of social learning using scores, which is discussed in Section 4.2 and to further evaluate the requirements to social learning and the likely barriers that exist and incentives that could be better utilized (Section 4.4).

4.2.1 Engagement of local actors and learning

Within the uMngeni catchment, there was a focus towards the inclusion of local knowledge within the multi-stakeholder processes, particularly from non-experts in communities. While stakeholders in all scales of multi-stakeholder engagement in the uMngeni catchment can be considered local actors, for the purpose of this research the local actors include the civil society or members of the communities who are not considered experts in the field of water resource management. It was found that most stakeholders either included local knowledge in their meetings together, or they

expressed verbally the importance of including citizen generated information in overcoming the persisting water problems in the uMngeni catchment. These stakeholders included the local scale community project groups (LCPG) such as the Mpophomeni Enviro-champions. However, an appreciation for local knowledge contribution to issues pertaining to water was also observed in the sub-catchments scale of engagement as well as the larger catchment scale of multi-stakeholder engagement; that is in the MCMF and the UEIP respectively. For the purpose of expanding on this subject, the following four examples will be presented.

Example 1: Visible inclusion of local knowledge in the UEIP and the MCMF

While engaging as a participant observer, the researcher found that at the UEIP scale, there was an influx of stakeholders belonging to private and public organisations focused on making local knowledge and experiences the focus of their catchment information, but not without its own share of challenges which will be discussed below.

Some of the findings from observing the reports given by members of the UEIP who belong to the public sector indicated that there was a positive correlation between local knowledge contributions and the engagement of local actor's community scale projects when it comes to water related environmental issues. Furthermore, local community actors who have the opportunity to engage with private or public organisations in a form of training and collaboration for dealing with persisting water related problems in their catchment have had positive results in their communities. For instance, it was reported in the meetings of the UEIP that as part of the Palmiet Rehabilitation Project, projects implemented at the local community scale can be used to drive environmental education of the civil society. For example, it was noted that in this particular project, communities who worked with government or the private sector as implementers at the local community scale in issues of water such as waste management of communities, decided to become the very advocates of their environment. The outcomes of such initiatives show that the process of engagement is effectively functioning to benefit the catchment when stakeholders at the local community scale are given an opportunity to be involved with actors across other levels of expertise.

In an MCMF meeting, some of the stakeholders representing the forum expressed the opinion that community experiences are used as a basis for discussing the issues pertaining to water in their meetings and could be further used to engage communities more actively. However, in line with supporting information flow essential for learning from the grassroots up, it was found that the engagement of local stakeholders in organised local based organisations of environmental impact (EI) monitoring is one of the greatest challenges due to a lack of resources from the MCMF to engage the local groups and to incentivize the citizen science work done at the local scale. Stakeholders admitted that money to support environmental impact assessors such as environmental-champions is often difficult to attain, even though such local knowledge is beneficial in gaining a more holistic understanding of the catchment, especially with regard to persisting water quality issues (Terry, 2016).[49] More insight into this observed phenomenon of stakeholder engagement processes is presented in example 2 below which gives further insight into how the engagement of local actors affects local actors in these communities who are struggling to engage effectively with expert groups such as the MCMF and the UEIP in the Upper uMngeni catchment.

Example 2: Declining funding to local actor initiatives

Another finding concerning the engagement of local actors to support social learning was that there exists the challenge of funding work done by local stakeholders or the civil society in approaching water related issues in their community. It was found that the multi-stakeholder groups such as the MCMF concluded that the engagement of local groups in stakeholder processes (both in the meetings and in matters concerning their catchment) was low and needed financial support to mobilize citizen science activities. According to one of the stakeholders, a member of the MCMF and participant in the learning exchange program of 2016: "*Very little funding goes to the people on the ground, as custodians of water resources*" (Learning Exchange program, 2016).

[49] This statement was based on a statement made by Steve Terry of uMngeni Water in the 2016 annual Learning Exchange program with the UEIP and other stakeholders operating outside of the uMngeni catchment.

Observed interchange of conversations between stakeholders in the UEIP showed that there is a common understanding on the processes that are important in ensuring that local community stakeholders are funded for their work in collaboration with the private and public sector organisations in the uMngeni catchment. Stakeholders expressed that there is a need to keep collaborating in order to obtain buy-in from other stakeholders. Stakeholders in the UEIP became exemplary to this through their various local community projects such as the Baynespruit rehabilitation project, the Palmiet rehabilitation project and the 'Save Midmar Dam" rehabilitation project. It was also observed that when stakeholders collaborated in this manner, they used the funding from the project to create jobs for local actors or the civil society.[50] Such examples were not always continuous and the financial support to local actors often ceased to exist after a project had reached its completion.

One of the major outcomes of the multi-stakeholder engagement processes, such as the one organised by the UEIP learning exchange program, was the need for the integration of local, social and biophysical knowledge concerning a community area where these is the threat of water quality and quantity decline. This is the case for the Mpophomeni area, and through the Mpophomeni Enviro-champions, such success stories of small group collaborations working towards the fixing of water quality issues became popular in larger catchment meetings. Stakeholder engagement processes such as learning exchange programs opened the pathway to inquiry on inclusion of local knowledge in the various project groups existing between stakeholder organisations in the partnership. Organisations from different parts of the catchment and neighbouring catchments of the uMngeni catchment shared the benefits of including stakeholders at the local community scale in their projects. However, without the long-term awareness of the benefits of supporting local actors at the community level such as the enviro-champions, the financial support to these groups through projects was also found to decrease. The opportunity for larger catchment management groups and organisational partnerships such as the UEIP to use their networks to induce

[50] . It is worth noting that some stakeholders involved in these projects are also active voluntary members of the MCMF, however, in this case the focus is on the UEIP as being exemplary due to the stakeholders in this group being given an opportunity to share their research in the collaborative meetings of the UEIP.

momentum in approaching persistent 'wicked' water related problems, engaging local communities as actors, was realized from observing topics discussed in these group meetings.

Example 3: Successful steps to engaging with community actors

When it comes to engaging with local communities - that is between expert groups and those who were considered to be at the local community level - stakeholders varied in their approaches and noted outcomes. In example 1 above, the inclusion of the civil society was discussed as a form of collaboration with standing organisations and at times with members of the community who did not belong to any local community environmental activist group such as the enviro-champions. From observing the engagement processes it was noted that the communication between scientific experts to communities was usually through a representative. When such opportunities for the engagement in meetings were successfully arranged; there was a reported positive change in perspective of the identity of the stakeholders at the community level. Stakeholders at the local community scale are considered valuable contributors to the dealing with "wicked" problems in the uMngeni catchment as a whole.

Local community actors who serve as representatives of a local community project group were taught by the organisations that are collaborating with them how to use indicators to explain what they were experiencing or seeing in their part of the uMngeni catchment. While the researcher did not engage in all LCPGs in the catchment, the findings from observing the Mpophomeni Enviro-champions (MEC) will serve as an example here again. With the support of DUCT as an NGO; members of the MEC acted to protect water resources by educating the community on waste management, saving water and conducting bio-monitoring in their local streams using citizen science tools for onsite water testing. The meetings for discussing findings and progress in the project this relatively small community group were held once a week with some members of DUCT and WESSA who were the main leaders in supporting the local project at the expert level. These members of the organisations worked with the representative members of the Enviro-champions to communicate feedback of the restoration projects and how they were received by the community. Such a collaborative working relationship between the experts and laypersons representing communities was successful when compared to the larger group counterparts

investigated in this project such as the UEIP and MCMF, who often worked in silo's and did not work closely with communities through representatives.

Further insight from the MCMF suggested that there was an awareness of the need to lead the monitoring efforts done at the local community scale. Such leadership will also mean better inclusion of representative stakeholders and the organisations that fund them doing valuable work at the community level. For instance, the uMsunduzi Municipality and DUCT who are also members of the MCMF, focused on reducing water pollution by involving local community stakeholders in the uMsunduzi sub-catchment rehabilitation project which subsequently created jobs through an initiative called the EPWP. One of the community engaging project efforts mentioned in the MCMF meeting included the monitoring of sewers or manholes by the uMsunduzi Municipality. This monitoring effort consisted of about 30 monitors scattered at chosen locations in the upper uMngeni catchment. The manhole monitoring project also included the education and training of local community actors by the community representatives. The training and education was particularly on the use of cell phones and social media as onsite monitoring and communication tools to alert expert stakeholders in the uMsunduzi sub-catchment such as the municipality and the municipality contractors who have the responsibility to fix sewers and manholes in the townships. Such local projects involving expert organisations provided a 'voice' for the engagement of the local actors and their representatives. As they became trained to monitor the catchment and produce information they became recognised as valid stakeholders working towards managing the 'wicked' problem that affects all stakeholders in the uMngeni catchment, namely water quality decline. Moreover, the discussion of monitoring efforts by DUCT and the EPWP local actors in close collaboration with the uMsunduzi municipality in the forum meetings of the MCMF, led to questioning if the MCMF could, as a collective group, support local community initiatives in an effort to support and expand their monitoring efforts. The statement below given at an MCMF meeting is testament to that fact. *"…how can the EPWP be more focused for expanding monitoring work… let's try and be leaders as the MCMF*." (Stakeholder of the MCMF in the 87th meeting).

Overall, this example showed the value of including presentations by the LGPG in creating awareness to local community initiatives and further showed the value of accessing, generating

and using information by larger multi-stakeholder groups such as the MCMF. It specifically showed the value of training and including community representatives in larger multi-stakeholder engagement groups. However, it was also found that the stakeholders in the uMngeni catchment had an even greater potential for movement towards successful engagement of the local communities. The example below elaborates further on this finding.

Example 4: Developments on successful local community engagement

Findings from observing how stakeholders engage in the LCPG scale has shown that declining water quality and quantity has drawn the attention of NPOs and NGOs in collaborating with government organisations for the training of the civil society to tackle issues surrounding water quality in their own communities. This trend in the uMngeni catchment has been key in the movement towards stakeholder engagement at the smaller local community project group scale as well as the larger catchment management scales.

One of the major outcomes of developing local community engagement groups was found to be the directing of efforts through organised government initiatives and funds in an effort to address major wicked water problems such as water quality decline and water quantity decline. The government's EPWP was designed for the "alleviation of poverty and unemployment" by facilitating engagement of Labour Intensive Methods of Construction (LIC) to develop skills in local communities (Maphanga & Mazeka, 2019). These quoted words were observed to echo by stakeholders engaging at the LCPG scale in the Mpophomeni Township. The focus on skills, education, training and development is designed to enhance economic growth, an ideal setting for industries to flourish (KwaZulu Natal Public Works, 2010) and an advantage for some LCPGs in the uMngeni catchment when it comes to water.

During the year 2015 and 2016, the EPWP funded the work originally started by citizen scientists known as the Environmental Champions in the Mpophomeni and the Ashdown Township. This work was particularly focused on the common wicked problem of water quality where monitoring of malfunctioning manholes or sewers was carried out. This was particularly important in the

Mpophomeni Township since it was related in conversation with the researcher from one of the community representatives during a brief meeting with the enviro-champions prior to conducting weekly manhole monitoring in the community that service provision in relation to waste management and the maintenance of infrastructure in the township was limited (A. Lipheyane, personal communication, October 13, 2015). Issues of sewer line and potable water line repair and maintenance were common during the time of the research with some community members complaining that they do not have the financial means to pay for repairs of the infrastructure, leading to unfixed leaks and overflowing manholes. The team of citizen scientists in the Mpophomeni township as part of a greater effort of improving the conditions in the uMngeni catchment were taught to be involved in educating the community on water monitoring and management in their own homes including the reporting and fixing of pipe and tap leakages, and the malfunctioning of manholes. Additionally, the stakeholders at the LCPG had small meetings before engaging in this field work. In this meetings stakeholders created a safe environment for the enviro-champions to discuss the challenges that they were facing in working in the community as well as possible solutions from various members in the group to work around the encountered problems. Such engagement at the local community scale became empowering to local stakeholders and created an awareness of the value of citizen scientists who originate directly from the local, disadvantaged communities as well as the responsibility to pass on the skills and knowledge that they have. The researcher learned this while communicating with the enviro-champions who were part of the EPWP community education and monitoring activities in the Mpophomeni Township.

"I try to help members of the community participate in the monitoring in the area around them. I am also involved in other projects focused on environmental education with DUCT for cleaning rivers and conducting miniSASS activities. I have to pass on all the information I have been taught about the environment to the kids in the community." (N. Mtambo, October 20, 2015).

From observing and noting the discussions of stakeholders at the LCPG scale, it was also noted that many local initiatives of improving water related issues such as the one funded by the EPWP need additional support. They have not been enough in helping to fix and maintain the poor infrastructure within the confines of the residents own home such as taps, toilets and overflowing

manholes that have been the man causes of the causes of pollution. A question of whether citizen based monitoring initiatives can be prioritized for funding and training the existing employees of EPWP in fixing these infrastructure is raised in the UEIP meetings as well as in the MCMF. Furthermore, such examples of involving local community initiatives as part of the greater discussion in larger multi-stakeholder groups such as the MCMF became a topic of interest.

4.2.2 Creation and establishment of relationships

The findings in the preceding sub-heading indicate that there was high emphasis on communication and the establishment of relationships with local community stakeholders. However, from engaging with stakeholders at all three scales of multi-stakeholder arrangements it was noted that establishing relationships across levels of expertise and disciplines was just as important. It opened the doors to networking and cross-sectional awareness of the deeper nature of common water related problems, which can be associated with creating and establishing current relationships. From analysing the examples, it is noted that there is a common challenge to establishing and sustaining relationships in the catchment due to the physical distance between stakeholders, a lack of a binding mandate for multi-stakeholder engagement groups and a lack of systems that support collaboration. On the other hand, this did not negate the existence of positive noted developments in multi-stakeholder engagement. In these meetings there were organisations of meetings that create awareness on what other stakeholders in the greater uMngeni catchment and neighbouring catchments were involved in. This also included efforts to listen and to learn from other organisation's presentations of their current research and efforts to approaching wicked problems in the catchment. It was found that groups such as the UEIP had the best potential to build relationships of expertise more than the LCPGs due to their larger size and opportunities to network as well as their more focused efforts in understanding the research and implementation efforts of the organisations in their partnership. All of these findings are supported by the examples that will be shared below.

Example 1: Networking and cross-sectional awareness

Creating a system where stakeholders are connected and are able to network, is an ideal that has been communicated frequently between stakeholders in the groups investigated within the uMngeni catchment. Stakeholders show signs of recognizing the need for raising cross sectional awareness on what is happening in the catchment by sharing opening the channels to the open sharing of information about the state of water resources and what stakeholders are involved in to resolve the issues. However, how stakeholders are able to achieve networking and cross-sectional awareness varies from each multi-stakeholder group.

Stakeholders of the UEIP were aware that there needs to be cross-sectional awareness between organisations in the group as well as communication between the group and other multi-stakeholder engagement groups in the catchment such as the CMFs. The major noted reason and expected outcome of forming large multi-stakeholder partnerships such as the UEIP as well as learning exchange arrangements with forum groups across the greater uMngeni catchment was to identify knowledge gaps in the management of natural resources where actionable knowledge could close. Networking and cross-sectional awareness was valued in its ability to link stakeholders on how to overcome, where possible, common water problems[51]. However, despite the various efforts of larger multi-stakeholder groups such as the UEIP and the MCMF, commitment of stakeholders to engaging and seeing the beauty of the end product of working collaboratively together was a noted challenge both by the researcher and stakeholders studied.
When it comes to cross-sectional awareness, it was found that the MCMF when compared to the UEIP has continuously been able to provide a state of the river report focused on major problems, mainly water quality. In the case of the MCMF, raising awareness took on the approach of reporting the state of water issues on a more regularly basis using one and later only two organisations.

Updates of water quality parameters were shared during the quarterly meetings while weekly updates of one of the parameters (E.coli concentrations) was also shared by email on a weekly

[51] It is worth noting that most stakeholders in multi-stakeholder meetings often did not differentiate the common problems that they were encountering as a group as wicked problems or not. This in itself became a noted knowledge gap that could be filled by this research and the understanding of social learning. Further discussion into this will be provided in Section 4.2.

basis. This information was successfully presented to all stakeholders in the MCMF. In addition to presenting this information, the forum platform allowed stakeholders present in the meetings to give their response to the state of the rivers. However, much like sustaining and creating strong relationships, the presentations were only impactful in the meetings and in the weekly shared emails which consisted mostly of tabulated data[52]. Methods of providing long lasting and impactful awareness were limited to quarterly meeting presentations and these weekly and monthly emails of E.coli concentrations and showed the lack of interaction and feedback from stakeholders in the MCMF on one end, and a willingness to share part of information owned by an organisation. While stakeholders were aware of the need to support information shared concerning water quality in order to create a more complete picture of the catchment through their face-to-face multi-stakeholder engagement, there were no other stakeholders or organisations to contribute such water quality related information with the stakeholders within the forum face-to-face or online. Stakeholders also commented during meetings that the platform itself could be better used to also encourage the sharing of time sequenced biophysical and hydrological information such as river water quality and dam water levels instead of just single parameters of water quality. However, despite awareness of the above mentioned issues very few steps towards action were taken to increase the knowledge spaces and create more awareness from the networks that currently existed in the MCMF.

Based on statements made at the quarterly MCMF meetings, the face-to-face engagement between stakeholders and even online was recognised as needing to provide more, in order to raise cross sectional awareness of issues in the catchment. It also needed real engagement with the civil society, government and business sector stakeholders in order to give a more holistic understanding of water related issues. Consider the statement made below:

'…solution to water quality issues requires a cross sectional approach between governments, businesses and civil society.' (Statement made by a stakeholder in the 87th CMF meeting).

[52] Details on how the current use of ICTs puts social learning potential at a disadvantage is discussed in the next chapter; Chapter 5.

Raising awareness has been a communicated goal for all the multi-stakeholder groups considered in this research. However, there is not enough engagement with the information that individual organisations share in a multi-stakeholder group to show that raising awareness is a goal. Stakeholders seldom volunteer their own information to shed more light into an issue that a stakeholder has shared information on. The desire to add to the knowledge space is not spreading amongst stakeholders in the MCMF or the UEIP. Stakeholders in government, civil society and business may be aware of common wicked water problems, such as poor water quality and water scarcity from water reservoirs and dams, through their being involved in the multi-stakeholder arrangement and attending periodic meetings. Opportunities for these stakeholders to add to the knowledge space are either not available as is the case for the LCPG stakeholders or stakeholders feel unmotivated or unobligated to share their pieces of information by placing it into the common space.

The above example showed how stakeholders in multi-stakeholder groups such as the UEIP and the MCMF are always seeking to raise awareness on issues in the catchment. Multi-stakeholder collaborations in these groups is an example of how these groups are acting to fill the gap of knowledge surrounding persisting water related problems. In the uMngeni catchment, one of the most desired essential steps of projects within the larger catchment management groups was holistically approaching projects focussed on a particular problem in order to increase awareness of issues in the catchment. Collaborative projects with stakeholders who are part of different organisations and are interested in the health of the uMngeni catchment has been commonly understood by multi-stakeholder groups to be beneficial in having a more direct and assisted approach to water related issues. This was primarily because this approach invites the opinion and expertise of other respected organisations in the uMngeni catchment and can potentially give more opportunities for social learning.

One of the significant ways to communicate and establish relationships illustrated by the research efforts within UCPP stakeholders who presented their work in the 2016 Learning Exchange program meeting was not only to talk about what each organisation was involved in, but to also use the multi-stakeholder arrangement to collaborate across disciplines in future projects. The main conclusions reached from the learning exchange program were that such collaborations would

create a context for learning. The aim of such collaborations was focused on achieving holistic understanding by using research topics and spreading these topics across institutions in order to not broaden the research approach towards problems in a catchment but to bridge gaps. These gaps according to the observed feedback from the groups presenting in the UCCP, were closing in order to put science and expert knowledge into action with the aim of benefiting communities whose members were often engaged and producing valuable knowledge because of the incentives that were put in place to support their input. Similar to this partnership, in the UEIP the relationships created between experts were understood to be beneficially used to create actionable knowledge that benefits a catchment as a whole. (Adapted from Learning Exchange Program meetings, 16 November 2016).

However, unlike the successes of the UCCP described in the learning exchange program within the UEIP, creating actionable knowledge that benefits local communities was expressed to be limited due to a lack of knowledge on how to include information from these local community originating groups effectively. The successes discussed in Section 4.1.1 on the engagement of local actors through collaborative projects spoke for guided inclusion by expert stakeholders on the UEIP on local citizens and not necessary on how the stakeholders could include information from existing LCPGs. These LCPGs already exist as community activist groups and are energized and mobilized to create simple data pertaining to their local catchment and water resources. It was found that this general lack of inclusion of local community generated information decreases the awareness of stakeholders in the UEIP when it comes to understanding how information created at the grassroots level could better assist their multi-stakeholder efforts in solving or improving wicked water quality problems. Including expert stakeholders in the front line and adopting a more *top down approach* to networking and creating awareness of local issues was something stakeholders in the UEIP pursued. Consider one of these projects in this example again: the collaborative Palmiet Rehabilitation project.

The Palmiet rehabilitation project as reported on in the 2016 Learning Exchange Program, embraced implementing a holistic approach against identified challenges within the catchment by focussing on bringing together governance, social issues and biophysical issues and information of the catchment. Through collaborations, stakeholders that were included were also part of the

UEIP and engaged in the lower parts of the uMngeni catchment where they too carry a stake in the water related wicked problems. This was the case for other successful multi-stakeholder collaborative projects reported in the UEIP too such as the Baynespruit Rehabilitation project of the upper uMngeni catchment where the government organisation mobilised action with communities using the research efforts of students in the University of KwaZulu-Natal. These collaborations raised cross sectional awareness as stakeholders from different organisations provided their expertise and perspectives of the problem as well as the best practice approaches to overcoming them in order to reach a common goal of a healthier uMngeni catchment.

For the smaller multi-stakeholder sub-catchment groups such as the MCMF; stakeholders expressed the necessity to engage organisations within their own forum space who were reluctant to attend the year quarterly forum meetings. One of the reasons why forum meetings were organized was to discuss water quality and the solutions towards water quality issues. However, some stakeholders such as those of the business sector were often mentioned by members of the MCMF during meetings to be inactive actors and were at some point suggested for inclusion for one on one discussions with the uMunduzi Municipality. This was not until the Msunduzi Rehabilitation project was created during the time of the research (the year 2016) that it was observed that the business sector[53] and industry were willing to participate through the collaborative project. Hence, in the case of the MCMF, this was an indication that the group could not their confirm availability for healthy discussions concerning wicked problems with all stakeholders. And that this lack of engagement in the available networks unless through a collaborative projects was a sign of a lack of transparency and openness in the MCMF.

More opportunities for stakeholders to engage in conversation and to increase their awareness as a collective about what is happening in the catchment needed to be created. A statement made by a stakeholder in the MCMF who was engaging in the 2016 UEIP learning exchange program below shows how a lack of frequent engagement was realized and not properly expanded on through the use of IT and social media.

[53] Mainly the Pietermaritzburg Chamber of Business

"*We can't wait for four months to bring something up- some people do not know how to follow through deals and use social media more*." MCMF stakeholder engagement, 16 November 2016, Learning Exchange Program

From the above statement, it became clear that there is not enough communication within larger multi-stakeholder groups such as the UEIP and MCMF or between them. The stakeholders collectively express an inability to use social media as a tool for communication and enhancing awareness of what is happening in a manner that will benefit their networking processes, even though this method was widely used at the LCPG scale and was able to trigger inactive members[54]. This particular finding supports the notion found in literature that local people who are motivated to make a change in their environments due to having a shared concern for the health of the communities that they reside in, can be at the forefront in encouraging learning on any work done in a community based project (Korten, 2015). Stakeholders at the LCPG are able to raise and trigger awareness on issues happening on the ground even outside of formal face to face meetings because they share a motivating vision. In the case of larger multi-stakeholder groups, the meeting of stakeholders only a few times in a year to have deep discussion has been a matter of concern both in the MCMF and the UEIP due to the lack of engagement preventing stakeholders from reporting on water related problems within their catchments on a more consistent basis.

Even though discussions during multi-stakeholder meetings of the UEIP and the MCMF can be beneficial face to face by strengthening networks and awareness; it is clear that further insight comes from the understanding that multi-stakeholder engagement is a voluntary process. A lack of an official mandate for engagement can significantly affect how relationships are created and established to support social learning. This is revealed in the second example below for creating and establishing relationships.

[54] Result concerning the application of ICTs as virtual spaces of engagement using social media platforms is discussed in the next chapter.

Example 2: Lack of official mandate for engagement

One of the barriers to creating and establishing relationships with a variety of stakeholders was that there are also external factors affecting the ability of stakeholders to form meaningful relationships. These relationships enable the sharing of valuable information concerning the catchment and for implementations in accordance with the behavioural changes undergone by multi-stakeholder groups and are therefore very importance in having sustained change. In the MCMF and UEIP where there was no official mandate for the engagement of stakeholders, the forming of relationships was affected.

Despite the relative good relationship between stakeholders within the MCMF as expressed during the UEIP Learning exchange program (2016), learning is still impeded due to the lack of organisation and structure of communication that strengthens these relationships. The MCMF stakeholders engaging in the 2016 UEIP Learning Exchange Program expressed that the group engages on a voluntarily basis having no funds, mandate, authority or formal power to encourage anyone to participate. This did not help in breaking down silo's which were separate spaces within their own organisations where the communication of information freely to other associates in the multi-stakeholder group did not occur. The group was also unable to ensure that all key stakeholders engaged in the periodic meetings; stakeholders such as those in industry and businesses. As a result of these factors associated with not having a binding mandate for engagement and discussions, the ability to access information from these actors, information such as that which is related to factors causing pollution was lowered. The lack of an official mandate also could not contribute in making stakeholder accountable for feedbacks or reports on implementations to reduce water related problems done by the organisations. The statement below is testament to this understanding.

"It seems to be just like a talk shop. No official reporting system of taking action or enforcing things." (Stakeholder within the MCMF, 2016 UIEP learning exchange program).

The importance of having a mandate was also linked to creating a context for learning and having more focused action and research by a multi-stakeholder group. The UEIP linked this learning to

the necessity of improving skills of engagement as seen in the statement shared by a stakeholder during the learning exchange program.

"It is important to create a context for learning and to enrich it, supporting it with knowledge from different sources such as collaborations, partnerships and focused research." (Stakeholder within the UEIP in the 2016 Learning Exchange Program).

Example 3: Engaging previously inactive groups

Collaborative projects in multi-stakeholder groups were also found to be useful in engaging previously inactive groups due to a lack of an official mandate. These previously disengaged stakeholders gain an opportunity to engage in the conversation pertaining to water issues in their catchment and provide valuable contributions as they work collaboratively towards a common goal, which all adds to the establishment of relationships. Such was the observed case with the involvement of the business sector through the Pietermaritzburg Chamber of Business (PCB) in the uMsunduzi Restoration Project of the MCMF. With the business sector committing to provide direct support to the existing local community scale initiatives, stakeholders of the MCMF shifted the energy in the MCMF and more people became excited to be part of the initiatives.

The adoption of collaborative projects and initiatives also led to steps being taken to gain financial support needed to carry out the projects. For instance, during the 87th meeting of the MCMF in the year 2016, the uMsunduzi Restoration Project was pitched to potential funders in the Upper uMngeni catchment. During that process, it gained substantial support in the form of interest from organisations within the forum group. When asked who would be interested in being part of the project, more than half of the stakeholders present in the meeting raised their hands. Such observed support on a collaborative project showed that collaborative projects could strengthen existing relationships and help to form new ones as stakeholders work together to solve a common goal.
It was found that stakeholders of larger multi-stakeholder groups, in this case the MCMF and UEIP had an affinity for committing to get multi-stakeholder groups in working towards getting collaborative projects going than to apprehend any stakeholders that refused to participate. This was clearly found in the MCMF where the "*important thing was the health of the uMsunduzi River,*

a tributary of the uMngeni catchment" (MCMF chairperson) and even though the multi-stakeholder group was designed to be a discussion forum, some stakeholders became interested in collaboration and its benefits in creating awareness on the issues face din the catchment. Prior to the public announcement of a collaborative project headed by the MCMF, the researcher was actively involved as a participant during the time of her internship in brainstorming and presenting ideas on how GIS powered ICTs can be used to communicate and map out citizen science activities by schools and enviro-champions, how infrastructure and businesses in the uMsunduzi catchment can be used for water harvesting, how the Municipality can be assisted in monitoring sewage malfunctions and also how different zones around the tributaries of the catchment could have their health protected. These conversations occurred between the researcher who represented the University of KwaZulu-Natal and NGOs such as DUCT, Wildlands, Talbot and Talbot, Phelamalanga Projects (headed by MCMF chair Rod Bulman), uMgungundlovu district Municipality and GroundTruth who were also stakeholders of the MCMF. The goal for this meeting held on the 7th of July 2015 was to improve the health of the UMsunduzi River ahead of the 2018 FNB Dusi Canoe Marathon through a collaborative project. An additional goal for proposed project at the time discussed during the meeting was to brainstorm how the Pietermaritzburg Chamber of Business could be used to influence and pursued industries to be involved in actions that improve the health of the catchment. Later on this goal was presented to the MCMF by the chairperson as a proposed collaborative project. The clear and consistent desire for ongoing collaboration by the MCMF was seen in each meeting in the year 2017 as the proposal and budget for the project was finalized and presented at the meetings and the activities of the organisations involved in the project from the MCMF was presented as well. While not all stakeholders of the MCMF were directly involved in this collaboration, they expressed their support and were kept up to speed with the developments that had been happening outside the year quarterly meetings which showed a good effort on collaboration and the creation of stronger relationships between the stakeholders, even though not all attended the meetings.

The examples shared above show how cross-sectional awareness has been met with challenges and successes in the different scales of engagement. For the most part, stakeholders are still working in silo's and are not sharing information actively outside the meetings even if they are bound to work together for a certain period of time through a collaborative project. Raising

awareness is valued in all scales of multi-stakeholder engagement and has the power to engage previously inactive stakeholders and motivate activity at the LCPG scale. However, such efforts without a place or platform for the information that comes out to grow and to be monitored has been another topic of discussion. It has led to much conversation during these multi-stakeholder meetings on the adoption or creation of innovative ICTs to boost networking opportunities and encourage information sharing at a wider and more efficient speed. However, the innovative use of information communication tools or ICTs has been a topic of discussion in larger multi-stakeholder groups such as the UEIP and MCMF, particularly in improving generating, accessing and using information pertaining to the catchment and in helping stakeholders become more coordinated in approaching catchment issues.

4.2.3 Innovative use of information communication tools

It is with the conversations of innovative use of information communication tools that the goal of *accessing, generating and using information* as described by Ward (2016) resurfaces time and time again in the uMngeni catchment. Much awareness on the inclusion of information systems in supporting the creation of awareness of catchment conditions was present in all the scales of engagement investigated in the research (ie. UEIP, MCMF and LCPG), even though it was not all the investigated groups that got round to applying such information systems.

Example 1: Developments surrounding raising awareness through ICTs

In an effort to create awareness on water related issues, it was also observed in line with the objectives of this research that stakeholders were invested in the narrative of creating a database for the catchment and its tributaries in the years 2016-2018. According to what was observed in the UEIP and MCMF engagements, the information system was to be integrative of biophysical information of the catchment as well as to carry the characteristics of a database management system for information pertaining to projects that the organisations of stakeholders were involved in. The expressed hopes of such information systems became indicative of the stakeholders hopes of creating a source of information to assist stakeholders in understanding the causes of wicked problems more and prioritize research opportunities in a more efficient way. This possibility was

expressed openly during the 2016 Learning Exchange Program. It was regarding creating awareness and integrating stakeholders and their expertise in order to improve access to information; much like what collaboration and face to face meetings try to achieve. Stakeholders of the UEIP often reiterated the objectives of the multi-stakeholder arrangement, pertaining to encouraging healthy catchments and ecological infrastructure. Most of these objectives geared towards the development of Information Communication Technologies or information systems and encouraging learning.
Consider the statement made below:

"Organisations that know how can help those that don't know- the UEIP helps find and create such collaborations." (Stakeholder in the UEIP stating objectives of the partnership, 2016)

One stakeholder has also emphasised in another meeting the importance of nourishing networks and becoming better at planning and prioritization (which support the narrative of using technologies) during a UEIP research meeting like this:

"We do not only need to know what we are doing (NRM), we need to know other types of information by having a communication plan that explores what work has been done and that ensures that key stakeholders are on board…" (Stakeholder in the UEIP during an internal research meeting, 2017)

Other objectives included transparency with cross-sectorial organisations such as the CMF and local community groups as well as within the UEIP itself through the creation of awareness of issues. In addition to these objectives, the UEIP was also found to be dedicated to preventing the duplication of efforts and projects within the uMngeni catchments, all of which often geared towards virtual platforms that house records of projects done and achieved by stakeholders. These objectives, goals and efforts that came out in conversation with members of the UEIP were indicative of the desire for stakeholders to use innovative information communication technologies in the management of information and in fostering learning.

Moving beyond notifying stakeholders of the overall water quality parameter readings such as E.coli in various points in the catchment, conversations within multi-stakeholder meetings started to include the development of information systems to document the monitoring of the sources of water pollution such was non-point source land pollution and malfunctioning or damaged sewer pipes. Overall, conversations within the MCMF showed that the interest was specifically centred on collecting data to monitor the water resources in the upper uMngeni catchment in virtual platforms that also showed the landscape and the hydrology that will most likely be affected by the pollution at various spots in the catchment. This development in the use of information systems emerged during the same time that the researcher presented her ideas on information systems to support multi-stakeholder engagement during these meetings.

Example 2: ICTs and the inclusion of the civil society for engagement

In light of the increased levels of E.coli concentrations in the uMsunduzi River and other water quality related issues in the upper uMngeni catchment, the uMsunduzi Restoration Project sought to repair damaged sewers and sewer lines and to monitor faults. ICT systems were considered not only in motivating for repairs by the governmental authorities (ie. Municipality) but to create continual monitoring of 'hot spots' and an awareness to all stakeholders who carry a stake in the health of the upper uMngeni catchment. This was the case for most water related issues discussed in the MCMF platform of stakeholder communication in the year 2016-2018. The vision for a more sophisticated ICT or virtual platform to monitor sewers became a topic of discussion in conversations with the researcher and other stakeholders during the year quarterly meetings. The desire to create sustained awareness of water resources from the grassroots level of monitoring on their catchment became prevalent.

The CMF as an engagement group in the development of the uMsunduzi Restoration project seemed to initially face the challenge of balancing the involvement of relevant stakeholders in the project and figuring out how those stakeholders can be organised to support the project and

persuaded into supporting the various project initiatives[55]. As a completely voluntary group of stakeholders, much like all CMF's, the challenges of the MCMF were also expressed to exists in the lager catchment management group; the UEIP. This was not the case for the smaller, LCPG in the Mpophomeni area where the smaller group with already established relationships was able to navigate through managing information created in the project fairly easily due to frequent meetings and the use of computer based information management technologies such as Google Fusion Tables which is an application on Google labs that integrates, collaborates and visualizes data online after it was edited using platforms such as Microsoft Excel. [56].

Stakeholders in the uMngeni catchment are open to moving towards supporting learning, collaboration and engagement using ICTs as virtual spaces of stakeholder engagement. In the UEIP, the development of integrated ICTs is favoured for organising project information for multiple stakeholders, in the MCMF it is favoured for integrated biophysical information of the sources of water pollution as well as the information gathered from the local communities. In the case of the LCPG, conversation surrounding the application of ICTs has been centred on the innovative use of technologies to share monitoring data obtained by the civil society concerning the local water resources. In all cases, the innovative use of technologies is considered important in supporting the relational practices occurring in each multi-stakeholder engagement group and across these groups.

The next sub-heading dissects the above described relational practices in the uMngeni catchment with regard to the potential for leading towards sustainable social learning. The next Section will also make definitive statements on how the above multi-stakeholder processes are currently meeting social learning requirements.

4.3 Assessment of social learning in multi-stakeholder processes

[55] Section 4.1.2, Example presents the findings in relation to this particular observation.

[56] Further details on how these developments influence the potential for stakeholders at the LCPG to undergo social learning is presented in Chapter 5.

Following the previous Section on multi-stakeholder processes, this Section evaluates the degree to which the requirements for social learning were met or were affected. The thought process exercised here is that of increasing or deeper learning of the researcher in line with the Theory U of learning by Scharmer (2009). The researcher grades multi-stakeholder processing observed in the catchment. Focus is placed on how the different processes speak to social learning requirements as noted from literature. These requirements are then more finely graded in relation to how they speak to social learning constructs that were reviewed in Chapter 2. As the researcher goes through her own deep learning from the findings, linkages between social learning are further strengthened by responses from semi-structured interviews on the state of social learning in the uMngeni catchment. This is finally used to make definitive statements on what was previously perceived as barriers and incentives to social learning. Figure 4.2 below shows the deep learning about social processes followed by the researcher.

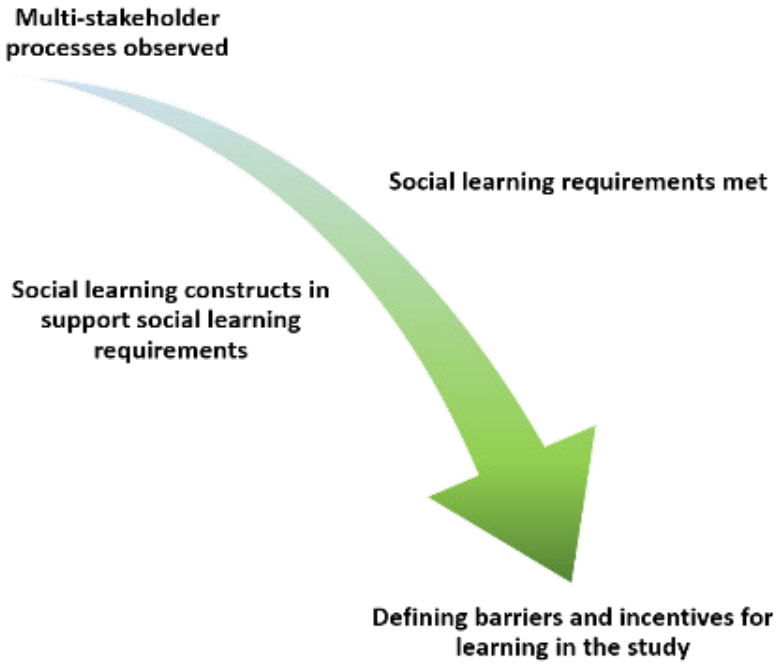

Figure 4.2 Thought process of evaluating the findings in relation to the processes of stakeholder engagement to the defining of social learning barriers and incentives.

4.3.1 Analysis of social learning requirements

From the processes observed in the uMngeni catchment that are presented in the previous section, it was found that the ability to communicate between multiple stakeholders and engage in processes of accessing, generating and using information to approach wicked water problems forms the overarching factor in multi-stakeholder engagement processes. Moving towards social learning with this is confirmed by similar findings from literature for multi-stakeholder engagement processes (Dana and Nelson 2012; Romm, Pliskin, and Clarke 1997; Pahl-Wostl 2007; Tippett et al. 2005). The communication referred to here can be communication between stakeholders *within* a multi-stakeholder group and *between/ across* multi-stakeholder groups (i.e MCMF, UEIP and the LCPGs) using various methods and technological tools. Furthermore, when compared to the descriptions for meeting continuous social learning requirements or qualities that build *capacity* by Pahl-Wostl and Hare (2004) it was found that all three group types investigated in the uMngeni catchment (ie. LCPG, MCMF and the UEIP) did not seem to be engaged fully in processes that lead to social learning. Consequently, it is necessary to be clear on the requirements for social learning regarding the communication between stakeholders in each multi-stakeholder group (ie. UEIP, MCMF and the LCPG) that now apply to the findings. There are five requirements for social learning met in different degrees found in this study that are used to make sense of the observations done by the researcher in her reflective learning process of the analysis:[57]

- Mutual awareness of each other's goals and perspectives
- Realization and understanding of stakeholder interdependency
- Building of trust and relationships between actors
- A shared role definition and fact defining
- A combined planning and implementation (ie. of projects towards dealing with wicked water related problems).

[57] For a detailed description of social learning requirements, refer to Chapter 2 Section 2.4 of this thesis.

A closer inspection shows that the requirements for social learning in the spaces investigated in the uMngeni catchment varied in degrees of strength across the groups and that the findings of the degrees to which social learning differs between all the multi-stakeholder engagement scales investigated is enough to distinguish social learning as an overall outcome between all of them when they are compared. As a disclaimer, it does not negate the fact that there are similar processes of engagement happening across stakeholder groups. What was analysed more closely were the observations that were most common during the time of the research.

The strength of application of the requirement of social learning in the different scales of stakeholder engagement is displayed in Table 4.1. The strength of the requirement as reflected in the processes of stakeholder engagement reveals the degree of connection made; both directly and indirectly to communication. The researcher considered the actions and circumstances in which multi-stakeholder group processes take place in the uMngeni catchment during the time that the research was conducted. For this reason, the figures given to the scores of social learning capacity or requirements measure these aspects in the groups as being related. The findings here are a result of the researcher attempting to measure attitudes and other aspects of stakeholder processes for such qualitative research on groups (Kearns, 2005) that are related to social learning which is described later on in section 4.3.2. In both instances, the findings on the attitudes that affect social learning are subjective and qualitative in nature with scores assigned in an effort to compare the multi-stakeholder groups. Five (5) means a strong connection with the requirement for social learning and one (1) being the weakest connection with the requirement of social learning in the multi-stakeholder engagement groups. The detailed meaning of the numbers from 1 to 5 and the scoring system adopted in the analysis are given as keys at the bottom Table 4.1. The above five requirements of social learning helped analyse the general communication and engagement processes between stakeholders, especially relating to the accessing, generating and use of information (Ward, 2016).

Table 4.1 Varying strengths of observed application of five social learning requirements

Social Learning Requirements	UEIP	MCMF	LCPG
Mutual awareness of each other's goals and perspectives	4	3	5
Realization and understanding of stakeholder interdependency	3	4	5
Building of trust and relationships between actors	3	2	5
A shared role definition and fact defining	4	3	5
A combined planning and implementation (ie. of projects towards dealing with wicked water related problems).	3	4	5
1 = Weakest connection to social learning where stakeholders are unaware and seem to not see the value of the condition of engagement it in the context of being a requirement of social learning- whether it is applied or not			
2= Stakeholders seem slightly familiar with the value of having this requirement met but show no indication of applying it or knowledge of it being applied in the multi-stakeholder group or know how it has been applied in the uMngeni catchment as a whole.			
3= Stakeholders see the value of having the requirement met and indicate in some way that the application of the requirement in the multi-stakeholder group would assist the process of social learning.			
4 = Stakeholders are very familiar with the requirement and believe strongly in its value and have been involved or know cases in which it has been met or not met to manifest social learning (eg. tackling problems).			
5= Strongest connection to social learning where stakeholders are very familiar with the requirement and believe strongly in its value in the uMngeni catchment. They may have also mentioned an example where it has been present or absent in as a valuable component in social learning (ie. tackling problems) within the multi-stakeholder group itself. The respondent further advocates for the nurturing of conditions in the group that will support meeting the requirement for social learning.			

Requirements (5=strong connection with requirement 1= weak connection with requirement)

The degrees of the strength of connection based on what was observed in the different multi-stakeholder groups is shown visually using Figure 4.3. From an initial examination of Figure 4.3 below, it can be deduced that the multi-stakeholder group scale that showed the deepest connection to social learning was in fact the group with the fewest number of stakeholders; the LCPG. While the multi-stakeholder group with the lowest potential for social learning was the group with the largest number of stakeholders spread across the entire uMngeni, that is the UEIP.

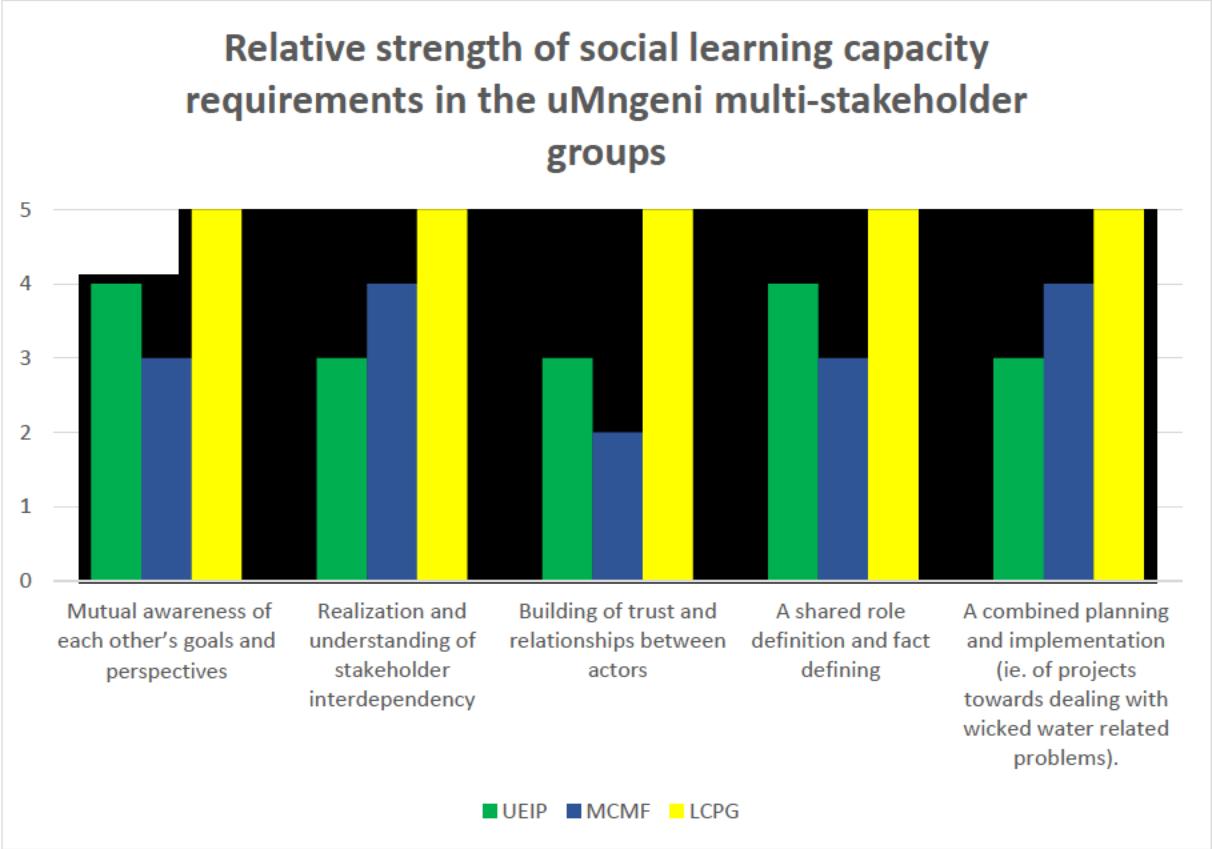

Figure 4.3 Strengths of reaching social learning requirements in the current spaces of stakeholder engagement in the uMngeni catchment.

In the next subsection, the first requirement for social learning is analysed further to match the relational processes undergone in this research.

4.3.1.1 Evaluation of mutual awareness of each other's roles and perspectives

There is reason to believe that the above findings of relational practices when it comes to social involvement as multi-stakeholder engagement processes in the catchment supported mutual awareness of the stakeholder's roles and perspectives at different degrees. When observed, all three of the multi-stakeholder groups investigated in the context of the uMngeni catchment did not have

a score below 3 for this requirement of social learning. This shows that the way the stakeholders engaged and the impression gained from their communication with one another was indicative of their knowledge of the value of the requirement, particularly in supporting learning processes. The LCPG showed the strongest connection with this requirement, evident in the manner to which stakeholders engaged, while the MCMF showed the weakest connection to this requirement of social learning. A sub-table based on the original table for all of their requirements; Table 4.2 is used in the discussion of the findings below.

Table 4.2 Mutual awareness of each other's roles and perspectives as a key requirement for social learning in the uMngeni catchment.

Social Learning Requirement	UEIP	MCMF	LCPG
Mutual awareness of each other's goals and perspectives	4	3	5

Requirements (5=strong connection with requirement 1= weak connection with requirement)

Through meetings, stakeholders became aware of the projects that other stakeholders within the group arrangement were involved in. However, in this research, this awareness was also dependent on the opportunities awarded to share perspectives during the meetings as well as between meetings. There is a direct correlation between the number of times stakeholders meet and the development of mutual awareness and perspectives between them (Pahl-Wostl & Hare, 2004; (Dyball et al., 2009). There is also a direct relationship between the number of strategic social involvement processes a multi-stakeholder group is involved in and meeting the requirement of mutual awareness of each other's goals and perspectives and perceptions where there is a stronger likelihood that the perceptions of problems will be viewed as a community (Anderson et al., 2007).. This supports the findings of this research regarding the frequency of engagement of stakeholders and the strength of their awareness with each other's goals and perspectives for the catchment and the problem they are trying to tackle. The LCPG has the highest level of this social learning requirement (a score of 5) due to having both of these relationships in multi-stakeholder processes, while the MCMF has the lowest potential for social learning (a score of 3) with regard to meeting mutual awareness and perspectives, not only due to the infrequency of engagements, but also

because of the lack of the group's ability to view problems in the catchment as community of practice issue where stakeholders work collaboratively to address the issues in the catchment (Anderson et al., 2007). Thus, both frequency of meetings and the content of the meetings and the level of collaboration that occurs affect mutual awareness. The social involvement processes discussed on creating networks and cross-sectional awareness presented in example 2, section 4.2.2 give another reason why this observation was made. The methods of providing long lasting and impactful awareness in the MCMF were limited to quarterly meeting presentations. Stakeholders really collaborated on providing insight and awareness on the same issue in a catchment – additionally the lack of a =n information repository to present information collected from all stakeholders so that they can increase their mutual awareness of each other's perspectives was not present. The stakeholders realized the importance of the requirement for social learning but the multi-stakeholder processes did not allow that to be fully explored as it was for the LCPG and the UEIP.

While the *UEIP* met the least frequently when compared to the other stakeholder groups, it was less impacted by this infrequency when it comes to mutual awareness of each other's perspectives. This can be deduced to be due to the specific efforts that were made to know what research or projects each member and organisation in the partnership was involved in. The research meetings described in Section 4.2 were effective in guiding stakeholders an opportunity to know what others are doing in the catchment. Additionally, the greater number of collaborative research and implementation projects of the UEIP enhanced the awareness between stakeholders. Having common aims and objectives on a particular part of a catchment being researched allowed the stakeholders to have open dialog on expectations of each organisation's contributions, goals and perspectives. However, according to literature, the current methods of stakeholder processes can still fall short of truly meeting this requirement of social learning. As previously reviewed in Chapter 2, to increase mutual awareness of perspectives such as the water security problem, social, political and economic awareness needs to become the product of collaborative water governance (UEIP Collaboration meeting, 2016). While there are findings to support the notion that awareness is being raised with regard to healthy ecological infrastructure, there is fundamental lack of mutual awareness of stakeholder's own perspectives goals and contributions to the health of ecological infrastructure in the UEIP. The lack of a system to support continual conversation on issues that

could very well be wicked problems such as water security beyond the biannual meetings and how collaborative projects are succeeding or undergoing challenges to attending to these issues is the reason why the requirement of social learning is threatened. It is also threatened by the fact that even the perspectives of some stakeholders within the UEIP may not be accepted on the basis of them being different from the common or popular view of solving water related issues (Collaborative meeting, 2015) This is also fundamentally important since it has closely been linked to stakeholder interdependency (Dyball, Brown, and Keen 2009).

The MCMF's lower than average score may be attributed to the lack of a mandate that encourages other stakeholders to participate in the year quarterly meetings. Furthermore, the lack of frequent communication between these meetings and the lack of participation of relevant stakeholder such as the business and industry sector mentioned in 4.2.2, example 3, lowers the mutual awareness of stakeholders.

The frequent weekly engagement of the LCPG discussed in Section 4.2.1 (example 3) gives it the highest score of mutual awareness of stakeholder goals and perspectives (score of 5). Stakeholders use the time to discuss challenges faced in educating communities and monitoring water pollution in the catchment, they increase their awareness. The varying challenges, raised freely during these frequent local meetings within their own communities showed the stakeholders varying views and perspectives and how they have mental mapped the catchment and possible solutions to water problems; mainly water quality. This is consistent with Pahl-Wostl and Hare (2004) views on actors mental modelling of the catchment where they can share their views and perspectives with the group. Networking and cross-sectional awareness as social involvement processes provided opportunities for stakeholders with many stakeholders such as the UEIP and the MCMF to develop mutual awareness of each stakeholder's goals and perspectives as a requirement for social learning. However, as it is going to be seen, this requirement for social earning does not exist alone in the case of the uMngeni catchment. It is also related to how the relational practices in the current spaces of multi-stakeholder engagement support social learning as a requirement.

4.3.1.2 Realization and understanding of stakeholder interdependency

With regard to the realization and understanding of stakeholder interdependency as a requirement of social learning, it was found that, despite the size of a group and the large area that it overseers, the multi-stakeholder group can still have an average connection with meeting the requirement for social learning. Despite the smaller size of the LCPG, on the surface level, it was found that the relational practices during the time of the research show that the groups have the highest connection with meeting this social learning requirement when compared to the UEIP and the MCMF. These results are tabulated in the extracted sub table below.

Table 4.3 Realization and understanding of stakeholder interdependency as a key requirement for social learning in the uMngeni catchment.

Social Learning Requirement	UEIP	MCMF	LCPG
Realization and understanding of stakeholder interdependency	3	4	5

Requirements (5=strong connection with requirement 1= weak connection with requirement)

A closer look at the methods and processes in which stakeholder engaged and the diversity of engaging stakeholders as described in Section 4.2.2 reveals that there was a significant difference in the way stakeholders viewed each other's roles and importance owing to the difference in their realization and understanding of stakeholder's interdependency.

As a result of the significant exclusion of local knowledge or citizen science knowledge and collaborative relationships with local actors, the UEIP showed to least meet the requirement above, showing a lower realization of their interdependency than other two multi-stakeholder groups, and scoring a 3. This is supported by what was said during a stakeholder meeting with some stakeholders of the UEIP in order to share some information on research occurring in the catchment.

"Workshops help us update information on who is involved and who needs to be involved. We need to develop a local understanding on who is doing what, where, how and with who and populate it. There is a lack of local stakeholder input from citizens and local government." (pers comm Cox, Institute of Natural Resources NPC, 3 February, 2016)

Stakeholders in the UEIP as seen in the processes of engagement described in Section 4.2.2, realized the importance of expert knowledge and partnerships, but could not see how local knowledge and expertise could be incorporated to create meaningful knowledge of the catchment other than the top down approach by the experts of the UEIP with the civil society (Section 4.2.1, example 1 and Section 4.2.2, Example 1). As seen in these sections, while members of the UEIP understood the importance of engaging with one another at the expert level, they did not sufficiently use their networks to incite momentum in approaching persisting wicked water related problems using local communities as drivers. The inclusion of expert knowledge however was present ranging from collaborative projects in selected regions of the uMngeni catchment, international stakeholder engagement, research meetings and coordination meetings held twice a year and workshops. Such efforts often excluded inputs from local contributors into the collective partnership space. Local contributors were only included during short term implementation projects where information flows mainly from the experts, and rarely from the local contributors to experts- adopting vertical approach which is important in mobilizing lasting change (Ward, 2016).

Below, is a picture taken from one of the workshops held at Institute of Natural Resources (INR) where expert stakeholders from around the uMngeni catchment and some, part of the UEIP met to engage in a participatory mapping of various projects they were involved in in the catchment. As they wrote up the different projects that they were involved in as organisations working in different parts of the catchment- there was no mention of an existing virtual platform to transfer such information to an open and transparent space beyond it being saved as an image in the information servers of the INR.

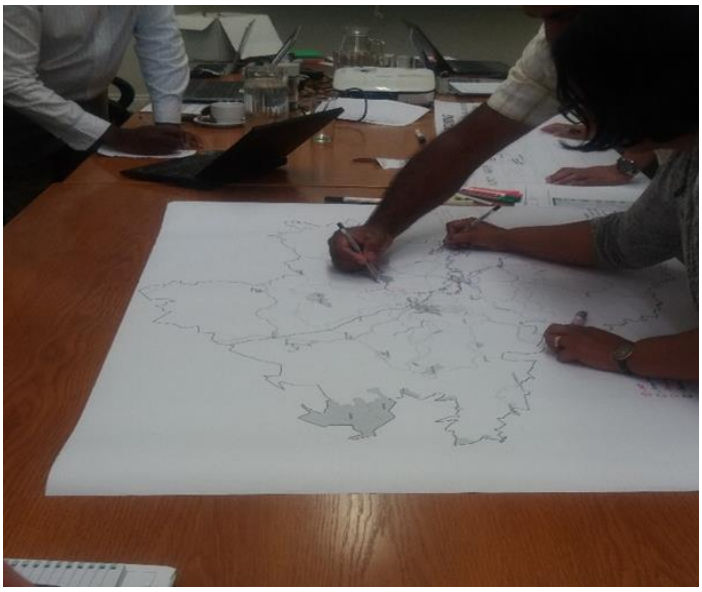

Figure 4.4 Participatory mapping of the uMngeni catchment in a workshop held by some members of the UEIP at INR (picture source: Thembeka Rachel Mhlongo)

The MCMF on the other hand, was able to actively encourage the participation of all of its members even those who did not regularly participate using collaborative projects that were integrated and focused on a common goal as in the case of the Msunduzi Rehabilitation Project. Such a project was not centred on experts as the main knowledge contributors, but lessons were also taken from existing projects at the local community project scale such as those of the Mpophomeni Enviro-champions and their monitoring efforts. This group also did so while encouraging the participation of local community representatives, thus being given a score of 4 which indicated that stakeholders were very familiar with the need to realize and understand their interdependency with local actors as a requirement for social learning in order tackle problems. Had there been more organisation and a more official mandates for all stakeholders to participate at the year quarterly meetings (Section 4.2.2, Example 2) in an effort to pursue more integrated approaches by ensuring all stakeholders are involved, this particular requirement of social learning would be met to a greater degree.

Unlike both of these groups, at the LCPG scale, stakeholders engaging at the community level were guided in their activities by community representatives who were trained taught expert organisations. This was described through the relational practices of social involvement processes

in Section 4.2.3, example 2. Because of model groups such as the Mpophomeni Envi-champions; through local collaborations with NGO's, government organisations who had expert knowledge input as well as lay person input represented by the civil society knowledge, the potential for current social learning is scored a 5.

4.3.1.3 Building of trust and relationships between actors

The connection between building trust and relationships as a construct of social learning between actors in multi-stakeholder groups it was found that there higher potential for this requirement to be met given the relational practices in the LCPG than the UEIP, while stakeholders at the MCMF exhibit the weakest potential for attaining this requirement for social learning. Table 4.4 below; the sub table of Table 4.1 extracts these findings for interpretation and discussion.

Table 4.4 Building trust and relationships between actors is tabulated as a key requirement for social learning in the uMngeni catchment.

Social Learning Requirement	UEIP	MCMF	LCPG
Building of trust and relationships between actors	3	2	5

Requirements (5=strong connection with requirement 1= weak connection with requirement)

The lack of an official documented mandate or memorandum of understanding for the engagement of stakeholders in the MCMF (Section 4.2.2, Example 2) also affected the potential of building trust and strengthening relationships, even though these groups met more frequently than the UEIP. As a result, they scored the lowest in this requirement for social learning, with a score of 2. This still did not mean that there was no social learning occurring at the sub-catchment scale. The findings did however coincide with findings by Pahl-Wostl and Hare (2004) where a lack of clarification or clear consensus on the processes taken towards collaborative projects and inter-actor communication meant that awareness and building trust between the stakeholders could not be improved in order to support social learning (Section 4.2.2, Example 1). Furthermore, clearing doubt about the state of water resources at the sub-catchment scale could not be said to be done adequately since the weekly sharing of E.coli did lead to the sharing of sharing of more biophysical

and hydrological infrastructure feedback. The lack of awareness through the sharing of additional data, from other members of the MCMF besides uMgeni Water and the uMsunduzi Municipality (Section 4.2.2, Example 1); particularly industry showed that the current relationships were not being used adequately to build trust that supports social learning.

With more collaborative projects in the MCMF focused on a common goal like the UEIP that had an overall score of 3, stakeholders in the MCMF can get more opportunities to get out of their own silo's and become more open to what they can contribute in terms of knowledge contributions thus building trust. The average low score of 3 by the UEIP showed that there is room to make use of integrated innovative technologies (section 4.2.3, Example 2) not only to document knowledge and data contributed by expert stakeholders in the UEIP, but also putting additional trust to knowledge contributed by the civil society or stakeholders engaging at the LCPG scale.

Unlike the MCMF and the UEIP, the LCPG scored a highest score of 5 for the highest potential for meeting trust and relationships between stakeholders as a requirement for social learning due to consistent communication, common interest in the issues affecting the health of water resources in streams (Pahl-Wostl and Hare 2004).

4.3.1.4 A shared role definition and fact defining

For stakeholders to share a defined common role and a fact finding process in a project or multi-stakeholder arrangement is a requirement for social learning. However, the connection that the current social involvement processes have with social learning varies from each multi-stakeholder group investigated in this research. It was found that the LCPG has a greater affinity to having a shared role definition and fact finding requirement for social learning being met. However, that cannot be said for the MCMF who had an average connection to this requirement for social learning as a result of the current social involvement processes occurring in the group. Table 4.5; the sub table that follows was extracted from Table 4.1 above and with it, further insight about what the relational practices presented as findings in the previous subsection are discussed.

Table 4.5 Having a shared role definition and fact finding in different groups is tabulated as a key requirement for social learning in the uMngeni catchment.

Social Learning Requirement	UEIP	MCMF	LCPG
A shared role definition and fact defining	4	3	5

Requirements (5=strong connection with requirement 1= weak connection with requirement)

According to Pahl-Wostl and Hare (2004); having a shared role definition comes with brainstorming and understanding clearly what the role of each stakeholder in the multi-stakeholder group is. That includes gaining a common understanding of how organisations can contribute to answering common questions about the issues surrounding water (mainly water saving, protecting water quality, creating coordinated action within the multi-stakeholder arrangement ect.). A *score of 4* by the UEIP shows that social involvement processes characterised by collaborative projects between expert stakeholders of the UEIP were beneficial in supporting social learning, this could also be owed to having mandate or memorandum of understanding as well as having research and coordination meetings. However the same process and top down approach to collaboration did not create a space for the inclusion of civil society or stakeholders at the grassroots level to organically create actionable knowledge that could be adopted in projects. Most stakeholders did not know how to include or integrate the information shared by the civil society in their spaces of engagement (Section 4.2.2, Example 1). Furthermore, meetings held only twice a year and separated into two parts with the approach of updating stakeholders on what stakeholders are doing in their own silo's (Section 4.2.2, Example 1) is also why these stakeholders are not having a shared role definition that is directly connected to solving and at times only improving the effects of wicked water related problems.

On the other hand, an average score of 3 for having a shared role definition and fact finding by the MCMF was an indication that the stakeholder's lack of a mandate does not lead them to achieving their full potential of social learning (Section 4.2.2, example 2). The use of this highly integrated sub-catchment management group as mostly a top shop and the lack of collaborative projects, even if they include previously inactive groups (section 4.2.2, Example 3) may not be enough in having a shared fact finding that supports social learning potential. This is because these processes lack

the fundamental aspect of learning to work together (Pahl-Wostl and Hare 2004b). Stakeholders do not learn how to work together from the grassroots up; settling disputes and prioritizing water resource problems to improve on the situation as a collective. These collaborative actions of a collective of the civil society who produce soft knowledge and expert stakeholders such as scientists, policy makers and industry owners who produce what is known as hard knowledge . The formation of collaborative projects such as the uMsunduzi Restoration project are positive steps that show that stakeholders can work together, however support needs to be given to ensure that such cases of having a shared role and definition and fact finding are supported by the innovative use of ICTs (section 4.2.3, Example 2).

The highest score of 5 for the LCPGs indicates the highest potential for social learning being pursued in this group. These groups of the upper uMngeni catchment have a shared role of being enviro-champions in their own catchments. They also have clear strategy of using citizen science tools in monitoring water pollution and an environmental education plan in their own communities in order to maintain the health of the streams in their catchments. These processes described in Section 4.2.1, example 2 and example 3 show how the training and guidance by expert stakeholders and organisations in multi-stakeholder groups with communities can aid in the fact finding process and allow all stakeholders at the LCPG to be on the same page. Furthermore, since these stakeholders met most frequently to discuss water issues compared to the UEIP and MCMF, the interactions that bring about clear understanding of water quality being the biggest wicked problem were strengthened, this supports findings in research about wicked water related problem, social learning and having a shared role in fact finding about problems (Thornton et al. 2013; Pahl-Wostl and Hare 2004; Ison et al. 2011).

4.3.1.5 Combined planning and implementation

When observed through the lens of social learning, the current methods of social involvement practices in the uMngeni catchment are indicative, and to a certain degree that having combined planning and implementation for a certain period of time in group, connects the group between to opportunities of undergoing social learning. However, within the uMngeni catchment, because of the arrangement of the groups, the activities they are involved in as a collective and the time that

they engage with one another to focus on these activities within the catchment, affects whether or not this requirement for social learning is met. Once again, there is a visible difference in whether the processes that stakeholders undergo lead to social learning as an outcome based on the relational practices in it. The sub table below is an extract from Table 4.1 and provides specific focus on combined planning and implementation in the different scales of social learning within the uMngeni catchment.

Table 4.6 Combined approach to planning and implementation as a social learning requirement shown at different degrees of connection in each scale of multi-stakeholder engagement in the uMngeni catchment.

Social Learning Requirement	UEIP	MCMF	LCPG-
A combined planning and implementation (ie. of projects towards dealing with wicked water related problems).	3	4	5

Requirements (5=strong connection with requirement 1= weak connection with requirement)

For stakeholders in the uMngeni catchment, there are different results for combined planning and implementation that is a requirement for social learning. This can be traced back to combined decision making efforts in the different multi-stakeholder arrangements groups. Planning and implementation trends were highest at the LCPG scale where stakeholders displayed the ability to share a decision and motivate implementation through the help of expert organisations at the LCPG than the MCMF and UEIP. At the largest multi-stakeholder group, this combined implementation was the lowest due to the limited time for engagement of the stakeholders and a lack of appreciation on the complexity of wicked problems and the inclusion of organically created knowledge about water resources contributed by the civil society as part of expert knowledge. The MCMF falls short to displaying the highest potential for meeting this social learning requirement due to a lack of collaboration by stakeholders in the group as well as the lack of effective steps taken to utilizing innovative technologies to integrate and share information more frequently and effectively with organisations who form part of the forum group.

Collaborative projects with community representatives and expert stakeholders from reputable organisations provided an opportunity for stakeholder to make decisions based on what they knew to be right as a collective, particularly when decisions are made on behalf of implementing an action such as ending manhole discharges in a local community (section 4.2.1, Example 3). The LCPG was most successful with a score of 5 due to unified monitoring efforts and clear consensus with single area focus- such was the example of the LCPG such as the Mphophomeni Enviro-champions. The successful implementation efforts of stakeholders at this small group has been well documented by actors such as Ward (2016)

The lack of meetings for the successful engagement of local communities in attending to wicked problems led the MCMF to having a score of 4. Even though there was an awareness for the importance of including the LCPGs in implementing monitoring efforts at the grassroots level, these efforts did not manifest to their full potential. The least to be able to do implement to improve the state of water quality problems was through multi-stakeholder interaction processes was the UEIP with a score of 3.

The above findings can be elaborated by understanding that the awareness of stakeholders 'sometimes different goals and perspectives' (Pahl-Wostl and Hare 2004, 195) was fundamental to the observed outcome of networking and cross sectional awareness. Networking and awareness was found to be generally increased with the increase in the size of the group; thus being the greatest for the UEIP than its smaller multi-stakeholder arrangement counterparts- the MCMF and the LCPGs, particularly the MEC[58]. However, due to limited communication between stakeholders in the UEIP, this networking ability is crippled and so too was mutual awareness of each stakeholder's goals and perspectives. While the UEIP arrangement of consecutive research meetings and coordination meetings were created to overcome the challenge of communication and networking gaps, the meeting of stakeholders only twice a year was only a contributing factor to the limitation of free communication, this is despite the fact that e-mail communication was enabled throughout this time to connect stakeholders. On the other hand; the smallest group, the

[58] Stands for Mpophomeni Enviro-champions.

LCPG scale (ie. particularly the MEC which is mentioned various times in section 4.2) was found to have had the greatest advantage of being able to communicate more readily and frequently due to their meetings twice a week. This small group also had the opportunity to collaborate with likeminded potential funders and NGO's such as Ground Truth, DUCT and WESSA.

Some of the stakeholders in the LCPG were part of the larger multi-stakeholder arrangements and thus lead to the conclusion that the LCPG used greater opportunities for cross-sectional awareness and networking. The groups investigated in the various scales of engagement involved belonged to various types of organisations including the public sector, non-government organisations and community activist groups (Mostert et al. 2007). The community activist groups which made part of the LCPG investigated in this research were characterised by those who had similar interests to the larger multi-stakeholder groups; interests in the environment such as ecology, water quality. Furthermore, the participation of the business and industry sector in all the scales of multi-stakeholder engagement was limited, stakeholders like those of the MCMF particularly expressed that this lack of engagement may be attributed to the stakeholders not being aware of the relevance of the process of engagement in water problems in their shared catchment. However, through combined projects such as in the case of the MCMF's uMsunduzi Rehabilitation Project, the involvement of the business sector in particular was realised when the group submitted a proposal of the project for funding.

While the three different scales investigated for social learning were already formed and active participation initiatives with ongoing processes of stakeholder engagement, there were observed commonalities in the processes significant to social learning. For instance, it was realised that voluntarily forum groups such as the UEIP who have a signed memorandum of understanding participated in the groups as representatives of their organisations, however this signed memorandum of understanding did not guarantee the participation of all stakeholders. All interviewed stakeholders of larger catchment engagement (UEIP) and sub catchment engagement (MCMF) admitted that participation in the multi-stakeholder arrangement helped them gain access to knowledge provided by other specialists and for them to come to an understanding of the issues that surround and affect their catchments and what other organisations are involved or not involved in attending to those issues.

When it comes to building trust and relationships at all scales of engagement the process of building trust and relationships was found to be both a process, a relational outcome, a requirement for building social learning capacity and a direct construct for social learning. This sub-section however, presents the applicability of building trust and relationships as a process achieved at various degrees by the stakeholders involved.

In the case of shared problem identification and fact finding- There is a general agreement amongst the stakeholders in various scales of engagement that water quality decline is the major challenge within the catchment. Various stakeholders revealed concerns on the interconnectivity of water quality decline with socio and economic issues. It is for this reason that water quality decline is presented in these findings as the major wicked problem and a problem discussed frequently in engagement spaces. The views of these stakeholders were raised within the processes that were undertook during their engagement. For instance, a common problem defined by the UEIP in the 2016 Learning Exchange Program was waste accumulation in peri-urban locations in the uMngeni catchment. This was raised by the Water Research Commission (WRC) and agreed upon by various stakeholders present within the UEIP on the 15th of November 2016 when the learning exchange program between the uMzimkhulu Catchment Management Partnership Programme (UCPP) took place.

The apparent wicked problem identified as waste in and around streams was concluded by the WRC to be an issue that could be approached by good governance- not pollicised but guided by a focus on people through initiatives *of citizen science*. Furthermore, the group made good use of a causal loop diagram to show the interconnectivity of the outcomes of human activities on water. This combined definition of a problem and identification of possible solutions through citizen science in encouraging governance was an important observation of the combined fact finding process within the uMngeni catchment by the UEIP and a movement towards social learning by a change in behaviour of communities of practice. The statement below clearly shows this connectivity made during the meetings conducted by the UEIP.

"Governance starts and ends with people."

(*pers comm* Madikizela, Water Research Commission, 15 November 2016).

In relation to the details of the applicability of the above summarised requirements in relation to the social constructs that build them, the following subheading will evaluate the findings with regard to social learning and how the above mentioned social involvement findings are also connected to the perceived observed outcomes of social learning. The next subsection will also discuss how simply meeting the requirements of social learning based on surface level relational practices can be finer graded by looking in to the opportunities for investing in social learning in a multi-stakeholder group based on the true nature of the social learning constructs at play in the uMngeni catchment.

The apparent meeting of social learning requirements or capacity, further led to the analysis of whether these requirements could be traced to the manifestation of social learning constructs being met in the longer term.

4.3.2 Analysis by constructs for social learning

This section discusses the linkage that exist between social learning requirements which are a product of social learning involvement happening in the uMngeni catchment and the key social construct at pay within the different scales of multi-stakeholder engagement. Even though there were about 17 constructs found to be at play from participatory observational research as well as the stakeholder semi-structures interviews conducted. Only five were found to be most connected with all of the above requirements of social learning (section 4.2.1) and will be used to lead this discussion. The remaining constructs are used to support the discussion on these observations. To put the discussion to follow in context, the information is tabulated in Table 4.7 to show the different expressions of social learning constructs in the different multi-stakeholder engagement group scales investigated in this research.

With regard to the *social learning constructs*, the key interpretation of the degree to which it is expressed in each scale of multi-stakeholder engagement is as follows:
5= strong connection with the social learning construct, 1= weak connection with the social learning construct. There are five main requirements considered in this research to represent social learning in the context of multi-stakeholder engagement processes of the uMngeni catchment and

those which literature mentions as being rooted in increasing the capacity for social learning to occur (Pahl-Wostl & Hare, 2004). These have already been discussed in section 4.3.1 and they will be marked as being connected to each social learning construct in Table 4.7. To reiterate what the relevant requirements for social learning are, here is an explicit breakdown of them using the keys that are shown in Table 4.7:

Requirement 1 – The evaluation of mutual awareness of each stakeholder's roles and perspectives

Requirement 2- The realization and understanding of stakeholder interdependency

Requirement 3- Building of trust and relationships between actors

Requirement 4- A shared role definition and fact finding

Requirement 5- Combined planning and implementation

Table 4.7 A tabulated list of constructs of social learning and scores of their perceived appearance in different scales of multi-stakeholder engagement.

ID	**Social learning Constructs**	**UEIP**	**MCMF**	**LCPG**	**Social learning requirements**
1	Transparency and inclusiveness	2	2	4	1 and 2
2	Trust and relationship building	2	2	4	3
3	collective action spaces	2	2	4	5
4	meaningful participation	2	2	4	2
5	stigmergic processes	2	2	4	2 and 5
6	post-normal science	1	1	3	1,4 and 5
7	citizen science and citizen agency	1	3	5	1,4 and 5
8	appreciative inquiry	2	2	4	1, 2 and 4
9	self-identity change	1	2	5	1,4 and 5
10	transcendence of intellectual barriers	2	2	5	1,4 and 5
11	Mental models	2	3	5	1, 2, 3, 4 and 5
12	whole systems institutional virtual spaces (virtual networks)	1	1	3	2, 3 and 5
13	transactional costs	2	3	4	5
14	energy flows and tempo	1	2	4	5, 1,2, 3,4

15	socially robust knowledge	2	2	4	5
16	Participatory Agent-Based Social Simulation Modelling (PABSSM)	1	1	2	2,3,5
17	practice architectures and safe places to experiment	1	1	3	2,3,5

As the researcher dug deeper through learning, it was discovered that the identified requirements for social learning, can be traced to the many constructs for social learning that have been documented in literature. For the uMngeni catchment, these social learning constructs show a deeper relationship between social learning involvement processes and the requirements for learning. This relationship is deepened from the knowledge that was acquired from semi-structured interviews as the awareness of the true state of social learning in the different scale multi-stakeholder engagement increases and the association with information systems is deepened. The relationship between these constructs and attributes of social learning can be can be summarized by the table above. The order of ideas followed in this Section is a discussion based on the most prominent construct when analysed from each requirements for social learning. As a result, this particular construct becomes the main heading in the subsection, and other constructs are described in relation to it and each other.

4.3.2.1 Appreciative inquiry

Through the researcher's engagement in the various positional roles during this research it was noted on many occasions that the form of inquiry that was most prevalent at the LCPG level was appreciative inquiry. During this same time in the positional roles of the researcher it was noted that inquiry in the MCMF level was only occasionally appreciative in nature and at the UEIP level even less so. This was found to most likely be due to other relational practices for social involvement within the UEIP and MCMF such as the lack of sufficient engagement between meetings, the engagement of stakeholders within their own silos and the lack of official mandates for stakeholder engagement.

While each stakeholder within the UEIP and MCMF is has their own commitments outside of the multi-stakeholder meetings; when stakeholders do meet it is usually to report on what each stakeholder is doing and there is not enough time during meetings and during the breaks to inquire what each organisation is doing and how they are approaching wicked problems. Statements such as the one below from the MCMF show that the inability to meet sufficiently had, in the eyes of the stakeholders become a barrier (or inhibiters) to engaging in a meaningful way by sharing information pertaining to the catchment.

> *"we haven't been able to meet in an unthreatening space or set-up to allow people to voice out their particular concerns and issues…I don't think that language is necessarily a problem,…, it's a barrier we can get over. The problem is rather finding the time and space for volunteers to meet."*
>
> -Participant in Pietermaritzburg MCMF, 5 June 2017

Thoughts on how a lack of engagement and domineering attitudes could be overcome between stakeholders was constantly associated with other constructs during the research from semi-structured interviews such as appreciative inquiry, self-identity change, transparency and the transcendence of intellectual barriers. This was the case for the UEIP as well who also agreed that there is not enough time available for engagement.

> *"I think that's a common issue with any kind of engagement forum or process, there are people who talk more and talk louder and I don't think the time provided for in the UEIP meetings necessary allows for some of the other people."*
>
> - Participant in Pietermaritzburg, UEIP, 11 June 2017

Thoughts on how stakeholders could transcend intellectual barriers, be more engaged in appreciative inquiry and strengthen their relationships beyond face to face meetings surfaced. This renders the second major construct of social learning in the uMngeni catchment important for not only supporting mutual awareness of each stakeholder's role sand perspectives, but also, how this

can be used to help stakeholders understand more their stakeholder interdependency. This is discussed further using transparency and inclusiveness as the leading construct in the next sub-section.

4.3.2.2 Transparency and inclusiveness

The findings related to creating and sustaining relationships in Section 4.1 showed how stakeholders in a quest to solve some of the problems associated with water, forming and strengthening relationships could easily become a challenge due to the necessities of trust, transparency and openness not being met to certain degrees. This was found to be particularly true for a forum group such as the MCMF where there are no legal or formal obligations for the engagement of important stakeholders in the Upper uMngeni catchment.

The multi-stakeholder processes show that there was only an average level of transparency and inclusiveness of stakeholders and information both in the UEIP and the MCMF (scale=3, in Table 4.7). The Statement made by a stakeholders in the MCMF who has a leadership role shows that stakeholders in the MCMF understand the need to nurture trust and relationships and actually opens up the practicing of other constructs of social earning such as appreciative inquiry- where stakeholders find it easier to ask each other any information that they may not understand.

"I think the minute we trust each other's information and the minute we are able to believe that the other person is giving us the true information then it makes it much easier to go forward. It does make it easier to discuss because you are no longer distracted saying that 'we don't believe that, you do not have the correct information' "

– Participant in Pietermaritzburg MCMF, 20 July 2017

In the LCPG, mainly the Mpophomeni Enviro-champions through initiatives such as the EPWP described above in Section 4.2, previously excluded civil society can be included in the engagement with fellow lay persons as well as experts trained to work with communities. As a

result of this inclusion, transparency of information became prevalent for environmental education and monitoring efforts carried out at the community level due to the strengthening of relationships between experts (representative members of DUCT, WESSA and at times GroundTruth) and lay persons (community members and enviro-champions). Thus, a strong correlation between an increase in mutual awareness of each other's goals and perspectives as well as the realization of each other's interdependencies as requirements of social learning increased. This may be why the connection between transparency and inclusiveness and social learning between stakeholders in the LCPG was strongest (scale = 5) when compared to the UEIP and the MCMF.

"So government officials whose main job is to serve society and not try and hold onto their jobs, […] as they begin to serve society, society begins to respect them. Trust can only come from shared action and practice. It cannot come from anywhere else, I can't buy you a cup of coffee and then suddenly you trust me, but if you and I have done something together, [maybe] we have gone to a stream and studied it together and we respected each other though that study trust will grow. So trust equals shared action and practice"

-Participant in Pietermaritzburg LCPG, 6 July 2017

The above quote highlights how important it is to build trust and relationships within the LCPG scales, especially when it comes to these stakeholders being included with expert stakeholders in monitoring water quality or other citizen science activity. As common interests are revealed in multi-stakeholder relationships through openness and transparency of information, adequate trust between individuals and organisations develops. The lack of transparency and inclusiveness as well as the lack of systems in place to support this construct of social learning outside meetings also has an effect on collective intelligence of a multi-stakeholder group. While demonstrating an ability to implement action in response to wicked problems concerning water; the UEIP struggled to be coordinated in action. Transparency and inclusiveness builds trust between actors and can help stakeholder improve on other affected constructs of social learning such as building mental models and better strategizing against persisting wicked problems such as water quality, as was the case for the MCMF. Furthermore, a focus on building stigmergic processes so that a range of actors can add in their pieces of information to the integrated picture, can support transparency,

openness, strengthen relationships in addition to building collective intelligence of an entire multi-stakeholder group. This would ultimately be in favour of building trust and relationships as a requirement for social learning.

4.3.2.3 Trust and relationship building

The formation of trust is crucial to relationship building and vice versa. Apart from the human trust and relationships that were built, particularly at the LCPG level the understanding of biophysical and socio-ecological systems were being built through participation in the wisely managed and appropriate processes at local level, particularly.
Findings from semi-structured interviews helped to understand why this particular construct was important. The interviews also became useful in understanding why strategies by stakeholders at the LCPG level were successful not only in monitoring the effects of wicked water problems such as water quality, but also in why a bottom up approach to social learning through other constructs such as supporting energy creation and tempo maintenance in information sharing was valuable. The response below from a member of a LCPG - the MEC (Mpophomeni Enviro- champions) supports the statement made above about trust and relationship building.

"Being included and working together is really important because different visions could be heard and the projects could proceed because without us, the project cannot be successful. They work in their offices, we are the ones who are really in the communities and can help them get information from us and for them to do their jobs easily."

-Participant in Pietermaritzburg LCPG, 15 September 2017

Trust and relationships are strengthened when information flows more frequently, easily and willingly between stakeholders and when stakeholders practice trust in order to work towards a common goal instead of withholding information or not sharing it more frequently. The results from semi-structured interviews show that stakeholders in the UEIP and MCMF are well aware of multi-stakeholder processes or relational practices that support these two major constructs of social

learning. These results also further help to understand why simply engaging in collaborative projects is not enough in strengthening the connection of the stakeholders have with social learning (section 4.2.1, example 1 and 4.2.2, example 2)[59]. The quote below from a stakeholder in the UEIP shows how trust and relationship building is connected to confidence in information from various actors.

"confidence in information is important… and agreeing that 'this is the situation… not just 'this is the water quality [but] also the implications of that water quality for the social and economic components of that system..."

- Participant in Pietermaritzburg UEIP, 4 July 2017

Trust is built on the agreement on the legitimacy and content of information presented in the engagement space. This confidence in information extends beyond an agreement on the scientific information but also, on the socio-economic factors implied by that information. Relationships are built on trust and trust means confidence and a greater ability to reach a consensus on major issues water related issues and the correct way to approach them. It is clear from this response that stakeholders have to indeed be involved and included in the same information set in order to share opinions, views and suggestions about issues.

4.3.2.4 Citizen science and citizen agency

The developments in citizen science which are discussed throughout this research are simultaneously vehicles for facilitating agency in citizens. Agency is the ability to act and it was notable throughout this research, especially at the level of the LCPG that citizens were developing such ability as they engaged more and more; hence scoring the strongest connection to social learning. These processes created a cycle of improvement in both social learning and the ability to act, thereby further supporting Theory U by Scharmer (2008) which says stakeholders will move

[59] The connection between these relational processes and multi-stakeholder processes as examples was established in section 4.3.1.3 above.

past the point of 'downloading' going deeper into understanding of the system and wicked problems and leading into prescencing, which is a process of going through the entire 'U' of deep learning The capabilities of the layperson to do this is supported by other constructs that were also scored to be strongly connected to social learning such as self-identity change and learning (see Table 4.7 above for the LCPG). Consider the response given below which is also shared by community representatives working as part of the LCPG. A shift in self-identity comes as a result of citizen science, where the layperson sees themselves as somebody who can contribute meaningfully to the space of knowledge, if granted the chance to do so across stakeholder groups.

"There was a project with the UEIP that was successful because … stakeholders with the Environmental Affairs were able to meet up with us and do a cleaning campaign …In terms of citizen science, it's very important and very, very effective because in the end we can learn things and they too can learn about the things they introduce to us, whether the methods used work the way they are supposed to because there are no people that they can test these systems to besides us, the people of the communities."

-Participant in Pietermaritzburg, LCPG, 17 September 2017

The results of social learning in building a positive self-identity change were also echoed in the responses reviewed from semi-structured interviews with the LCPG stakeholders who can be considered as experts in their own organisations, but also learners and teachers when they engage in citizen science activities as part of these groups. Such stakeholders evidently went through a process of social learning as the wicked problem of water pollution and water quality decline was better understood by engaging with communities in citizen science activities.

"People raise issues on pollution but unless you have engaged in citizen activities, you cannot really understand and talk with meaning. …. to learn that nutrient loading or food going to the rivers is the biggest risk to rivers, I thought it was industrial pollution ... So it was only through working in a community of practice of people who taught me these things that I have come to a different understanding."

– Participant in Pietermaritzburg, LCPG, 10 October 2017

The results of citizen science in building citizen agency as a construct, were not strong for the UEIP and the MCMF. Socially robust knowledge supports social involvement of the layperson; that includes information whether scientific or not; since the relational practices in the MCMF and UEIP do not allow the integration of local knowledge more fully into the 'agora' space, this potential for social learning is lowered. Stakeholders in the MCMF and the UEIP are aware of this, even though the integration of local knowledge through citizen science is not fully practiced. The response below was based on citizen science being seen as valuable for information gathering for approaching water problems.

"because of the inadequacies of the various government departments to do the monitoring it's been clear from what's come out of the UEIP that the shortcomings in monitoring is a massive gap in us being able to manage the catchment so it's [citizen science] got a major role to play with we going forward …. And job creation."

– Participant in Pietermaritzburg, UEIP, 10 July 2017

Citizen science activities compensates for some of the short comings of government in monitoring, which is indicative of their inadequacy to manage the catchment. Citizen science according to this response is also valuable in catchment management. It provides jobs and a source of income for those in communities.

The lack of use of citizen science as a method to communicate with experts in a meaningful way, also affects another construct for social learning, for example the transcendence of intellectual barriers and appreciative inquiry towards those who have valuable information, at the LCPG scale. Stakeholders in the UEIP and MCMF may say that they value the inclusion and education of local actors or the civil society, but a lack of inclusivity sends a different message. Using citizen science and the nurturing of citizen agency, by the UEIP and MCMF at the local level would feed into the understanding that these LCPG groups having a shared role definition as 'experts' and a collaborative fact finding processes, which is a direct requirement for social learning.

4.3.2.5 Collective action spaces

Like citizen science and citizen agency development, the practice of developing and nurturing collective action spaces is closely associated with socially robust knowledge and social learning The results of this research showed that while large multi-stakeholder groups such as the UEIP and the MCMF displayed an ability to debate over issues and results that others shared during meetings, such debates were limited by the short time they spent together. While admitting that finding time to engage outside of the quarterly meetings is a challenge, the participants in the MCMF responded that they needed an effort to engage outside the shared space and deal with complexities brought about by multiple perspectives and personalities of dominance.

"It's a challenge, I don't know how we are going to overcome it but we just have to keep on trying."

–Participant in Pietermaritzburg, MCMF, 11 January 2018

Furthermore, examining and requesting more information where appropriate was often disrupted by the long time it took until the next meeting to hold multi-stakeholder discussions over such information (section 4.2.2). To add to this disadvantage, virtual updates outside meetings were limited to emails and rarely led to further discussions and sharing of information to the collective, especially in the case of the UEIP. Some stakeholders even being observed to mention how their engagement in the first place was purely voluntarily due to their intensely busy schedules in their own organisations. A similar occurrence was observed for the MCMF. While stakeholders engaged well in smaller groups for the formulation of a project to improve the state of uMsunduzi River[60], a few times between the major meetings in the year 2016. A lack of frequent communication between these stakeholders and the entire group outside seeing each other face to face decreased potential for building socially robust knowledge. The lack of collective action

[60] The uMsunduzi Rehabilitation Project which consisted of a few none government organizations present in in the forum was described in various areas of Chapter 4

worked against the positive efforts by the UEIP in networking and raising awareness. There were challenges to cross sector awareness as stakeholders were still working in silos and were unwilling to share information that could be useful in approaching wicked problems actively outside the meetings. This was besides the fact that these stakeholders were bound to work together for a certain period of time through a collaborative project and they said that they considered collective action as valuable. The statement from semi-structured interviews supports this observation.

"I really think it [the UEIP] needs to be action orientated, so people can see change happen and can see what is their role is in contribution … for people to be involved they need to see how their involvement is contributing to a specific thing…for the UEIP to expand and bring in all the role players we need to expand away from this water centric focus and understand the concept of what goes to the catchment… for integrated water resource management about taking a water focus approach you should involve everyone"

– Participant in Pietermaritzburg UEIP, 16 August 2017

Meaningful participation and sustainability through collective action is dependent on the ability of stakeholders to measure and see their progress. A space that documents collective action or supports it in the long run is necessary, once again, the importance of using whole system institutional virtual spaces to support social learning, became clearer. This is further supported by looking at the MCMF.

The lack of application of collective action within the MCMF became evident in the poor state of the rivers. MCMF, stakeholders simply could not interact enough outside face to face meetings to impact the quality of the rivers. Stakeholders in the MCMF showed that they could not engage effectively to create socially robust (actionable) knowledge that might improve appalling water quality conditions in the catchments.

This was despite well documented success of LCPGs to organically create information and approach wicked water issues such as water quality decline caused, in large partly sewer discharges. As a result, the transcendence of intellectual barriers is lowest at the UEIP and MCMF (scoring 2), while supported stakeholders at the LCPG become more equipped to transcending

intellectual barriers (scoring 5). In all of these constructs in support of social learning, the development of whole system institutional virtual spaces becomes more and more important but poorly applied and limited to emails for the UEIP and the MCMF (scoring 1), while the LCPG with much potential, also scores an average (3) for whole system institutional virtual spaces.

There is also reason to believe that collective action spaces which are also supported by stigmergic processes and collective intelligence are also hindered by the lack of an official mandate for stakeholders to participate in organising information in a meaningful and communicative way outside face to face meetings. Consider the response made by a stakeholder in MCMF who admitted that the institutional arrangement or the lack there of in the group is not suitable to support real change and that finding time to engage meaningfully during the short space of time during meetings as a collective is a major challenge.

"*The CMF has no formal existence. It's not an organisation with an institution. … people accepted a frame of reference but we have got no dedicated secretariat. The day to day running is all done by volunteers which is fine but it means you look along where you find a space… it's a challenge, I don't know how we are going to overcome it* …"

- Participant in Pietermaritzburg, MCMF1, October 18 2017

The properties for achieving socially robust knowledge are closely related to building institutional memory of information related to wicked problems. It has been documented that social learning in the context of wicked problems has to become an exploration process that is open ended and continuously happening (Paquet 1999). Without stakeholder's continuous engagement and sharing of experiences of how they are implementing in the catchment that they manage, such a process constantly redefining a problem by using socially robust knowledge until a wicked problem is better understood is one of the reasons why groups such as the UEIP have low social learning. Such should be the purpose for various multi-stakeholder initiatives surrounding the management of complex natural resources like water in the uMngeni catchment. If implementation cannot be mobilized at the large catchment management and sub catchment group more urgently (section 4.2.1.5); helping mobilize motivated and available groups at the

grassroots who have proven to be successful at implementing to reduce wicked water issues such as water quality decline (E.g Mpophomeni Enviro-champion) may be a necessary step to be taken. Mobilizing these LCPG with funding and training for long term projects will benefit the catchment as a whole and keep the ‘flame of socially robust knowledge alive (Dent, 2015).

4.4 Barrier and incentives to social learning

The most prominent mechanism for learning as introduced by Ward, (2016) is accessing, generating and using information. Depending on the social relation practice of a multi-stakeholder, stakeholders apply the concept of social learning or work against at it. For this reason, the term ‘barrier’ and ‘incentives for social learn use interchangeably with enablers and inhibitors of social learning.

From the requirements described above and supporting social constructs, the researcher was able to define the barriers and incentives to social learning, as conditions within the multi-stakeholder platforms that enable and or inhibit work that encourages social learning. An understanding of these barriers and incentives of social learning, provides an opportunity to think about how social learning could be improved and how virtual information communication technologies could be applied to overcome the inhibitors and maximize the enablers. In all barriers and incentives factors one can see the value of information: none of the list of factors would happen without regular, clear, relevant, trustworthy, affordable exchanges of information between the parties or stakeholders involved which involves good communication. Social learning enabling factors were determined to include empowered civil society, established networks of communication, increased awareness of wicked water related problems and increased trust and established relationships between stakeholders. On the other hand, inhibiting factors with regard to communication and information were defined into reduced transparency and integration, lack of sustained energy of engagement, lack of trust through the withholding of information, over-simplification of a complex system and physical barriers to engagement. This Section will explain these in detail.

Like similar research by Tippett *et al.* (2005) where a combination of the factors that enable social learning in the uMngeni catchment can be applied in specific techniques of engagement and processes in order to make frames of understanding in the catchment implicit and the assumptions

to problems visible to a variety of stakeholders so that solutions to problems can be crafted. Below is a definition of the above mentioned factors.

4.4.1 Incentives for social learning

Assessing social learning from multi-stakeholder processes has shown taht the accessing, generating and using information has to be granted to all actors- even the layperson and community representatives in LCPG in the uMngeni catchment, and further to include valuable information from the community level.

The findings regarding self-identity change and its relationship with the requirement of realization and understanding stakeholder interdependency are an indication that when previously excluded actors are seen as valuable stakeholders in an engagement; they can undergo positive self-identity change. This positive self-identity change has been well documented to be a reason for the empowerment of actors as stakeholders gain responsibilities to their own catchment and a further reason not only to participate in meetings but to engage meaningfully (Pahl-Wostl 2002). This empowerment of stakeholders is closely related to the spaces of engagement enabling and encouraging stakeholders of the civil society to share their views in relation to others considered valuable stakeholders in the group. Reflecting on what one of the members of the LCPG gained from participating with a variety of expert stakeholders, this was their view.

"*Although we have old infrastructure in the Mpophomeni area which has not been upgraded, but by getting into contact and meeting together with other organisations and people, new projects open up were strategies of what to do to solve the problem are explored, all this from connecting with these other organisations through those meetings*"

- LCPG participant, Pietermaritzburg, 12 October 2017

The above statement points to how significant the empowering of stakeholders in the uMngeni catchment has been. Stakeholders felt like valuable entities in the uMngeni catchment and part of the groups working towards solving the water related problems in their communities.

Dominant attitudes are common in any arrangement of stakeholder engagement, however, in kind contributions to knowledge have been as source of such hindering mechanisms being reduced because of an inherited appreciation for others and respect. This was clearly visible based on how expert stakeholders who engaged at the LCPG scale had come to an appreciation for the valuable citizen science work done at the community level in well organised communities of practice.

All the above mentioned enablers of social learning, are essentially the incentives for social learning in the uMngeni catchment. The Figure 4.4 below summarises the entire discussion on incentives for increasing the potential for social learning in the current multi-stakeholder spaces of uMngeni catchment as well how each multi-stakeholder group can play a role by pursuing relational practices (in green) and the core incentives for social learning that are governed by social learning constructs (in blue).

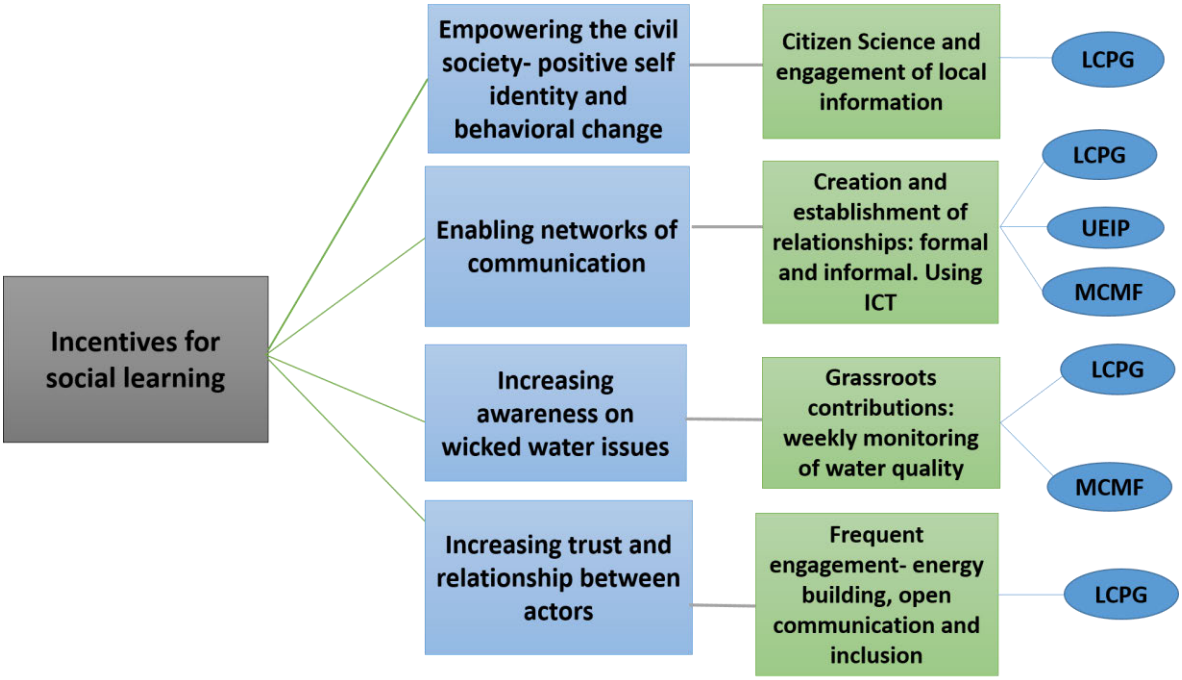

Figure 4.4 Incentives for social learning in the uMngeni catchment linked to a summary of relational practices in support of social learning and the different scales of multi-stakeholder groups that can apply them in order to increase social learning potential.

4.4.2 Barriers to social learning

The following discussion will define what the barriers to social learning were concluded to be in this research. These barriers to social learning are not definitive. What was once perceived as a barrier to learning, can fluctuate to being an inhibitor which can change for the positive outcome if the relational practices and multi-stakeholder processes that support social learning change. In such a case, barriers can be viewed as inhibitors, in line with what Ward (2016) found. Certain social constructs are common more than others and barriers to social learning can be more cmmon in certain social involvement processes.

The findings from assessing social learning in multi-stakeholder processes indicate that the relative transparency of information pertain to the catchment is one of the barriers to social learning when it is absent. This is mainly because the lack of transparency of larger catchment managements stakeholders such as it was found for the UEIP led to various unanswered questions pertaining to the real wicked problems stakeholders are working to towards overcoming in order to improving ecological infrastructural health. One of the essential constructs to acquiring the social learning capacity of having a 'shared role definition and fact defining' is the creation of participatory, agent based, social simulation models (PABSSM) evaluated in Section 4.2. This construct in itself requires other constructs to be exhibited such as transparency of information stakeholders are communicating across and the integration of knowledge through communication. When these conditions are not satisfied, social learning can be prohibited. One of the findings from the stakeholders interviewed indicated that a holistic understanding of the catchment water resources must be enabled due to the complexity of the water catchment, however this integration needs to transparency. The UEIP respondent cautioned against focussing too narrowly on limited aspects which reduce transparency in this words:

- "*So I just think that we are a little too water focused…. I think we need to [be integrated*]".

These findings are in line with Allen *et al.*, (2011)[61] idea that integrated knowledge is necessary in wicked water related problems. Social learning is inhibited when stakeholders cannot integrate information of all types, 'scientific' or not. The relationship between all these barriers that inhibit social learning are shown in Figure 4.5

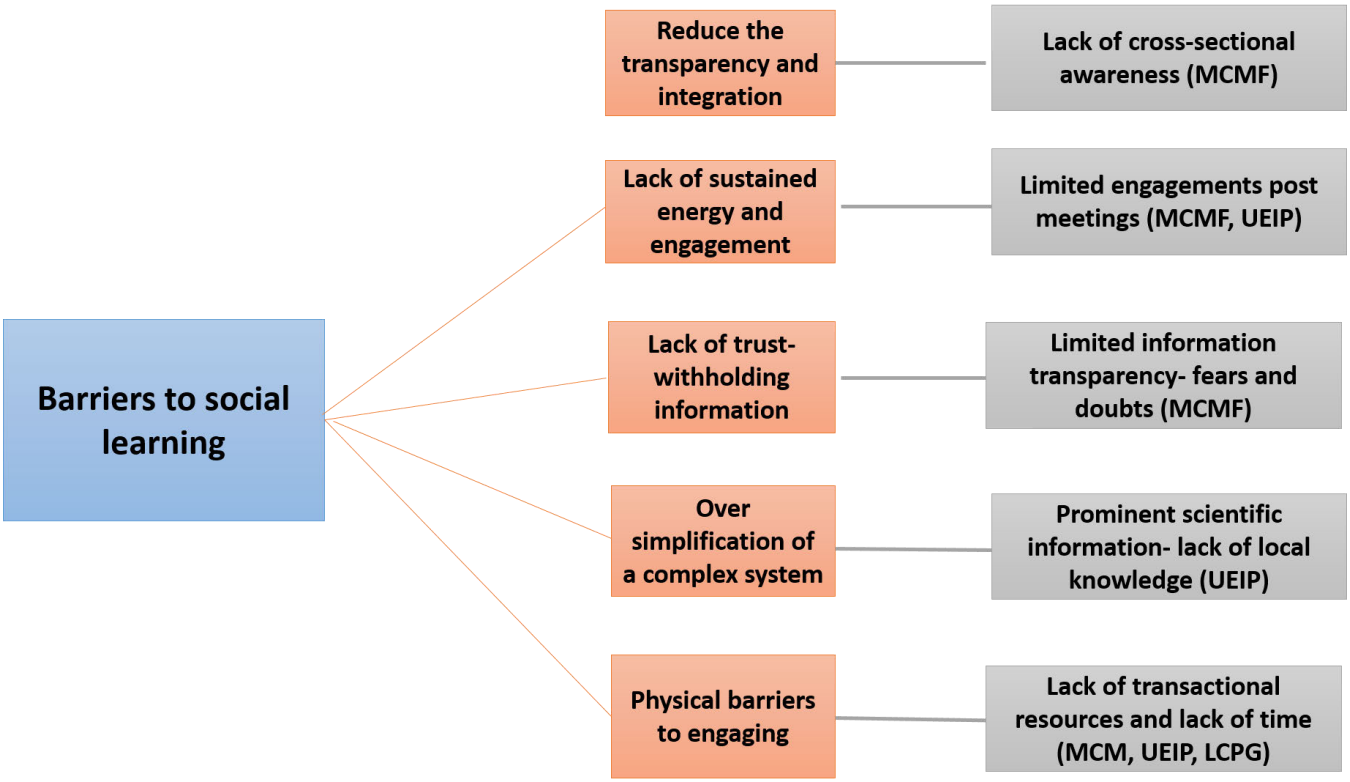

Figure 4.5 Barriers to social learning in the uMngeni catchment (in orange) linked to relational practices (in grey) working against social learning and the different scales (in grey) of multi-stakeholder groups that can

[61] Allen et al's (2011) research showed how a growth in the understanding of different perspectives, values of others and of themselves, agreements and disagreements takes place between individuals, groups and organisations when they engage in a dialog of conversation that leads to social learning. A shared understanding of the catchment is adopted as innovative solutions with the capabilities of supporting adaptive management evolve.

avoid them in order to increase social learning potential in the current spaces of multi-stakeholder arrangement.

4.5 Conclusion

The above discussion shows that there is a need for a conversation surrounding how information systems or ICTs are being used to foster social learning and help overcome existing inhibiting factors to social learning. Even though at first the challenges to achieving the identified requirements of social learnings seemed to be barriers and the social involvement processes or multi-stakeholder processes that were working in favour of meeting the requirements were considered incentives, a closer inspection shows that, that a dogmatic view needs to be reconsidered. Deeper social learning using Theory U by the researcher lead to the realization that the barriers to social learning can be exploited using a change in multi-stakeholder engagement processes in order to create incentives for social learning by creating enabling conditions. The possibility of using information communication technologies as whole system institutional virtual spaces in the uMngeni catchment, especially with a focus on the civil society as valid contributors of knowledge from such systems in order to foster the enabling factors for social learning exists. This finding will be further explored and discussed in Chapter 5.

Chapter 5: Discussion of results on the role and contribution of information systems to social learning

Chapter 5 is focused on examining the findings of this research as they pertain to the role of information systems and computer technology (ICT) in these social learning dynamics in the context of three geographic and organisational settings. As discussed in Chapter 2, the literature shows that there are a number of attributes of an organisational context which are conducive to social learning and therefore whose presence signals that some degree of social learning is probably taking place. The greater and stronger the presence of these attributes and or constructs, in a stakeholder engagement context, the more one can say, with confidence, that social learning is taking place. The question then becomes, to what extent is the use of appropriate ICT contributing positively to these attributes and constructs and thereby lowering barriers to social learning. The two emerging ICT systems that were examined in this research are the Mathuba WIKI and MIKE-INFO.

Information is at the very heart of communication. Whether the information in ICTs is in the form of qualitative or quantitative information ie. numbers; stories; verbal exchanges; pictures; videos; maps; diagrams/graphs- information plays an important role in supporting social learning, in the uMngeni catchment. The ICT lowers the transaction costs of creating and sharing this information and soliciting feedback, which feeds the social learning processes of stakeholders, well-illustrated by Theory U in this research.

The road map (Figure 4.1) of emergent understanding of the relationship between social learning processes and the application and use of emergent and existing information systems was used to answer the second objective of this research.

5.1 Roadmap of emergent understandings on information communication techmlogies

The social learning attributes which were examined, are woven into the narrative of this Section 5.1 and together they form a roadmap of the emergent findings and understandings from this research. Each of these social learnings will be explained in more detail in the Sections indicated, using an understanding of the attributes in support of social learning and its requirements. The discussion of the findings commences with a recognition of the value of *collective action spaces* (Section 5.1.2) and an understanding of *stigmergic processes* (Section 5.1.3) Techniques to *surface assumptions* and *mental models* (Section 5.1.4) that contribute to an understanding of the concept of *socially robust knowledge* (Section 5.1.5) and how to develop it. This would include appreciating the process of *emergence of change* and recognising and using virtual networks in that process. A key to creating such networks is valuing and appreciating *inclusiveness and transparency* (Section 5.1.6) as imperative facilitators of resilience which depends, *inter alia*, on recognising the value of *trust* and how to build trust through *meaningful participation*. Cultivating *meaningful participation* (Section 5.1.7) helps to developing energy flows and tempo in stakeholder relationships which both yield and make it easier to recognise the power of *citizen science and citizen agency* (Section 5.1.8). This in turn reveals the value of *self-identity for social learning* (Section 5.1.9) legitimacy and the effectiveness that comes from the influence on connections and power, values and ways of engaging. This all brings to the fore the vital importance of the different ways to lower t*ransaction costs* (Section 5.1.10) in multi-stakeholder engagement and its influence on the abilities of the actors to learn. Such learning stimulates the *co-generation of information and knowledge* (Section 5.1.11) and thereby expands the *bounds of the groups rationality* (Section 5.1.12) and thereafter wisdom and ability to develop appreciative inquiry. Vital in the processes of stimulating *appreciative inquiry* (Section 5.1.13) is the creation of practice architectures and safe places to experiment, utilising models as metaphors to assist public participation (Section 5.1.15) Consistent with Theory U's approach to continuous learning the above processes develop ever growing absorptive capacity amongst stakeholders (Section 5.1.15) to engage participatory agent based social simulation modelling.(Section 5.1.16). The tables in each subsection of Chapter 4 show a combination of the results while alluring to the potential role that the emerging information systems such as Mathuba WIKI and Mike INFO

information systems could play in influencing the constructs of social learning linked to the enablers (incentives) and inhibitors (barriers) to social learning.

5.1.2 Value of collective action spaces

Evidence gathered from being a participant observer in this research revealed that the three spaces of multi-stakeholder engagement researched were already organized into motivated groups designed for collective action. However, when it comes to the importance of organized collective action spaces, the effect that they have on how much learning can occur beyond face to face meetings, this research showed that the number of times stakeholders met face to face and sustained their contact virtually is important to learning. Table 4.7 showed how the quality and effectiveness of the collective action spaces, in support of social learning, in the uMngeni catchment differ for each multi-stakeholder group.

UEIP's method of engagement outside of face to face meetings reflects a process which does not deserve to be called "collective action". At the largest catchment level of engagement as represented by the UEIP in this research, stakeholders only met twice a year as a group. In between these times the members of the group worked almost exclusively on their own projects, seeking opportunities to update the entire group only bi-annually[62]. While some stakeholders of the UEIP mentioned that they had to organize small group meetings more frequently the content of these smaller meeting was not disclosed to all members in the partnership and did not fulfill the essential role of embracing collective action spaces as a phenomenon of social learning. The lack of a shared and commonly accessible ICT repository to connect stakeholder in between these meeting times in what could be called a collective action space, inhibited social learning. This is one of the reasons why the UEIP falls short in this requirement. Furthermore, this large catchment management group was noted to not have, any coherent coordinating framework other than that they were working in the same catchment and would connect via email. During the time of the research, it was observed that the silos to which the members had *de facto* assigned themselves,

[62] Chapter 4 briefly discusses some of the information gathered in those voluntarily meetings which were held twice a year, and ran for two days each. One meeting was 'research meeting', the other a 'coordination' meeting.

effectively prevented them from generating a common information space in the form of an ICT supported system. The main method of communication and information sharing used by the UEIP includes sharing reports of past projects and minutes of meetings post face to face meetings using the email system. These actions alone were not adequate in supporting the engagement necessary for social learning outside face to face meetings. A collective meeting point for stakeholders to engage whether directly or indirectly with the information each stakeholder or organization produces was not possible even though the mandate for having all these experts in one space was valuable and contributed to various collaborative projects during the time of the research, it fell short of sustaining this communication free flow outside meetings. Which ultimately, disqualifies their current use of ICTs as supporting collective engagement and eventually, action.

At the sub-catchment level- where the MCMF engaged 4 times a year in stakeholder meetings the organized collective action space worked in almost the same way as the larger catchment management group, the UEIP. The quarterly meetings were essentially focused on reporting on who is doing what, in their own silo. Besides a few notable exceptions very little collective action that meets the attributes of social learning outlined in Chapter 2 and Section 5.1, emerged from these quarterly meeting or activities in between meetings. While there have been actions taken towards collaborating with other organizations in the group in working on common issues of the catchment such as in the case of the uMsunduzi Remediation Project[63], this collective effort was limited to discussions with the entire group; only 4 times a year. Furthermore, it was the only known collaboration project that truly was said to be spear headed by the MCMF during the entire time of the research. The lack of engagement and the effect this has on the collective action spaces as a valuable construct for social learning has been assessed in Chapter 4 already. While being very interested in the use of ICTs and in communicating what is happening in the sub-catchment of uMsunduzi, smaller groups of engagement within this project, stakeholders as a collective, did not make use of ICTs to share this emerging information widely to other members of the group, between face to face meetings. As a result, a common information system in support of a collective

[63] Brief discussion of these observations can be found in Chapter 4.

action space for projects such as the uMsunduzi Rehabilitation project, still does not exist. When it comes to the use of ICTs, the email system that this group heavily relies on for communication and information sharing outside the physical collective, does not have the attributes that qualify it to being a collective action space just as was the case for the UEIP. This method of sharing information and communication does not contribute to social learning. This limited the ability of the MCMF stakeholders to learn socially and hence make much progress on persistent wicked problems such as water quality and other more social issues such as the lack of engagement of NGO, academic & local government stakeholders in the sub catchment level with business and industry stakeholders[64].

Contrary to the two larger groups the LCPG, epitomized by the Mpophomeni Enviro-champs and others like them, were more motivated on water related issues. The Mpophomeni Enviro-champs, were well organized as a community based multi-stakeholder group. They met bi-weekly face to face. In these meetings, the collective action that characterizes the LCPG: Mpophomeni Enviro-champs was that of a carefully coordinated group of actors with a common agreed and transparent project agenda, working on monitoring in their community[65]. Their strategy of engagement using ICTs involved the use of cellphones and social media using the Whatsapp application. The social involvement included a system for sharing progress on the community education project, which included both the bi-weekly face to face meetings as well as updates and chats on cell phone based social media. In addition to the Mpophomeni Envio-champions, other enviro-champions in other townships, in the uMsunduzi sub-catchment also made wise use of social media in sharing information and keeping all stakeholders updated almost on a daily basis. This was through projects created by DUCT and WESSA on the monitoring of manhole spillage in Mpophomeni and some parts of the uMsunduzi sub-catchment[66]. The collective action space formed by the

[64] This has been well detailed and associated with social involvement in Chapter 4, Section 4.1.2, examples 2 and 3 and associated with the requirements of social learning in Section 4.2.1.5

[65] A brief discussion of how this was done with the aid of ICTs is expanded on in this chapter.

[66] Details on the processes of these monitoring efforts and stakeholder engagement will be discussed in further sections in this Chapter. However, a presentation of findings with regard to social involvement for this monitoring activity by enviro-champions in sections 4.1.1, Example 3 and 4.1.3, Example 1 and further discussed with regard to meeting social learning requirements in Section 4.2.1.5 partly for the MCMF and the LCPG.

stakeholders engaging at the LCPG scale using cellphones, social media and even GIS based Google Earth maps of activities was thus assessed as being more successful in facilitating the constructs conducive to social learning than the UEIP and MCMF groups. This conclusion is supported by literature documenting the Mpophomeni Enviro-champions by Ward (2016). He described collective action in the catchment that came about from the local community Enviro-champions being embedded in between government and non-government organizations. This simple multi-stakeholder relationship increased the collaborative disposition of all the persons involved, as they immersed themselves in the local community in question and considered themselves responsible for the catchment. As a result, such a connected network and relationship between scientific experts and local citizen scientists, even in small groups is what led to cooperation and success in *collective action* of monitoring efforts at the LCPG scale. Furthermore, the incorporation of ICTs in the use of cellphones, computer applications and the websites solidified these relationships of collective action and in the information being shared. Figure 5.1 below depicts one example of how this monitoring was done by the enviro-champions supervised by DUCT. These enviro-champions resided in the upper uMngeni Catchment and used cellphones in monitoring manhole sewer issues, which were photographed on site and then share to a central location on the cloud. The stakeholders at the grassroots community level ensured that such issues were raised in the group and where water related issues had not been fixed, this was highlighted.

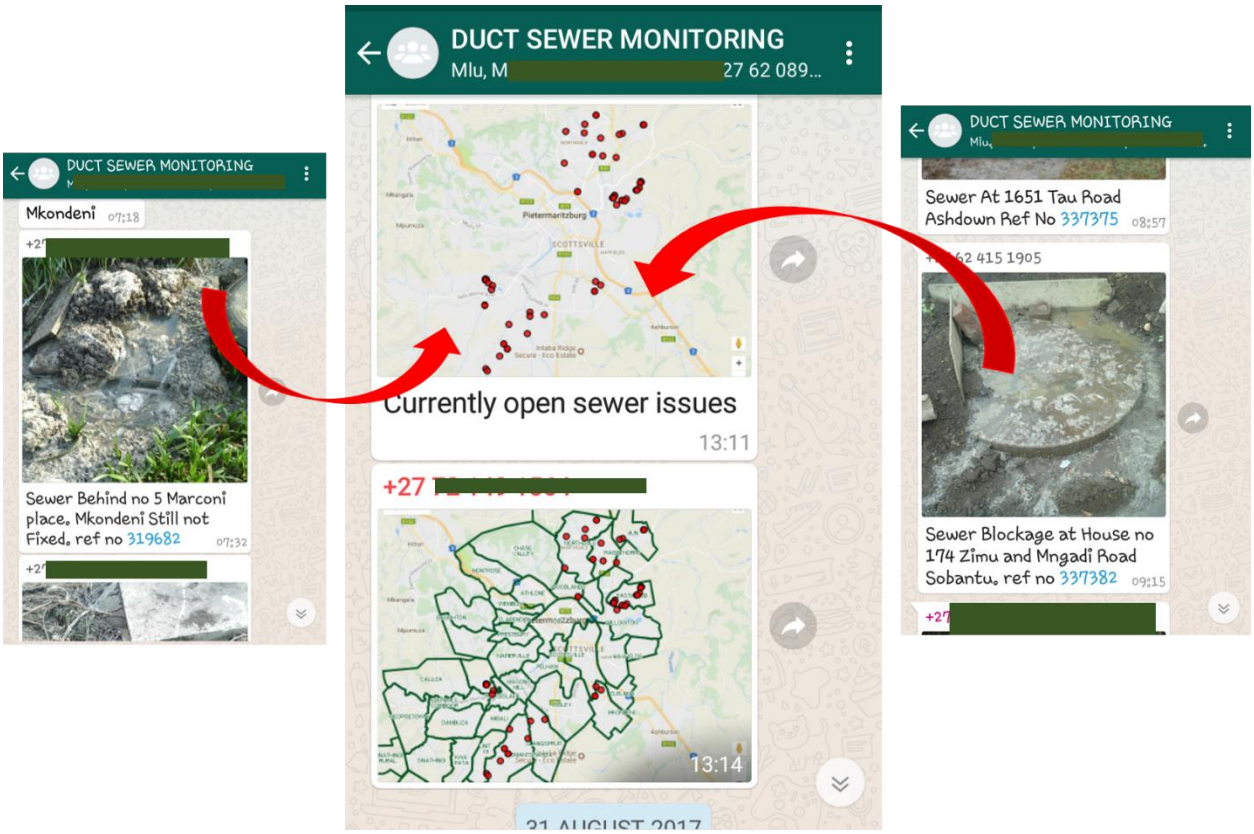

Figure 5.1 A depiction of images shared on a multi-stakeholder local community monitoring group formed by DUCT where snap images with geo-locations of sewer issues in the uMsunduzi catchment were captured and were examples of reported issues by enviro-champions using cellphones, Whatsapp and social media.

It was found that the more the information regarding the state of the catchment and related water resources was shared, and the more connected the virtual space became (ie the number whatsapp connected stakeholders in the group), the higher the interaction observed. This evidently helped build trust and recognition in the local initiatives as citizen science monitors were recognized and praised, by the group, for their prompt monitoring updates. It also built trust in the expert-community partnerships that these efforts are based on, thus evidently increasing relational practices that are known to be in support of social learning processes (Pahl-Wostl et al., 2008). The sustained relational practices within the local community project group through the Whatsapp group and shared Google Earth information collection point, was evident in the back and forth

conversations that continued between the enviro-champions that represented the local grassroots level, who were doing the monitoring in the field, and the local government stakeholders who were responsible for fixing the pollution problems. This monitoring created a two part success; one of raising awareness of the benefits of community and expert partnerships in monitoring, which in this case, work was overseen by expert stakeholders in DUCT, the NGO who facilitated the citizen science stakeholders in their efforts to form the online network group. The other part was in raising awareness for better on the ground repair work by the engagement of implementers and government stakeholders, who were also connected through the Whatsapp group. The engagement of LCPG into larger groups through simple spaces to connect through ICTs to motivate collective action both by awareness, monitoring and implementing is further evidence social learning is enhanced by collective action through ICT. Furthermore, discussions behind the scenes on how to possibly solve water related problems that the citizen scientists had identified, were also encouraged, especially in situations where a problem seemed to be ignored or unaddressed by the local government officials, whose job it is to fix such problems. Further insight into the LCPG collective action cohesion using ICTs will be addressed in all of the sections to follow in this chapter. One of the most essential social learning constructs linked to nurturing collective intelligence in the multi-stakeholder groups is stigmergic processes. This construct is presented and discussed in relation to ICTs as information systems in the next sub-section.

5.1.3 Stigmergic processes

The ability of information shared in an ICT supported platform to encourage collective understanding, collective responsibility and social learning is an attribute that was found to be least developed in the larger catchment management groups and far greater in the smaller local community groups. The smallest, local community project group was the most effective at leaving trails of information that enriched the knowledge space of all engaged stakeholders, hence being relatively exemplary in showing stigmergic processes in action.

Stakeholders interacting at the local community project group scale in the uMngeni catchment are developing ICT techniques of documenting information with internet communication technologies with which they are familiar or have been taught to them by more expert stakeholders. Other

stakeholders can therefore access information concerning their activities without actually contacting each other face to face. This is an example of a stigmergic process, explained in Chapter 2.

Table 4.7 in Chapter 4 showed how stigmergic processes as a phenomenon differs from each scale of multi-stakeholder engagement investigated in this research in relation to the social involvement or multi-stakeholder engagement of stakeholders. What follows is a discussion of the findings and a connection to the current uses of ICTs and or information systems in the uMngeni catchment and the limitations and advantages to social learning that could be affected by the use of the emerging information systems, the Mathuba WIKI and Mike INFO as part of stigmergic processes.

The information placed in the common Google Earth based information system by stakeholders usually prompts and encourages other stakeholders to share some of their own information, that relates to what is already there, for example a follow up stream clean-up 6 months later can be critiqued or highlighted as an area of focus or conversation since the information is already in the virtual platform. Stakeholder representatives in various LCPG also provided information for populating shared KMZ files of local community citizen science activities. This results in a rich information sharing space in each KMZ/KML file that can be displayed on Google Earth. An observation that was evident in the smaller enviro-champs stakeholder groups of the uMngeni catchment was that they were comfortable using such platforms.

While the research itself showed that in the context of the three spaces of multi-stakeholder engagement[67] investigated as a participant observer; all were engaging in some form of stigmergic process. However, with regard to the use of ICTs to accomplish learning through collective information contributions- this research showed that the larger catchment management group (UEIP) that made use of mainly the email mailing system to share information, had the least useful stigmergy occurring. The UEIP made use of the email system for sharing updates on past meetings,

[67] Results pertaining to the phenomenon called stigmergy as an observed process and attribute of social learning in the uMngeni catchment is discussed in Chapter 4. This was based on how the stakeholders gathered information in their respective organizations and brought it to 'the table' during periodic face to face meetings. Evidence of these meetings in relation to social learning was presented in Chapter 4.

project partnership reports, job vacancies and sometimes updates on new laws and amendments passed by government officials. However, the UEIP had no common GIS supported ICT system, no common accessible repository for information on the catchment in general, no plans to produce such a system, and no commitment to contribute to emerging system like the Mathuba WIKI and or MIKE INFO[68] which would be the first indicator of a stigmergic process of any consequence. Instead, any information was discussed infrequently by the collective of stakeholders via email. If it was to be touched up on further, briefly, face to face during the coordination and research meetings held only twice a year. As a result, the information shared did not accumulate and take shape to form meaning through the stigmergic processes where others would be prompted to comment and add to the information that was shared. It is thus reasoned that this decreased opportunities for this phenomenon to lead to social learning. This was also because constant awareness on what was happening in the catchment water resource did not accumulate and cause actions to be taken, that were consistent with learning Theory U.

Some members of the UEIP multi-stakeholder group attended a workshop to be educated and updated on how coordination could be improved. The workshop attendees produced a map which has already been discussed and documented as Figure 4.3 in Chapter 4. The map was hand drawn as a once off exercise and could not be shared in virtual on-line spaces where stakeholders could interact with and add to it in real time. While there was optimism in this kind of "integrated" map of multiple activities being used as a base for a platform to document the many activities and projects of the stakeholders and organizations that make the UEIP, only an image without a link to a GIS supported information system or place for the stakeholders to interact with the data was achieved. Such a "platform" could not be construed as stigmergic, in nature, and still does not exists to support the openly discussed wicked problem of coordination in the UEIP, for the benefit of the greater uMngeni catchment.

Similar to the UEIP, the MCMF also struggled to show any manifestation of the stigmergic process outside the face to face meetings and to some extent within organizations working largely within

[68] Insight on how these contribute to social learning is discussed further in this chapter.

their own silos. Aside from sharing the minutes of meeting using emails, Umgeni Water and DUCT who form part of the MCMF also shared the E.coli concentrations in the steams of the uMsunduzi sub-catchment once a week and once a month respectively. However, since this information was not in a set place that could be observed by other members as a stigmergic virtual location to mark or flag work done, it was not effective in stimulating more stigmergy or an increased contribution of information and data into a common space, by other stakeholders. This was evident in how both the UEIP and MCMF groups had many one sided emails sent, often with no replies from the collective of stakeholders. Their methods of sharing information using ICTs such as email simply did not support an increase and accumulative collection of information from the members of the groups. Furthermore, both of these groups could not expand their virtual knowledge space to more integrated information management systems that would stimulate a stigmergic process to occur. As a result, real actions, as required by Scharmer's Theory U that come from increased awareness, deepening knowledge and learning of the catchment also struggled to occur. This may be the reason why complex wicked water related problems in the catchment such as the water quality decline and pollution of the uMsunduzi catchment, have persisted for years without improvement, even though there were expert stakeholders and organizations working on the catchment in various projects.

Contrary to the larger multi-stakeholder groups discussed above, by far the most successful in stigmergic processes was the LCPG, the Mpophomeni Enviro-champions (MEC). With the additional help of expert stakeholders and organizations such as WESSA and GroundTruth[69] this relatively small group became very successful in encouraging stigmergy using ICTs and storytelling with the information they created. There were various ways this was possible at the local scale including the following:

- Making good use of the citizen science activities and miniSASS to monitor streams in the catchment. This enabled knowledge about the catchment streams water quality to be

[69] The local community project groups were multi-stakeholder groups with the assistance, guidance and at times funding of government and non-government organizations. Ground Truth, a non-government organization providing tools for citizen scientist's stream bio monitoring, water quality testing as well as ICT based systems to document results of such citizen gathered information such as what is known as the MiniSASS website.

documented using placemarks on miniSASS website Map[70]. Each point or placemark had the name of the citizen science group in the community that engaged in the bio-monitoring, and also a record of the results they obtained, that day. It encouraged other groups within communities to do the water quality testing as well, thereby adding to the knowledge space.

- Sewage line manhole monitoring and record keeping using the online Google Fusion Tables was another method. Ayanda Lipheyane, a member of the Mpophomeni Enviro Champions, who had learned all his skills through the Enviro-Champions program, helped the small LCPG monitor sewage manhole discharges and other malfunctions, recording a time series of his observations online. This enviro-chmapion was taught by the university students at the time some technical skills to integrate all the manually gathered and recorded data. Ayanda gathered monitoring data tabulated on sheets of paper by all the enviro-champions working in the Mpophomeni township area, and transferred it onto Excel spreadsheet which was then uploaded these into Google sheets. With the skills he had, he was able to convert the raw readings made on site into a tabulated format that calculated a summary of the accumulated results of the number of days sewers were leaking, reported and repaired as well as the frequency of these events overtime. With the help of international exchange students and student researchers from the University of KwaZulu Natal and the management skills and oversight of WESSA, this relatively small group in the Mpophomeni Township was able to keep track of their monitoring efforts of sewage manhole malfunctions and the response times by government officials, responsible for fixing the sewer problems. Such information could then presented as graphs and heat maps online after being edited and prepared offline. The presents of a single technically skilled community representative such as Ayanda Lipheyane of the Mpophomeni Enviro-champions reduced the need for all members of the group to edit and upload the data into spreadsheets weekly themselves which could reduce the costs of data to access the internet. The involvement of NGOs such as WESSA

[70] The miniSASS Website consisted a map of points of the results of water quality bio monitoring testing.

also provided financial support to cover any data needs associated with keeping a record of the monitoring process when it was needed. As a result, whenever the information on their local catchment went 'live' into fusion tables, it could
be edited, shared using links to the rest of the members of the local community project group and even to interested expert stakeholders in established organizations (eg. members of forums, partnerships such as the UEIP). This ICT virtual communication space helped to engage stakeholders in scientific organizations, NGO's, Government and municipal authorities, to gain an understanding of what kind of pollution was occurring at the local scale. This stigmergic process helped these persons to discern the effectiveness of the monitoring programs and it influenced them to pursue such work in their own catchments. The comment below from the semi-structured interviews shows the effect such widespread interest in the monitoring efforts at the LCPG scale had on the stakeholders at the grassroots level.

"Even the Department of Water and Sanitation is trying to adopt our strategy of Enviro-champions. The Enviro-champs was started here in Mpophomeni and was enlarged because now we are at the meeting with the Minister of Water and Sanitation in Durban…and other members in the team they were going to Cape Town to make a presentation of what we are doing…"

-Participant in Pietermaritzburg, LCPG, 10 August 2017

- Local community led, recordings, mapping and graphing of suspended solids readings for a site at the outlet of storm drains. This work was assisted by post-graduate students of the University of KwaZulu Natal and GroundTruth. They used stream measuring tools suitable for local citizen scientists. Sibongile, an Enviro-champion women working at Shiyabizali informal settlement collected water turbidity testing results for over a year , 3 times a day, 7 days a weekazs4 from the return flows at the outlet of the Howick Waste Water Treatment Works. These samples became valuable information, when graphed and tabulated, as shown in Figure 5.2. As a result, Sibongile's local effort in monitoring, under the mentorship of persons from WESSA, stimulated much conversation and further insight by

other stakeholders and organizations in uMngeni catchment. The question mark following the mapping of clarity analysis from the field work of citizen science water clarity testing and the spreadsheet documentation and presentation shows the endless possibilities of analyzing and modelling information about water quality in the Upper uMngeni catchment. Through the use of information systems, valuable work contributed by the civil society could initiate series of similar monitoring work because of the stigmergic processes that support continuing deep social learning[71].

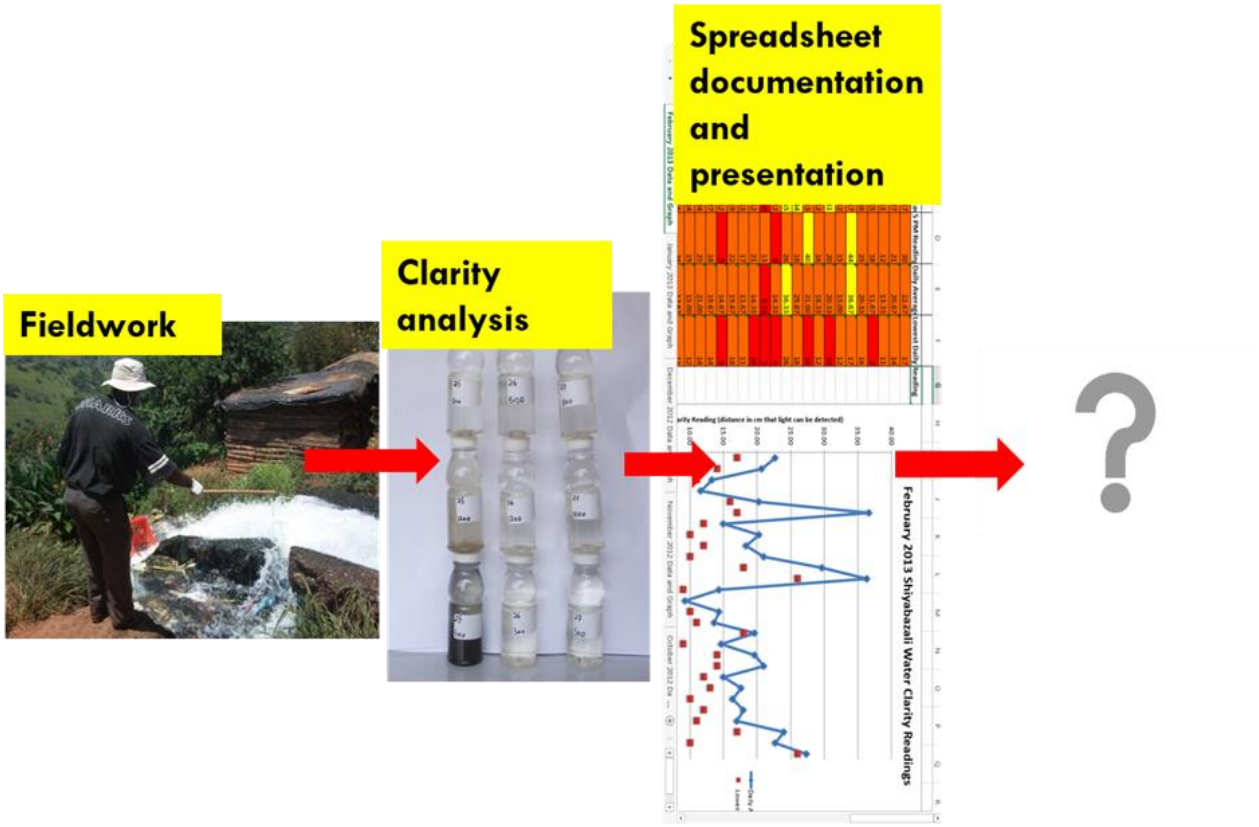

Figure 5.2 Observed water turbidity sampling and results display by Enviro-champion Sibongile, at the outlet of the Howick Waste Water Treatment plant near Shiyabazali

[71] Detailed review of how stigmergic processes are linked to social learning processes is provided in Chapter 2, Section 2.5.4

- Making use of Google Earth in story telling of events occurring in the local streams of uMngeni catchment. The Enviro-champions again with assistance from DUCT, WESSA, GroundTruth and the University of KwaZulu-Natal and others, could use this online system to record their citizen science activities. These activities included observations of factors affecting water quality such as sewage manhole malfunctions, stream clean-ups, local floods alien clearing and relevant multi-stakeholder meetings. This method involved the Ice Berg model of storytelling[72], described in Section 5.1.4 below, enabling participants in the catchment collective action space to learn what others are doing in the catchment. This created connections, enthusiasm and in some case contributed to the critical mass to get things done and stimulated others to do more work in their own parts of the catchment.

All of the innovations, actions, processes and procedures described above are examples of, stigmergy, commonly known as "*marking the work*". However, the stimergic ability of information by a variety of stakeholders including the civil society can also simultaneously nurture social learning through the surfacing of assumptions. The Iceberg Model of Storytelling used by some stakeholders in the uMngeni catchment as a result of the Mathuba movement is described and its significance discussed in the next sub-section.

5.1.4 Surfacing Assumptions: The Iceberg Model of story telling

A distinctive method of surfacing assumptions noted to be successfully applied by numerous stakeholders in the LCPG was the Iceberg model of storytelling by Peter Senge (2008). The Iceberg Model of storytelling is described in Figure 5.3 below shows how reactive learning ?n the surface on a metaphorical iceberg can deepen to the point where individuals observing what is happening in the catchment pertaining to water could surface understandings of 'patterns and trends'. It is then followed by a deepening understanding of the kind of forces were at play in the observed event in the catchment as well as their own assumptions as mental models in terms of the kind of thinking that allows the situation or event observed to persist.

[72] Details on the Ice berg model as a feature in Mathuba WIKI maps is discussed further in this chapter on emerging systems for social learning.

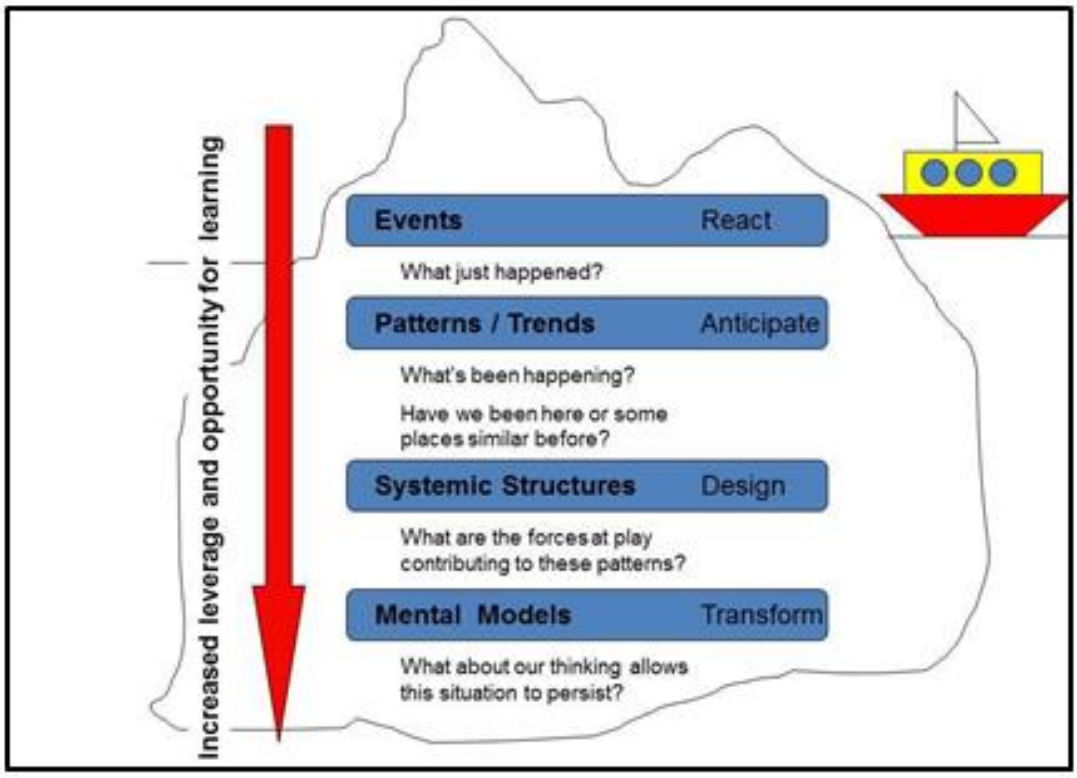

Figure 5.3 The Ice-berg model of story telling (after Senge *et al* , 2008)

It was found that these "iceberg conversations" as they are termed within the Mathuba Program's communities of practice, enhanced understanding of biophysical and human relatedness and hence feelings of relevance by the participants involved or observing this occur. The transformation of feelings from irrelevant to relevant in the youth and adult participants associated with Mathuba Program related activities, has been significant (Boothway, 2013; Taylor 2013).

An essential element of applying the Iceberg model of telling stories, about water related events in the catchment, is the way in which such thinking helps to surface systems thinking and assumptions, also known as mental models. One of the ways to find out if assumptions are sensible is to lay them out for others to see, for others to think about, talk about and critique. The reflection needed to be able to articulate any assumptions made is what happens at the bottom of the U

(Figure 3.1) in Theory U of social learning. There was evidence from this research that a new form of information was evolving using the Ice-berg model of storytelling, one that embraced a post-normal science approach to problems by surfacing assumptions and supporting social learnings. When it comes to utilizing ICTs as virtual spaces to share information, the larger catchment management groups, ie. UEIP and MCMF only shared facts about what work organisations were working on in the form of presentations and reports, information in the form of tables of catchment water conditions and pictures. None of these broke down assumptions of findings in a way that could be understood by non-experts. On the other hand, the LCPG showed itself to excel in this attribute of social leaning, surfacing assumptions using the Ice-berg model of explaining observations, accompanied by geo-located pictures of the activities and observations in the catchment. Since the reflection needed to be able to articulate what each person's assumptions are this connected to a key element of Theory U of social learning, that is what happens at the bottom of the U in Theory U, the LCPG was most successful in supporting social learning through this construct.

Stakeholders of the LCPG in various parts of the uMngeni catchment told many *citizen stories* about the events that were affecting water resources observed in the catchments. One of the most successful examples of this method of story was that of the Enviro-champions of Mpophomeni. These enviro-champions with the help of NGOs such as DUCT and WESSA who had been monitoring manhole malfunctions and sewage discharges from them in their communities were taking pictures and recording each manhole malfunction and sewage spillage event in their catchment with the help of the community. However, because of their close collaborative efforts they were soon able to pin point the causes of the malfunctions: the discarding of foreign objects into the toilets of households. This lead to house to house community education efforts where the enviro-champions alerted the residents of Mpophomeni township of the harmful effects of throwing foreign objects into sewers and toilets and got the community involved not only in monitoring but in reducing the occur ace of pollution events. Another assumption for the common and unreported events of manhole spillages and malfunctions was surfaced through this monitoring process. This was the inadequacy of the Mgungundlovu Municipality operating in the area of Mpophomeni to attend to manhole malfunction on time. Manholes were left unrepaired and spilling for many days and sometimes for many months. The Enviro-champions were able to create links between patterns and trends of such events of pollution from their community with the rising

E.coli concentrations of streams leading to the Midmar dam such as the Mhlathuze River which runs across the township as well as the much needed involvement of the municipality in repairing the damage to sanitation infrastructure in the townships. With the help of NGOs such as DUCT and WESSA they were also able to create the linkage between increasing reports of manhole malfunctions and poor foundations of sanitation infrastructure in the Mpophomeni Township (Dent & Taylor, 2017).

Compared to the LCPG efforts of surfacing assumptions, the monitoring efforts of the MCMF some members of the forum, that is a representative of Umgeni Water and the Msunduzi Municipality sharing E.coli concentration readings from various streams of the uMsunduzi sub-catchment. Umgeni Water reported these publicly in an email to the forum members on a weekly basis using spreadsheets and colour coding keys to show when numbers exceeded safe levels of E.coli concentrations at various points in the uMsunduzi catchment including at the outlets of Midmar dam and other streams that fed into this water resource. These weekly updates were accompanied by an explanation of the events and likely link to rainfall events during the week that watched out the pollutants into the streams. The reporting did not surface any deeper assumptions on the causes of the pollution from various streams like the LCPG did, neither did the reports through emails and presentation during the MCMF meetings indicate how the problem of pollution could be traced to the sources of pollution which were likely manhole malfunctions or how this problem could be solved or approached effectively.

The most common method of communication outside face to face meetings between the large catchment management stakeholder groups (ie. UEIP) and the smaller sub-catchment groups such as the MCMF was through the use of emails as it has partially been presented in the preceding subsection. While different organisations in both of these groups with expert stakeholders had their own organisational websites, such websites only shared factual or hard science information in the form of data, reports and other documents and in some cases, as pictures. All of this existed in their own silos, within their own organisations. Without further openly sharing their thoughts and what the observations mean to encourage dialogue with others. If such information was shared with the greater number of stakeholders, it was verbally during face to face meetings- four times a year for the MCMF and only twice a year for the UEIP. Emails were used in sharing

documentation and other forms of updates, no major explanations of the reality of the catchment were encouraged from what was shared. This resulted in various stakeholders in these large stakeholder groups not understanding what others were implementing and what assumptions of the catchment led to their work even when factual knowledge of projects was shared. Even when face to face meetings were used to review previous minutes of meetings, these reviews were brief, reading what was shared by stakeholders in the previous meeting, leaving little to no room for dialogue and reflections on current and past projects by stakeholders in the groups. Such findings were said to be connected to hindered coordinated action, reflection and learning social learning[73],

The LCPG of stakeholders were well coordinated on reporting on the catchment. With the help of experts stakeholders; researchers from the University of KwaZulu Natal, these community based stakeholders and the non-government organisations they belonged to were able to explain reality of the catchment using the Ice-berg model of storytelling[74]. These stakeholders used Google supported mapping to document their work in the catchment, their observations concerning wicked problems such as water quality as well the intervention they were part of as community activists. This data was shared not only as pictures but a structured story, using the Ice-berg model, as a pop up message under a placemark location on a Google Earth map. This explained reality by surfacing assumptions and figuring out patterns leading to the observations made. This led to internal learning by those who were documenting this information onto maps on Google Earth. This led to many conversations about the catchment and allowed stakeholders to understand the deeper issues behind persisting wicked problems. While the stories were structured such as the one pictured below, the stories encouraged free speech embracing information that was post-normal and not necessarily hard science based thus encouraging social learning.

In Figure 5.5 below, one of the stories from some of the KML/KMZ files of ‘placemarks’ of activities is presented. These stories could be viewed and interacted with on various platforms,

[73] Findings relating to the current state of social learning in the UEIP and MCMF due to the limitations of their meetings and the effect it had on multiple social constructs was discussed in detail in chapter 4.

[74] The Iceberg model of storytelling and how it was relate to social learning was reviewed using literature in Chapter 2, Section 2.4.1

such as Google Earth on laptops or on smart phones through any free website for viewing KML or KMZ files. A community representative and expert stakeholder who engaged directly with the civil society in miniSASS activity of water quality biomonitoring in one of the streams in the uMngeni catchment helped the local stakeholders to composed a systems thinking story on the activity on that particular day. These stakeholders at the LCPG scale also go through process of deep social learning as they document the systems thinking at play, patterns and trends and even the mental models that led to these activities.

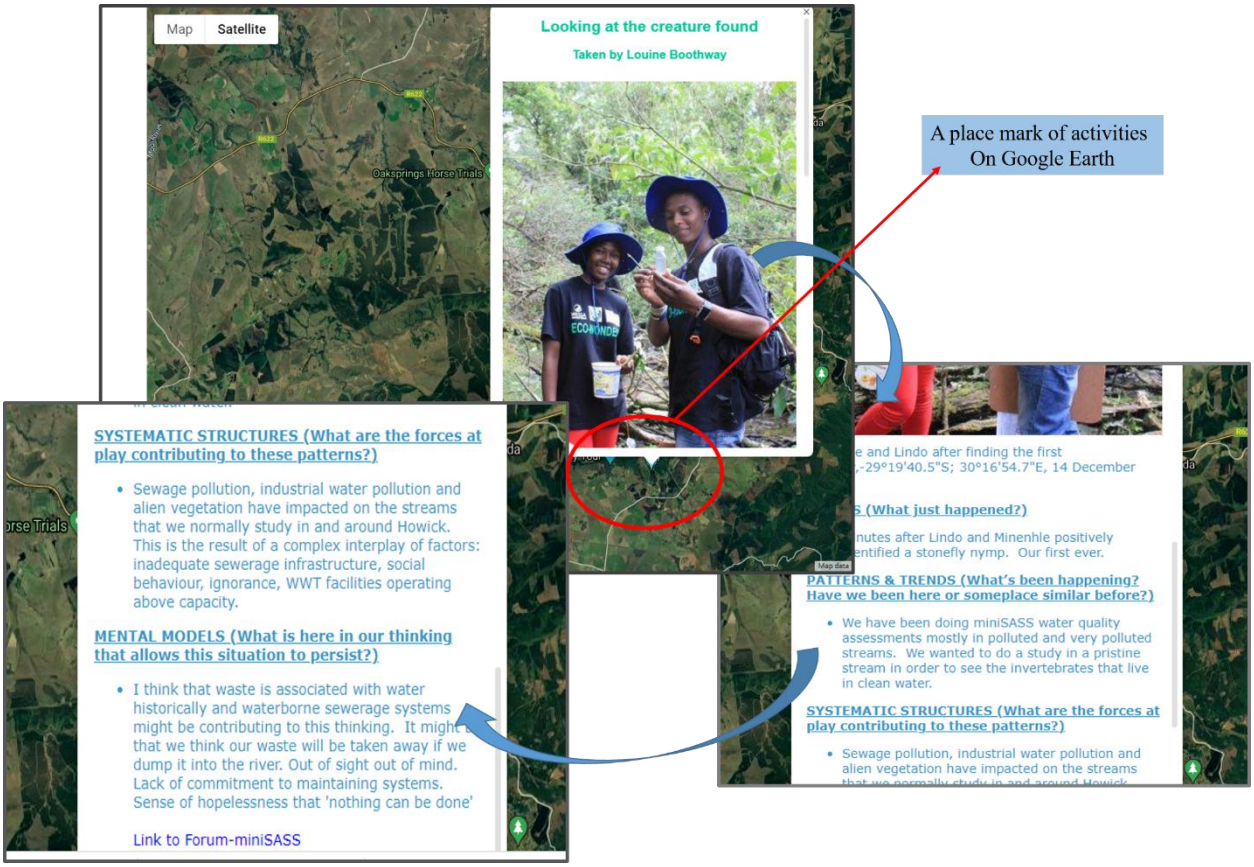

Figure 5. 4 The Iceberg model is used to tell a story about a specific placemark location on Google Earth in the uMngeni catchment where a miniSASS activity had just taken place and assumptions are being surfaced through deepening learning.

A KMZ/KML file that has many such activities as seen in the diagram above as placemarks of mapped events and observation stories has greater potential to surface more assumptions about persisting wicked problems, in the catchment. The engagement of society in surfacing assumptions is invaluable and further emphasises the importance of highly interactive ICTs or information systems that integrate all such activities to tell various stories of what is happening in the uMngeni catchment. This is what the Mathuba WIKI attempts to do by housing citizen science stories in one Map view.

5.1.5 Socially robust knowledge

The phenomenon of socially robust knowledge described in Chapter 2. This research showed that knowledge that is kept to oneself can never become socially robust and that it needs the involvement of other stakeholders to question and review the information in the light of their experiences, perspectives and systemic understandings of the situation and to reconcile that they can trust the information before it can be considered to be 'socially robust'. Socially robust information is also known as actionable information.

Information in Table 4.7 in Chapter 4 shows how socially robust knowledge as a construct of social learning differs according to the scale of multi-stakeholder engagement investigated, in this research. In this chapter, it will be followed by an analysis and discussion on how the current uses of ICTs and or information systems in the uMngeni catchment limit or support social learning when it comes to this vital construct of social learning.

The Mathuba WIKI is a free Google powered website which was created as an information inquiry for river health monitoring happening in and round the UMngeni catchment. It has taken various virtual representations over time, each time being more integrated and user friendly and public in presenting information. Mathuba was created out of the realisation that the many dedicated efforts of people, organisations and environmental activists in the uMngeni catchment did not improve the state of rivers, particularly with regard to the continuously rising levels of pollution. The Mathuba WIKI was created to be a Virtual Systematic Inquiry with an anticipated output of creating socially robust knowledge from the many role players and contributors of information

that would be developed as stakeholders engage with it. Inquiring with the information in the online platform was believed to lead to deeper understanding of the wicked water problems that exist in the catchment, heighten the connections between the role players and to create a sense of agency with all stakeholders residing in the UMngeni catchment. The free Mathuba WIKI website platform also creates an opportunity for collective actions such as citizen science too be contributed by citizens. The information added to the WIKI is mapped and links to citizen science stories. These stories also connect to websites of contributors such as those of the NGOs that worked with citizens in reporting on the uMngeni catchment. The citizen science stories in the wiki site also consist of hyperlinks to both public and private forum pages where open discussions on the observed events in a story can be discussed further on the website itself. Additionally, the Mathuba wiki has other forms of data collected through the contributions of citizens and researchers such as downloadable kmz files of place marks of citizen science activities, downloadable document and uMngeni waterworks data of E.coli concentrations. A brief look into how the emerging Mathuba WIKI can specifically benefit the furtherance of this construct in the uMngeni catchment and the potential for it to be supported by stakeholders in the multi-stakeholder groups is worth considering.

Socially robust knowledge creation is affected, *inter alia*, by the time between meetings and the efforts taken by stakeholders to continue engagement outside face to face meetings. It has already been discussed how findings of engaging in face to face meetings of larger multi-stakeholder groups such as the UEIP has great potential for encouraging constructs of social learning due to them being well structured and having different sources of stakeholders as knowledge contributors. However, when it comes to applying these constructs of social learning outside face to face meetings, with the aid of ICTs, this was not the case. Since socially robust knowledge is stimulated by creating a nourishing environment for creativity and the sharing of ideas, when dialogue is not focused on creating options for collective action of the civil society, socially robust knowledge generation is also limited (Weingart 2011; Nowotny 2003) and this was the case for the UEIP. By the very definition, information and knowledge can only become robust when it is thoroughly examined, questioned and debated in an open and transparent multi-stakeholder environment. This is what was found again to be active and ongoing at the local scale through online tools of

knowledge sharing as well as face to face[75]meetings. On the other hand, the lack of actual continued dialogue at the UEIP, the large catchment scale and at the MCMF, the sub-catchment scale, delayed the process of creating socially robust knowledge. Since socially robust knowledge is as a major construct of social learning, particularly in inspiring critical factors such as shared fact finding, the involvement of the civil society as contributors and the existence of spaces where information can be cogenerated to inspire collective action is important, but this is again lacking in application outside face to face meetings for the UEIP as well as the MCMF. This has been discussed also in Chapter 4.

"*…all these different departments and organisations have different mandates for collecting and making information available…. Who is the central coordinating body for pulling everything that is relevant about the catchment... it's not something we can deal with within the UEIP*"

- Participant in Pietermaritzburg UEIP, 16 July 2017

Creating information systems to support stakeholder interactions, social involvement and socially robust knowledge generation is clearly a necessity for a catchment such as the uMngeni, yet achieving this is very tricky as the choice of information systems to manage information is not an easy one furthermore, the respondent's comments in the UEIP and MCMF interviews showed that such stimulus was lacking and that stakeholders identified a need for the use of ICTs to provide a means of creating socially robust knowledge but they also felt incapable of doing it themselves. The linkage between a self-sustaining collective intelligence virtual space that feeds into creating socially robust knowledge seems farfetched and yet it is a process that has been shown to be possible (Nowotny 1999; Heylighen 1999).

Unlike the UEIP and the MCMF, the LCPGs of the upper uMngeni catchment in particular, had frequent contact and resulting collective action with the help of expert knowledge as already discussed in the sections above. Furthermore, it is clear that other constructs of social learning

[75] Findings pertaining to multi-stakeholder engagement face to face and the expression of socially robust knowledge was detailed in the previous chapter: Chapter 4, Section 4.2.2

such as, stigmergic processes and in some cases the Ice Berg Model of story-telling (Section 5.1.4), lead to the use of ICT supported tools such as Google Earth placemark mapping as already discussed in the preceding subsections. This had a positive effect on the interactions between these stakeholders in the LCPGs[76] face to face interactions which is important for the development of socially robust information. Moreover, in this research it was also found that the appropriate use of cell phones combined with GIS to communicate at the local community scale was most effective at building socially robust knowledge since it addresses major issues in information sharing. These are mainly, accessing the group of stakeholders fairly by being transparent, frequently communicating and updating to facilitate the building of tempo and inviting social involvement by others either, directly or indirectly[77]. The ICT system is the place to put, geo-located and time stamped information "out on the table" and in one place and to allow stakeholders to question it and to form relationships between the various elements of the overall puzzle. For this reason, it is imperative that stakeholders in a multi-stakeholder group engage frequently not only face to face, but also virtually in a common space that has time and geo-location capabilities to share and build on ideas (Barre 2010).

Since the ICT system is the place to put that information "out on the table", in one place and allow stakeholders to question it and to form relationships between the various elements of the overall puzzle, it is imperative that stakeholders in a multi-stakeholder groups engage frequently. This is not only face to face, but also virtually between face-to-face meetings. When stakeholders are separated by time and space and cannot all be in the same physical room at the same time, then being able to engage the emerging puzzle (system) through the stigmergic processes in information systems is a cost effective and practical way to stay mentally connected and it is one that can be achieved through information systems such as the Mathuba WIKI. This is what the LCPG stakeholders did using various ICT supported tools; from cell phones and social media to computer assisted online mapping programs like Google Earth, all this made them better equipped to build

[76] While there are various groups LCPGs in the uMngeni Catchment- this research again focuses on those in the upper uMngeni Catchment, specifically those that are made up of the Enviro-champion members such as the Mpophomeni Enviro-champions (MEC).

[77] Transparency and openness and building Tempo are all complimentary constructs of social learning already reviewed in Chapter 2, sections

socially robust knowledge. The use of emerging information systems such as the Mathuba WIKI can serve to increase the likelihood of this happening as it situates all activities contributed by the civil society with regard to approaching wicked water and environmental problems online.

5.1.6 Transparency, inclusivity and trust

In order for transparency and inclusiveness to exist outside face-to-face meetings, stakeholders need an integrated information system that "represents" them and their work. In this research, it was found that this information system was needed for the larger catchment management groups (ie UEIP and MCMF); to be a platform that is open and accessible for others to view and critique. It was found that the various kinds of Enviro-champions in the uMngeni Catchment who had engaged in citizen science activities were connected in such a way virtually. Unlike the larger catchment management groups such as the UEIP and the MCMF who had no such organized information system, the stakeholders of the LCPGs through their ICT processes and procedures, developed for themselves, greater opportunities to show their commitment to transparency, inclusivity and trust building and thereby contributing to social learning and further encouraging social learning using ICTs in their own groups. Table 4.7 showed how transparency, inclusivity and trust as a combination of phenomena's acting together differs in each scale of multi-stakeholder engagement investigated in this research.

Stakeholders who were interviewed in the uMngeni catchment showed awareness of the importance of having a transparency in information systems outside face to face interactions as a requirement. This was even deemed to be important in overcoming persisting water issues in the catchment. Consider the response below.

"Everyone has their different expertise and if everyone shares their results, it builds a more accurate picture to work with. So finding solutions to the problems that arise are easier because essentially the foundation work is there."

- Participant in Pietermaritzburg MCMF, 10 October 2017

The MCMF, much like the UEIP, did not have an integrated information system that was transparent and inclusive. This again lowered the ability for this multi-stakeholder group to be transparent, inclusive and in support of social learning

Contrary to groups such as the MCMF and UEIP, groups such as the MEC (Mpophomeni Enviro-champions) and other various formal and informal stakeholders who form an active part of their LCPGs were again, benefiting by being united in information sharing. Common projects and frequent meetings assist in this and so too do frequent meetings assist in forming relationships built on trust. However, without having a common repository space to share common information about the catchment, stakeholders may not be capable of embracing this construct of social learning fully.

By having such a system to include their work, transparency in terms of what work they were involved in was created and so too was a degree of trust from observing stakeholders who do not form part of the local community. Such transparency and awareness of what other smaller groups of local community level stakeholders were doing kept them connected as part of a united group of stakeholders who are dedicated to making a change. Such inclusive engagement has further made them resilient and able to approach water related wicked problems with the potential to make real change. All of these reasons favored social learning.

5.1.7 Cultivating meaningful participation

A key finding in this research was that when the participation of stakeholders in a multi-stakeholder group does not lead to socially robust (also known as *actionable)* knowledge[78] as described above, it is not meaningful. While building institutional memory of the catchment is possible through transparency and inclusiveness of stakeholder information management systems, it was also found that cultivating meaningful participation in such virtual spaces is just as important in the uMngeni catchment. In this research it was found that the use of ICTs in communicating

[78] Or Socially Robust Knowledge

findings concerning water in the catchment by stakeholders in the LCPGs, was useful in getting meaningful action taken towards addressing any identified issues. Furthermore, this information was able to be shared to stakeholders in both government and non-government authorities telephonically and even graphically using the ICTs available. Such involvement through active information sharing with others, attracted participation and resulted collective actions being taken which suggests strongly that the participation in the LCPGs was meaningful. Expert stakeholder belonging to the UEIP and the MCMF did not make strategic use of information systems to participate meaningfully which significantly lowered socially robust knowledge generation and social learning potential.

Table 4.7 shows how cultivating meaningful participation as a phenomenon that supports social learning differs for each scale of multi-stakeholder engagement investigated in this research. Stakeholders in the UEIP and MCMF participated in a formal presentation followed by questions and answer sessions, which in most cases were very brief. This form and level of engagement did not lead to openly meaningful participation and or deeper relationship building within such groups. An observation that is made worse by the long gaps between meetings and the increasing information generated by different organizations without a collective space to be integrated, critiqued outside face to face meetings. The response below by a member of the UEIP supports this conclusion.

"…Information management is …a massive challenge because the people are generating information and data at such a rate, in such different formats for different purposes, … it doesn't have some kind of collective platform for managing it and making it accessible to role players in a simple but meaningful way…."

- Participant in Pietermaritzburg, UEIP, 17 November 2017

On the other hand, from observing and engaging with information supplied by the LCPG using integrated information systems, it was found that by their utilizing of available technologies, including the emerging Mathuba WIKI meaningful participation developed further through energy flows and tempo stimulated by the information exchanges. This strengthened stakeholder

relationships within the LCPG and between the LCPG and larger multi-stakeholder engagement groups such as the UEIP and MCMF, gaining recognition and attention for their work and activities within their catchments. This would not have been possible, had the stakeholders in the LCPG been unable to learn how to communicate the information they had on the catchment effectively to experts- translating information from pieces of paper to a live virtual platform that tells a story about the catchment. Such stories covered what and where pollution monitoring is taking place and where bio-monitoring and testing is being done and how to get into contact with stakeholders involved in all such efforts. For instance- a trained member of the LCPG in Mpophomeni and the MEC (the Mpophomeni Enviro-Champions) used his ability to project the messages of what work the MEC group was involved in and the findings they were gathering with the help of available ICT tools and features such as heat maps; GIS place mark mapping of monitoring efforts as flags or place marks and other analyses from his base of spreadsheets of data. Such capabilities were profound to observe. All of this made the stakeholders at the LCPG more involved in making their participation meaningful and therefore this had an observable impact on them as well as the expert stakeholders belonging to larger multi-stakeholder groups, who observed their work. .

5.1.8 Citizen Science Agency

Table 4.7 in Chapter 4 shows the results of an assessment of how cultivating citizen scientists helps to create citizen agency, which is in a sense is the ability to act meaningfully and as such supports social learning amongst stakeholders at the local community level. This citizen science differs from each scale of multi-stakeholder engagement investigated in this research

The assessment covered citizen scientists from the LCPG and sometimes isolated groups of people that later joined or became part of a LGPG such as organized Enviro-champions with community representatives as described in Section 4.1.1, Example 3. These citizen scientists developed the ability to communicate information pertaining to the catchment effectively to lay persons and professional managers operating in the water related space, in the catchment. Furthermore, because of this citizen science agency as an attribute of social learning expressed by various stakeholders in the LCPGs, grass roots stakeholders were able to minimize knowledge power disparities. This

was even more evident as this citizen science information was housed and could be shared in open and transparent virtual spaces such as Google Earth (explained above in Section 5.1.3) and fusion tables (Section 5.1.3 and 5.1.7). While the results of citizen science activities were admired and appreciated by the larger multi-stakeholder groups who were engaging at catchment level, these groups which included the UEIP and MCMF faced their own challenges when it comes to the power of knowledge. When one or more stakeholders hold superior knowledge power over others, trust is put in jeopardy and in some cases it was observed that deception or suspected deception can take place in face to face meetings. For the UEIP, some stakeholders became aware that a distorted picture of what was happening in the catchment or sub-catchment was developing. However, not including citizen science information as an additional source of insights on the true causes of wicked problems major wicked problems of the uMngeni catchment such as water quality decline was a disadvantage. Facts on wicked problems such as the poor water and sanitation infrastructure in impoverished communities being the cause for poor water quality in many streams along the upper and lower uMngeni catchment were not realized fully until the use of ICTs and citizen science (Ward 2016; Dent 2007). A lack of incorporation of citizen science particularly in ICT platforms led to distorted insights in larger catchment management groups and posed a disadvantage for the much needed, collective action.

While the stakeholders belonging to the UEIP and MCMF were often heard to embrace the information that was produced through monitoring efforts and other citizen science based activities, they practiced, limited engagement with the information, in their virtual platforms and even in face to face biannual meetings. For instance, cellphones and social media, with the use of WhatsApp specifically was useful in enabling stakeholders at the grassroots to share information and was useful in lowering the number of unaddressed cases of sewer line malfunctions[79]. However, this method of using social media was not translated into similarly appropriate ICT

[79] DUCT initiated a monitoring project of manholes in many sub-catchments and areas of the upper uMngeni Catchment using grassroots and community originating Enviro-champions. Using WhatsApp stakeholders belonging to the MCMF were linked to receiving updates on what manholes needed fixing and other pollution and water based information in real time. This method of monitoring by stakeholders in the MCMF was part of a greater project of the uMsunduzi Rehabilitation and was successful in keeping stakeholders aware to a certain degree of monitoring efforts through citizen science.

applications at the UEIP level. Furthermore, the monitoring efforts using Google Fusion tables was not up scaled or embedded into more interactive and integrated virtual platforms by these "expert" stakeholders.

Social media and the sharing of pictures is useful in exposing catchment snapshots in time and location as described in Section 5.1.2 for mobilizing collective action spaces and developing citizen agency as a construct in support of social learning. However, if the coverage is limited to cell phone apps such as WhatsApp then only those in the social media group get the information. Hence the valuable citizen science information is not always open to more stakeholders, in formats and platforms that encourages helpful discussions on persistent wicked problems. Moreover, while very useful in connecting willing stakeholders to citizen science information; cellphones and picture sharing snapshots such as the ones depicted in figure 5.1 in Section 5.1.2 still need to be used in virtual platforms that allow all stakeholders to engage with the information meaningfully. WhatsApp groups also do not prevent irrelevant information unrelated to water and monitoring from being shared in the group. The discipline of placing an Ice-berg formatted Story onto a shared Google Earth map, can act as an effective filter to such "clutter", the researcher as an observing member of all 3 sized groups found that tendency to irrelevant Whatsapp messages that created clutter, was a disadvantage and irritant to many expert stakeholders. Furthermore, such picture based information with no story or discussion initiated, remains simply pictures and invites thoughts of "so what", which are disempowering. While such pictures could effectively move government officials who are responsible for implementing repairs and quick fixes, to do so, more promptly, in identified locations, it did not contribute to the long-term goal of institutional memory nor did it do much fore stakeholder engagement groups, by showing the power of citizen science in making ordinary community activist into citizen science agents.

One of the significant findings pertaining to the use of information systems in the LCPG scale was that that citizen agency was active on the ground and on online virtual platforms. The power to project a message and to reveal a picture of what is going on has been hugely amplified by the ICT platforms, particularly Google Earth based platforms. The stakeholders at LCPG scale did exceptionally well in showing an overall picture of what is happening in their sub-catchment with the aid of social media sharing as well as Fusion tables for graphing a time series of observations

and even the use of available websites; including the miniSASS website and the emerging Mathuba site. [80]

5.1.9 Self-identity role in social learning

The self-identity of stakeholders is how they perceive themselves and this is, to some extent influenced by how they are perceived by others as well. All stakeholders in the three different scales of multi-stakeholder engagement groups expressed the feeling that they are important, to the health and well being of the catchment. Stakeholders belonging to the LCPGs expressed how the use of ICT systems was valuable in developing their positive "*we are part of the solution*" self-identity. Of particularly significance was the fact that the LCPG stakeholders could engage and communicate comfortably with stakeholders in larger catchment management groups such as the UEIP using the ICT generated information. To put this into clear perspective, the assessment reflected in Table 4.7, Chapter 4 is used to reflect on how the current self-identities of stakeholders in the uMngeni catchment affects their ability learn socially.

The LCPG used graphs, tables and diagrams in their meetings with the UEIP and MCMF stakeholders to good effect. Stakeholders in these larger multi-stakeholder groups saw stakeholders originating from the community multi-stakeholder groups as valuable contributors of the knowledge space concerning the catchment. Such positive feedback further provides an incentive for the use of emerging ICTs such as the Mathuba WIKI and MIKE INFO to support social learning.

Stakeholders at the LCPG scale also emphasized a deep desire to promote their work beyond the uMngeni catchment, not only in South Africa as they have successfully been able to do but to influence opinions internationally, regarding the value of their work. Their development of new applications on top of the base information is a significant indicator of their change in self-identity

[80] Further details of these findings is given under Section 5.15 where the Mathuba WIKI and MIKE INFO are discussed in terms of findings in experimenting with their use for the uMngeni catchment as practice architectures and safe spaces to experiment.

and self-confidence. The response presented below from conducting semi-structured interviews with members of the LCPG revealed these common feelings of these stakeholder, showing their radical self-identity change as a result of the incorporation of information systems in their catchment monitoring work and citizen science activities.

"*…if you have a bigger format for reporting that you think other people can see, if you do not have maybe you can try and think how we can implement that. In other words, we know we are doing the good work but we haven't had much resources on how we can market the work globally*."

- Participant in Pietermaritzburg, LCPG, 17 August 2017

What is evident in the above statement from one of the Enviro-champs and from knowing his background is that he has transformed from feeling like a helpless victim of his grim circumstances to a person who is wanting to market his work and that of his colleagues, globally. Moreover, such opinions are shared by many actors in motivated LCPGs such as the Mpophomeni Enviro-champions and their citizen science work has been popularized because of its success as already noted in the previous sub Section, 5.1.8. There was no such evidence of self-identity transformation in the UEIP or the MCMF. Stakeholders are aware of who they are as experts and contributors of scientific expertise, yet wicked problems surrounding water are still not successfully addressed, interpreted or approached in a way that will yield sustainable results for all stakeholders in the uMngeni catchment.

Wenger (2009) emphasized that self-identity is the key to learning. If the self-identity of a stakeholder is that he/she is legitimate or that he/she is a valuable part of the social dynamic and has a positive and wise role to play, then that stakeholder will engage the learning process in a positive way that is completely opposite to how that stakeholder would engage if they had exactly the opposite self-identity. LCPG stakeholders are also pursing learning as they are able to see that their participation in their uMngeni sub-catchment is transforming their identity as stakeholders who are motivated and activated to act on behalf of water resources at the community level. This observation supports findings on self-identity change by Wenger, (2009). It is evident that the

LCPG needs to be invested in and these stakeholders need to be supported for their citizen science work and enabled to participate meaningfully using ICT systems.

5.1.10 Lower transactional costs of engagement

Sharing relevant information is a core part of any meaningful stakeholder engagement process as well as meaningful participation and social learning as already discussed in the findings above. However, it can be costly, especially if it requires regular meetings face to face as it has been discussed in this research for larger groups such as the UEIP and the MCMF who engage on a voluntary basis (Section 4.1.2, Example 2). Such regular engagement is imperative for the stakeholders to understand their interdependency and build trusting relationships. Having a shared role definition has been identified as a key requirement for social learning. The introduction of ICTs has a positive effect in lowering the costs of engagement. The potential for social learning is increased as barriers to engagement are lowered. The internet and the use of open servers such as Google can be an advantaged for social learning as elements of ICT. The potential for the Mathuba WIKI to enable this beyond simply social media messaging applications deserves exploration as it enables stigmergic information processes to form and allows for online commentary and discussions to be geo-located and time stamped which brings invaluable context to the dialogue.

Relevant information that is designed to foster understanding and learning can have a significant role to play in allowing real change to occur and in addressing the most persisting wicked problems in a catchment. This research showed that when this sharing of information is expanded outside face to face it not only could allow better opportunities to form an institutional memory base for the multi-stakeholder group, but it also significantly lowers transactional costs of engaging. All multi-stakeholder groups investigated in this research that is the UEIP, MCMF and the LCPGs in the upper uMngeni catchment made use of lowering transactional costs of sharing information using ICTs. However, it was the LCPGs with the assistance of some expert stakeholders that were able to do this on a significant scale, more effectively and more consistently. The LCPG used a variety of methods of communicating that were both simple and user friendly. One of these was through social media and instant messaging, the other was email communication and the use of

tools for reporting at any given time such as the Mathuba WIKI. Moreover, the stakeholders at the LCPG could meet more frequently during the week and see in real time the causes of pollution and water resource degradation that they were working hard to monitor. Such issues and persisting wicked problems became a matter of concern to the stakeholders as they residing the community that these issues were occuring and conversation concerning the issues was constantly occurring between them. Even so, this research also revealed limitations of current methods of lowering transactional costs, such as them not being merged in more complete, integrated information systems for the greater uMngeni catchment stakeholders- many of whom are considered experts in the realm of water resource management.

The degree of application of this construct of social learning varies from each of the groups. The UEIP and the MCMF, only lowered transactional costs of sharing information marginally because they only used email. The MCMF arranged a more frequent system of emails from uMgeni Water for disseminating water quality monitoring. Below are some of the thoughts of stakeholders in the 3 contexts when asked about co-owning an information system that could lower significantly, the costs and raise the effectiveness of their engagement.

"I do appreciate the opportunity to get feedback from other people working in the catchment ….but I do feel frustrated that I don't think we necessarily make the best use of that time as I think it would be better if we share but then watch how we address some of the key issues in a more structured way."

- Participant in Pietermaritzburg *UEIP, 5 December 2017*

Stakeholders in the UEIP have similar views when it comes to the use of time for engagement in the space within the stakeholder meetings.

The LCPG stakeholders were in a better position to lower transactional costs of their engagement. They were already making good use of social media as already discussed, as well as various Google supported tools for virtual information sharing and mapping (ie. Fusion Tables, Google place mark mapping) and citizen science information. The example of Sibongile, an environmental champion in the Shiyabazali informal settlement, Howick Upper uMngeni catchment, is one such

example. Sibongile was unemployed and lived in an informal settlement where an open storm water drainage pipe ran. Sibongile also lived a fair distance away from other enviro-champions and was still interested in the environment but also in the health and safety of the members of her community to which the storm water and the potential pollution it brings from upstream was affecting. After being an enviro-champion with the heal of WESSA and DUCT and being trained to use citizen science tools to test turbidity, Sibongile began her monitoring of the clarity and turbidity of water that was gushing downwards through storm water drainage pipe in the informal settlement. The value of her engagement at the LCPG scale largely did not come from engaging on arranged face to face meetings held at different intervals of the year, it was from her gaining the ability to use picture sharing of her monitoring efforts with expert stakeholders also engaging with her at the LCPG scale. Raw results of clarity were collected from visualized data collected by Sibongile and send to GroundTruth using social media. Using citizen science turbidity test tools developed by GroundTruth, this LCPG member took readings of the turbidity in the Howick Waste Water Treatment Works (HWWTW) outlet channel that flowed past her informal settlement community of Shiyabazali. She took grab samples of the water at 8 am, 12 noon and 5pm. She then took pictures of water samples and transmitted them to a mentors in WESSA and later DUCT on a daily basis. The water clarity was then determined according to GroundTruth standards. Her efforts were invaluable in helping experts analyze the water clarity from the HWWTW outlet using ICTs and mathematical calculations for determining the level of suspended solids and what that meant for the quality of water flowing through the community from upstream. All of this engagement with the local based stakeholder's information was possible with limited face to face meetings and showed the possibilities of the ICTs in communicating citizen science information to experts, particularly through the Mike INFO system, at the more advanced end of the ICT spectrum. The diagram below is a step by step process of how the citizen science, described above, was used to communicate trends of water clarity changes overtime and further, how the Mike INFO system can be used as a sophisticated platform to communicate these and lower the transactional costs of the citizen scientist in the LCPG. Through a process of participatory action research (PAR), the researcher was able to use the given spreadsheet of information in order to show how the Mike INFO information system was able to display these data in a meaningful way. As seen in the diagram, the research showed how by clicking on the GIS place mark map of the exact location where the monitoring of water clarity in a storm water outlet in Shiyabazali on the

Mike INFO- Platform user interface opens the time series information of turbidity (an interpretation of clarity).

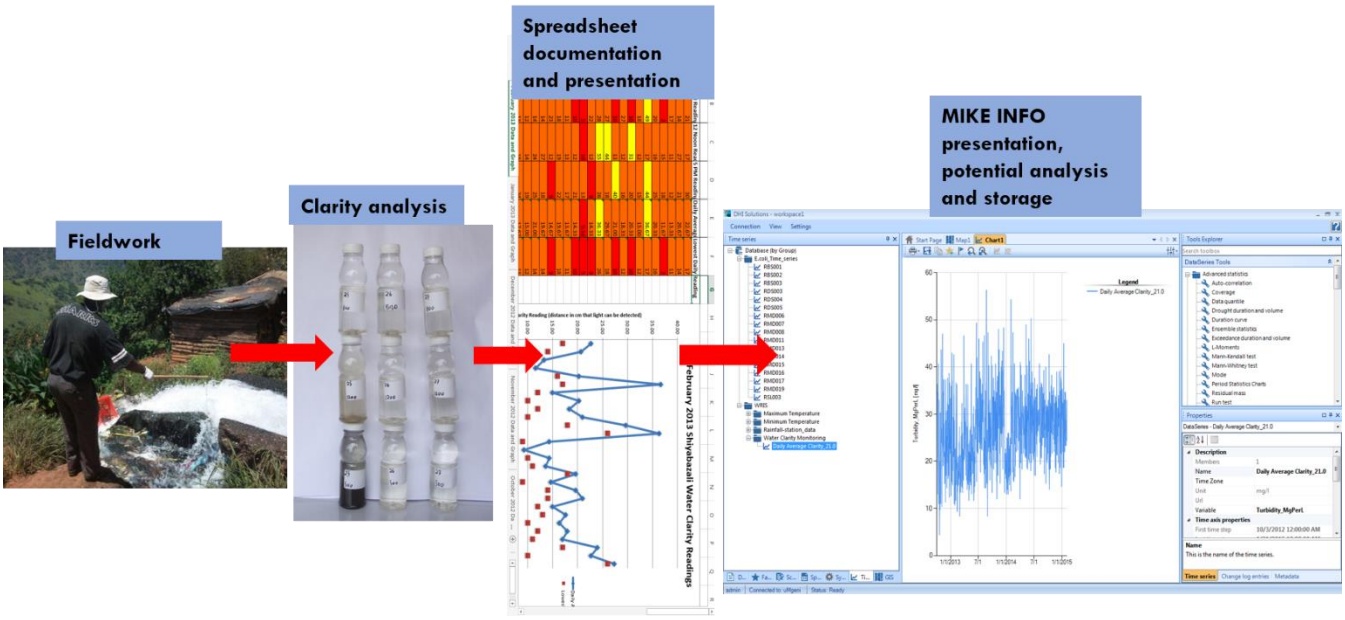

Figure 5.6 A process depicting the flow of information from a citizen scientist testing and monitoring of water clarity, to a sophisticated, point based, time series graphing system on the Mike INFO, platform interface.

Such applications are beneficial to the support of LCPG and they allow work to be tracked and for these stakeholders to be given monetary rewards for their monitoring efforts. From this example of a stakeholder of the LCPG, it can be seen how appropriate the use of information systems can be in lowering transactional costs of the multi-stakeholder engagement even in disadvantaged communities, who work with NGOs. Lowering transactional costs of engagement for the LCPG of stakeholders using social media and information sharing systems empowered their ability to engage with "expert" stakeholders as well as increased the likelihood of their being rewarded in monetary terms, for their hard and useful work.

5.1.11 Co-generation of information and knowledge

In order to form more of a holistic understanding of the catchment it was evident from this research that information needs to be integrated. For this to be possible, co-generation of information and knowledge needs to be practiced in the uMngeni Catchment. Furthermore, as a best practice to the co-generation of information, the energy flows and tempo that enables the effective information co-generation is in the uMngeni catchment beyond face to face interactions in multi-stakeholder groups, needs to be understood and facilitated.

Emerging information systems such as the Mathuba WIKI were an example of the importance of an abundance of information that is credited to multiple stakeholders. Furthermore the ability to share such information with others through the internet at the click of a button without having to go through the challenges that come with sustaining the energy flows and tempo through face to face interactions between stakeholders. This co-generation of information and also knowledge is fundamental to the processes of building a trusting relationship around the emerging understanding of the systems between the stakeholders themselves.

The application of ICTs as a space to build and sustain the flame of information co-generation is imperative to support social learning incentives. The researcher's own experience in using the information systems and in observing how stakeholders in the various levels of multi-stakeholder engagement showed that the quicker and more consistent the information is shared to stakeholders, the greater the potential for them to go through iterative processes of learning and discovery. This finding is consistent with what was found in literature concerning the role that the researcher plays in discovering this about stakeholder relationships as an active participant in the space, as well as how information systems affect such stakeholder relationships (Gibbon et al., 2004). The evidence revealed in this study showed that the LCPG context (Enviro-champs) was a better setting for such information co-generation, sometimes with the assistance of expert stakeholders, from the UEIP and MCMF and those of local NGOs. However, some stakeholders in these larger groups show signs of not being aware of the importance of information co-generation using ICTs, especially in sustaining the sharing of information and experienced outside the long periods of time without meeting during the year. It was concluded that the LCPG and its regular use of the information

gathering and sharing using ICTs, including emerging technologies such as Mathuba, placed them at the best position to lead in the co-generation of information in virtual platforms.

All stakeholders in the three different multi-stakeholder groups investigated, agreed that an integrated information system needs to be pioneered in the uMngeni catchment due to its ability to support the creation of a whole system institutional virtual space. This was particularly clear in the sub-catchment management group, the MCMF and the large catchment management group represented by the UEIP. For the UEIP for instance, an information system that was wholistic, with co-generated information from different stakeholders was an issue that was consistently mentioned in the semi-structured interviews. However, this group of stakeholders seemed to be content with the idea of having only expert supplied information from research reports to be contributed in the integrated knowledge space. This can be noted from the different expressions received such as the ones documented below.

"I think its important people have confidence in the people who are managing it and the system that has been selected and how it is structured"

- Participant in Pietermaritzburg, UEIP, 18 September 2017

For stakeholders belonging to the MCMF, similar feelings about the responsibility of managing a truly wholistic and integrated system came into discussion during the semi-structured interviews. From the responses, it is evident that these stakeholders while being in support of the co-generation of information and co-ownership of an information system that allowed it, were hesitant or unmotivated to make use of available emerging information systems such as the Mathuba WIKI. Questions such as '*who will manage such a system'* and whether the desired information system should truly be co-owned were raised and could not properly be answered in the semi-interviews with stakeholders operating at the UEIP level.

This was not the case for stakeholder's engaging at the MCMF. Stakeholders at the MCMF were in agreement with the use of information systems to support engagement outside the space of

meeting collectively. Consider the statement made below which revealed that there was a lack of awareness of the importance of a true whole system institutional virtual space for the co-generation of information.

"I believe it must be possible…I think given some goodwill there is no reason to why it shouldn't be possible. It's a question of overcoming people's territorial view of them requiring to own information. People need to be prepared to share the information. Once that is done, we are fine."

Participant in Pietermaritzburg, MCMF, 7 July 2017

Certainly one of the hindrances to applying valuable of information systems is people's personalities. Even though the collective management is good in that it distributes power, it can still mean some stakeholders hold back their information, which means the goal of collective learning through integrated information, is met with some challenges. However, theoretically this challenge can be overcome with time as trust is built and fears are overcome by stakeholders with the strengthening of their relationships. In line with Theory U of learning, stakeholders would have to move beyond stages of 'downloading' old habits of stakeholder engagement (Scharmer, 2009) and embrace the need of sharing their own information to the collective in order to create whole system institutional virtual space. The more individuals become aware of the benefits of information co-generation through the use of ICTs, the more inclined they would be to sharing information which would in the long run improve their relationships and build the trust between them. Regarding their personalities, it is evident that some stakeholders in the MCMF also realize that self- identity change is possible with stakeholders who feel the need to be territorial about information. In support of what is known from literature, such views support the understanding that ICTs can improve processes of communication which leads to increased degrees of understanding between the stakeholders. If this process is facilitated through the use of ICTs then an environment where reflection, dialog exchange and deep learning can be created which will help push past some of the challenges to information co-generation and social learning as stakeholders learn each other's views and perspectives and avoid misunderstandings (Gibbon et al., 2004; Scharmer, 2009).

Such a positive view by the MCMF stakeholder on the application of ICTs to facilitate the co-generation of information is further supported by the fact that there was a reported interest noted by the research for the adoption of information systems in supporting engagement at the MCMF during the time of the research. This was documented in Chapter 4, Section 4.1.3, Example 1.

Various stakeholders at the LCPG scale expressed the need to move towards an information system that was truly inclusive of their contributions. Stakeholders in the LCPG had proved to already be capable of developing skills to add information of their work within integrated information systems. For instance, in the monitoring of manholes project in the Mpophomeni township one of the enviro-champions leading the LCPG at the grassroots level who was able to effectively transfer raw data collected by the group into a sophisticated ICT display platform showed the growing capacity of stakeholders at the LCPG scale[81]. The transfer and translation of raw data and numerical information of monitored observations at sewer manholes into tables, graphs of trends and 'heat maps' of problematic manholes in the sites next to water bodies using Google Fusion tables. This work has become a valuable source of inspiration to many other stakeholders in the uMngeni catchment. The trends that emerged from plotting this information on various time lines, helped powerful and influential stakeholders in the catchment, to better understand the growing dangers that they faced from steady pollution of the main drinking water dam that feeds cities that represent 10 percent of South Africa's economy. Stakeholders at the LCPG scale were thus successfully able to not only share information in their own engagement spaces, but were able to communicate effectively and consistently the monitoring that was involved in their catchment and what it meant for streams, rivers and water bodies connecting the wider range of stakeholders in the uMngeni catchment.

[81] Section 5.1.3 has already mentioned the name of this enviro-champion as being Ayanda Lipheyane. He already had some computer skills but he was specifically trained by researchers of the University of KwaZulu-Natal to start transferring the information into spreadsheets that could be interpreted into Google fusion tables- an online ICT platform. Details concerning this project and the roles of the researchers in transferring such skills are mentioned in more details earlier in this chapter.

This research thus showed that LCPGs such as the enviro-champions in communities involved in various citizen science related activities and information management work needs to be at the forefront in helping stakeholders in the co-generation of knowledge. Using their acquired skills in the use of ICTs and in order to ensure that a common vision for the catchment is shared and that it embodies the thoughts of a variety of stakeholders. These findings showed that stakeholders engaging at the community level can be placed at the forefront in helping other stakeholders to co-generate information. Furthermore, this research has also shown that when stakeholders work together to openly share what they know concerning the catchment using ICTs they engage in a process of information co-generation. With the co-generation of information, a more complete picture of the catchment can begin to form, even when stakeholders do not see each other face to face on a regular basis. The effects of opening up knowledge in the minds of stakeholders engaging in different levels of their multi-stakeholder groups can open up their rationality in topics concerning the complex catchment that they may have previously been unaware of, or uneducated about.

5.1.12 Bounds of the group's rationality

The capabilities of ICT systems in helping to expand the boundaries of the group's rationality in different ways and in all scales of multi-stakeholder engagement considered in this research. This is what is discussed in this subsection and analyzed from the views of stakeholders.

When stakeholders belonging to the different scales of engagement, participate meaningfully using ICTs, then information not previously known, is enabled to come to the surface and overcome areas of bounded rationality. This was particularly true for the LCPG stakeholders, who demonstrated effective ways of participating meaningfully with ICTs to present information concerning their catchment monitoring efforts. Using, graphs, and live maps of point sources of pollution- these stakeholders were able to educate others from larger multi-stakeholder groups including the UEIP and MCMF. However, despite this demonstration the key elements of the processes to widen the bounds of the group's rationality in the LCPG, such processes were not taken up by the MCMF and the UEIP to any meaningful degree.

Government authority personnel who are members of the UEIP and the MCMF could thus learn from the socially robust knowledge provided by the LCPG, and widen their previously limited understanding of the poor infrastructure management in some areas of the catchment that are causing pollution. Such unlocking and opening up of knowledge spaces helps to overcome bounds of rationality and supports the processes that increase capacity for social learning as discussed in Chapter 2 and Chapter 4.

Findings concerning bounds of rationality in the uMngeni catchment and its relation to the use of ICTs shows that each time a new piece of information is added to the integrated knowledge space using ICTs, the stakeholder's understanding of what is going on in the catchment, deepens. This supports the process of learning as explained by Theory U in Chapter 2, Section 2.4. Despite these observations and appreciation of the LCPG as groups of motivated members of society or citizens, there was no clear indication by the UEIP embedding the LCPG knowledge and information in common platforms where local knowledge contributed by the layperson or civil society could be included into long term decision making and accepted as a meaningful participation in the dominantly science 'agora' (Nowotny 1999). Organizations such as GroundTruth develop and create a space for citizen science information in the form of bio monitoring and miniSASS mapping on their website are signs that this can happen at a larger scale and that science dominated spaces can be inclusive and thereby increase the bounds of rationality of multiple stakeholders.

5.1.13 Stimulating appreciative inquiry

In this research it was found that stimulating appreciative inquiry is possible through the strategic use of integrated information systems and is highly dependent on the relationships stakeholders form with one another based on how much they appreciate each other's contributions to the greater knowledge space. Table 4.7 showed results of the assessment as to the effectiveness of ICT to stimulating appreciative inquiry and thereby social learning at 3 different multi-stakeholder engagement scales.

The findings for appreciative inquiry in improving social learning in the uMngeni catchment which would not be possible through exploring the full benefits of integrated information management

and modelling systems (IIMMS) such as the Mathuba WIKI. The findings were in line with the definition of appreciative inquiry described briefly in Chapter 2. Showing appreciative inquiry in a multi-stakeholder engagement space means asking questions in a way that seeks to deepen common understanding and to bring the person being asked the question into the conversation. This is contrary to asking questions in what could be construed as an accusatory manner. Research findings showed that the interactions between stakeholders was enhanced by the stigmergic processes of recording events in the Google Earth based ICT systems which then provided the questioner with a ready base from which to formulate an appreciative inquiry. The questioner could begin the appreciative inquiry by acknowledging the contribution that is captured in the ICT system and then advance the opportunities to learn more by formulating an appreciative question. At times these appreciative inquiries from expert stakeholders in the UEIP and MCMF to the LCPGs even opened pathways for the former's continual funding support for local projects.

On the other hand despite the good efforts of individual stakeholders, due to dominating attitudes between "expert" stakeholders engaging in the UEIP and MCMF groups, productive steps towards appreciative inquiry were hindered using the time of the research. As a result there was an indication that trust and dominating self-identities were present and that mutual trust was hindering the appreciative inquiry process.

Appreciative inquiry as a construct for social learning benefited stakeholders interacting at the LCPG scale. The case of the Mpophomeni Enviro-champions served as an example of this and showed that this group benefitted the most from appreciative inquiry. Such inquiry came from stakeholders engaging in the large catchment management groups like the UEIP. These stakeholders observed how ICTs were used at the LCPG scale to communicate information, such as sewer manhole discharges in the community and how awareness of such information could be used to, effect timely interventions to unblock sewer lines and hence lower the harmful effects on water quality. This was just one observed example of how the use of ICTs, such as fusion tables, also led to an appreciative inquiry by expert stakeholders to community based activist groups. Furthermore, since it is preferable to pose the questions towards the "growing systemic picture in the middle of the table", in this case through a common ICT platform rather than at the person/s in a manner that seeks to put them on the spot, the use of ICTs to improve appreciative inquiry is

worth considering in the uMngeni catchment were attitudes and self-identities can be a hindrance to public face to face dialog.

It is also true that there is also a matter of stakeholder motivation to inquire appreciatively of one another's work as they work in the same area. For instance, the frequent meeting of the stakeholders of the LCPG in Mpophomeni as well as the fact that they were residing in the communities heightened the urgency to constantly communicate with one another to solve problems waste management and pollution occurring affecting water quality in their catchment area. Moreover, as such citizen activities became educated about the value of water resources and the role that a community plays in its health, their self-identity changed and they approached such issues with a sense of responsibility and an awareness of the importance to work together towards a common problem that affected all of them. However, in the case of the LCPG this was not only isolated in the Mpophomeni township, but enviro-champions in this area also saw the value and the need for communicating with enviro-champions throughout the catchment who faced similar issues concerning water resources as well as stakeholders who did not belong to the uMngeni catchment but shared the same challenges that they faced. The statement quoted below shows how much the stakeholder values and takes pride in being able to communicate the work that he is involved in using ICTs with stakeholders in the catchment and around the world. ICTs opened the way for expert stakeholders to engage in appreciate inquiry of the success of the work that he and many other stakeholders at the LCPG level have engaged in as seen in this quoted response from a key informant in the LCPG of Mpophomeni.

"Citizen Science tools and Mathuba can help other stakeholders to be aware of what we are doing and they can be involved…the use of social media and ICTs has helped [us] a lot. When I present the work that the enviro-champions have been doing- using pictures, the internet and the computers [it has] helped other people know about the work that we do, even people in Europe. That has made me feel so good! Lots of people from around the world have been interested in the methods used in Mpophomeni. After my presentation in Stellenbosch, twenty people came to ask me how they [could] implement this in their areas because we are all affected …[by] similar problems. If there are people in higher organizations who see what we are doing and they want to implement it to see if its working, it makes us proud!"

Larger multi-stakeholder groups such as the UEIP and the MCMF were limited in their engagement due to the long period of time between stakeholders meetings: bi-annually for the UEIP and four times a year for the MCMF unlike the LCPG in the Mpophomeni Township that met weekly and engaged on a near daily basis, using cellphones and face to face interactions. In the UEIP and the MCMF, the long periods without face to face meetings, as well as the poor use of ICTs by the collective of stakeholders in engaging with each members supplied information pertaining to the catchment meant appreciative inquiry of each other's work when needed was rarely practiced and interactions often followed a format of keeping up to speed with the activities and projects that have been ongoing within the past six months by certain members of the group. This method of engagement provided structure and ensured that the stakeholders were engaging with the motive of following a system set in place to coordinate the groups as they were mandated to according to certain predetermined objectives for the engagement as was the case of the UEIP. This organized and formal approach of stakeholder interactions was described well by one of the key stakeholders of the UEIP in the fowling quote and showed the context and circumstances to which appreciative inquiry would have to occur.

"The governance structure of the UEIP has a coordination committee…and we have a research subcommittee… we have demonstration projects that we agreed on in the inception of the UEIP- things that we would focus on, put out energies on to. Yes there are other things happening and organizations have their own mandates going on between and some of those do play a role in the work that we do. But as a whole, but in terms of the governance of the UEIP- there are three demonstration projects that are headed by these three municipalities. So our focus at the meetings is obviously going to be feeding back on the progress of the demonstration projects to the coordination committee."

The UEIP was highly organized and had a highly structured governance structure with hierarchies of reporting and engaging with the general focus of the meetings being to assess the progress of ongoing projects and reporting back into the coordination committee. However, this highly organized structure does not seem to provide enough time for stimulating appreciative inquiry to stakeholders who may share new thoughts or unique views and insights than the ones the group had been accustomed for the past six months. The group also does not have or make use of a

functioning information system that allows new assumptions and knowledge views to be surfaced outside the organized meetings and appreciated by others. Signs of this disadvantage of the group were evident in the responses received to semi-structured interview questions. The absence of actively used integrated information systems as virtual spaces of engagement limits the great number of stakeholders in the larger multi-stakeholder groups such as the UEIP and the MCMF from fulfilling their place in the group as essential knowledge contributors. This was evident during face to face meetings as already discussed in Chapter 4. The stakeholders in the UEIP and the MCMF may have also lacked the motivation that the stakeholders at the grassroots level had. These LGPG stakeholders saw the effects of persisting wicked problems such as pollution from poor waste management and poor public service delivery, particularly pertaining to sanitation in their communities on a daily basis. Unlike the larger groups whose main domain of engagement were scheduled meetings for discussion on issues arising based on the agenda, the stakeholders at the LCPG level confronted issues daily which heightened their sense of urgency to talk about them- particularly as they become more aware of the adverse effects of pollution on water resources overtime. In the UEIP and the MCMF this may have not been the case. Moreover, in the UEIP and MCMF the attitude between stakeholders at times was confrontational with some stakeholders feeling the need to defend their place in the group when their information and contributions to the group, as organizations, were poorly understood or poorly supplied. To this, the UEIP was observed to be least effective in supporting appreciative inquiry and hence its social learning was impaired.

Appreciative inquiry as an observed phenomenon in the uMngeni Catchment can thus be said to have a high potential of encouraging social learning when ICTs are included as an additional aid of communication outside of face to face multi-stakeholder engagement regardless of the contexts in which stakeholders engage- whether more informally like the stakeholders of the LCPGs or formally, like the stakeholders of the UEIP and to a lesser degree, the MCMF. The practice of appreciative inquiry in a group between stakeholders becomes evident based on how stakeholders feel in the group, how they are treated by others and how they are affected by the issue in question. This manner of inquiry is in stark contrast to an accusatory tone and "sharp" questioning that seeks to trap, belittle, demean and make irrelevant the person being questioned due to not understanding their stance or their contribution. However, in the uMngeni catchment, the practice of this

phenomenon associated with social learning is beneficial for building positive self-identity change from stakeholders in a multi-stakeholder group or out. The more wicked the problems faced in a catchment and the more complex they seem, the more it is necessary that stakeholders strengthen their bonds and relationships using a common information system that is integrated, open and transparent to all who carry a stake in the catchment. Furthermore, such ICT systems allow for any issues or inquiries or be directed towards the "growing systemic picture in the middle of the table" rather than at the person/s in a manner that seeks to put them on the spot. This would otherwise damage the potential for social learning. In terms of Theory U for learning, this appreciative inquiry in the uMngeni catchment will serve any multi-stakeholder groups in deepening their understanding because it increases stakeholder willingness to let go of an "old" understanding and let new insights come in, from others.

5.1.14 Practice architectures and models as metaphors

From the researcher's engagement with the identified integrated information management and modelling systems, opportunities of overcoming major prohibiting factors[82] to social learning were identified due to the new found abilities of users of the Mathuba WIKI and MIKE INFO to act as practice architectures, in which models are used as metaphors of the actual catchment. Both information systems are integrated in design, however, one is online based and open for viewing, the other; the Platform User Interface of MIKE INFO[83] was desktop based and only granted access to those having the program in their private PC. The latter is less of a drawback now, for multi-stakeholder engagements, because of the screen sharing capabilities of online meeting platforms such as Zoom. Both information systems, if used wisely, are forms of practice architectures, in which multi-stakeholder social learning can be advanced.

[82] Chapter 4 Section 4.3.2 identifies what the current prohibiting factors to social learning are in the uMngeni catchment.

[83] MIKE INFO user interface as it was referred in the official document for the then version of MIKE INFO 1.3.0.6 is the integrated user friendly part of the software. Both the MIKE INFO user interface (UI) and the Platform User interface are used to add or populate data as introduced in Chapter 2. Because of the encountered technical difficulties in adding data to the MIKE INFO UI, the Platform UI was used in most cases by the researcher.

It is widely accepted in scientific and business circles that well designed information systems and models can be safe spaces for stakeholders to experiment with ideas and perform "what if" scenario analyses, to stimulated both strategic and operational conversations. In a practical sense, the presence of these information systems and the related human practice architectures that housed them contributed to varying degrees of multi-stakeholder participation in the 3 geographic and organizational contexts studied in this research. As was shown in Table 4.7 all constructs reflected more effective social learning in the LCPG and this was, in part due to the much better use of ICTs in the LCPG. Both the MIKE INFO and the Mathuba WIKI showed potential of becoming safe spaces to enact virtual experiments.

5.1.15 Growing absorptive capacity amongst stakeholders

Absorptive capacity is the ability to absorb knew information and convert it into wise and actionable knowledge (Hughes et al., 2014). Growing the absorptive capacity amongst stakeholders to engage in social learning is centered on how much stakeholders engage in processes that support them meeting social learning requirements. Through observing and engaging with stakeholders in all three scales investigated in the uMngeni catchment, the researcher found that there were currently various opportunities for stakeholders to increase their individual's adsorptive capacities to engage in social learning. This was based on stakeholders exploiting the currently existing opportunities from projects in order to increase their potential to engage in processes of social learning. Table 4.7 in Chapter 4 shows how growing absorptive capacity as a construct of social learning not only differs from each scale of multi-stakeholder engagement investigated in this research, but that it also differs in its ability to grow depending on the current ICTs being practiced by a multi-stakeholder group and possibly through the use of the emerging Mike INFO and the Mathuba WIKI, depending on the features of each.

The researcher's own ability to create absorptive capacity was tested as she engaged with the ICTs being investigated in this research- the Mathuba WIKI and the Mike INFO system. The Mike INFO user interface as it was referred in the official document for the then version of MIKE INFO 1.3.0.6 is the integrated user friendly part of the software. Both the MIKE INFO user interface (UI) and the Platform User interface are used to add or populate data as introduced in Chapter 2. Because of the encountered technical difficulties in adding data to the MIKE INFO UI at some

point in the research due to limited technical skills, the Platform UI was dominantly used in most cases by the researcher and using this platform available data that was shared across the UEIP, MCMF, the LCPG and any other data the researcher found to be valuable in adding to the virtual space, was added into the system.

The opportunities for the stakeholders in this research to improve their absorptive capacity to engaging with ICTs would have included them exploring how to expand on the currently available methods of using features of ICTs to share information with others in a multi-stakeholder groups. Positive observations from some of the stakeholders in the LCPG confirmed that the use of citizen science activities in conjunction with good training on how to use it to enhance their knowledge sharing abilities, empowered and gradually increased these stakeholders abortive capacity. While being more skilled in the technical aspects of using ICTs and having more resources in using them in stakeholder engagement processes, stakeholders in the UEIP and MCMF did not use them fully to increase their own groups abilities to engage in social learning which is increasing absorptive capacity, particularly ones that had characteristics of an IIMMS such as the Mathuba WIKI and it's multi-stakeholder group extension and MIKE INFO. One of the consistent reasons for this observation given by the stakeholders in the UEIP and the MCMF was that they did not know who was going to take on the responsibility of 'running' the technical aspects of the information systems as well as who was going to fund the management of the database that was being created or host it in their organization. However, opportunities to pilot test integrated information management and modelling systems as tools to support coordination and support the stakeholder's absorptive capacity to engage in social learning were present. Stakeholder responses gave reason to believe that the notion of such a system was well supported by the groups. The different features and abilities of both the MIKE INFO and the Mathuba WIKI make them suitable integrated information management and modelling systems for this desired outcome

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5.1.16 Engaging Participatory Agent Based Social Simulation Modelling (PABSSM)

This research gives enough insight to create the argument that when it comes to the use of information systems, the current elements of ICTs have a potential to support social learning by overcoming identified limitations and barriers in the much relied on face to face engagements.

Arguably at the top end of the range of social learning processes in the water space, is the practice of participatory agent based social simulation modelling (PABSSM)[84]. Table 4.7, Chapter 4 for PABSSM as a construct that differs from each scale of multi-stakeholder engagement groups in relation to the strength of its relationship with social learning.

The PABSSM construct of social learning was one that stakeholders in all scales of multi-stakeholder engagement investigated could envisage engaging to different degrees using ICTs to overcome the limitations of their face to face engagements. Despite having various stakeholders as potential 'agents' of social simulation modelling in their different multi-stakeholder groups, evidence from this research shows that none of these contexts in the study reached the point of being able to say that the stakeholders were engaging in PABSSM. However, research supports the conclusion that all three contexts were part way along the emergent pathway to effective PABSSM.

5.2 Conclusion

With regard to the original second objective in this research when the potential for integrated information systems are investigated in their ability to aid in multi-stakeholder social learning, in real and virtual spaces it is clear that opportunities for the Mathuba WIKI and the MIKE INFO to fulfill that role as integrate information management and modeling systems (IIMMS) is there. However, both of them do not fully accomplish all the needs for social learning by meeting the enabling factors at play in the current spaces of multi-stakeholder engagement. Of primary importance are the ability of both of these virtual spaces of engagement to supporting self-identity change, coordinated action capabilities and even mental modelling and necessary surfacing of assumptions in a catchment full of wicked water related problems. But having characteristics such as openness, transparency, accommodation and encouragement of citizen agency these information systems are able to support grassroots activities and large multi-stakeholder groups in a catchment in order to increase the chances of social learning.

[84] This is a practice that combines almost all the elements of Sections 5.2 to Section 5.15 and Scharmer's Theory U as well as the ICT systems discussed in this study.

Chapter 6: Conclusions and recommendations

Having studied the possibilities of social learning within the uMngeni catchment explored through several different participatory engagement practices with the various groups of stakeholders, various conclusions regarding what is required for effective engagement processes began to emerge. The dependency of social learning on multi-stakeholder processes has pointed to even bigger questions such as where should energies and resources be best invested in to ensure that the wicked problems of water related management within the catchment are better addressed. It is evident from this research that the progress of groups in addressing wicked water related issues is not dependent on the amount of expertise offered by the various actors in the room but on engaging in wise actions related to the issues. It has been clear from this research that the LCPG has been more successful in providing change through social learning, than the MCMF and the UEIP.

6.1 Citizen Science, the future hope for facilitating social learning in multi-stakeholder engagement processes.

Cases like that of LCPG such as MEC[85] show that when citizens are empowered by participation and inclusion, *emergent change* occurs. Information is undoubtedly powerful and must be mobilized through networks in such groups in order to initiate real change that benefits not only the uMngeni Catchment but also other catchments in South Africa. This research which also confirms that of Kolbe (2014) and Ward (2016) and others[86] has and has resulted in groups such as the MEC becoming an example for other groups to learn from, through citizen science. Groups like that of the MEC have demonstrated that information systems can be an excellent aid in educating, connecting and guiding the working of these local groups. While most stakeholders seem to be in a state of downloading, according to Theory U, that is repeating past patterns that do not allow deeper learning and real transformational change in the system through social learning as has been expressed by stakeholders in various meetings, the focus on citizen science in the

[85] MEC- Mpophomeni Enviro-champions

[86] For details on these research outcomes which had a specific focus on the MEC, academic research by Kolbe (2014) and a report by Ward (2016).

LCPG offers a way of providing real change on the ground. Citizen science is an approach that has proven to provide real change in how stakeholders engage to promote leadership and learning.

The introduction of information systems through programs such as Google Earth and mapping has played a significant role in achieving this change. One-on-one semi-structured interviews revealed the innermost thoughts and feelings of the citizen scientists. Citizen scientists who engaged in multi-stakeholder processes that tackle wicked problems shared a positive self-identity regarding their place in the uMngeni catchment. Social involvement processes that included the work of citizen scientists and made it public to stakeholders engaging at the larger catchment management level led to empowering the civil society and enabled deep social learning. The more stakeholder involvement processes allowed information to be open and transparent to all stakeholders involved in a multi-stakeholder group, the greater the trust built which was an incentive for a greater degree of social learning as it meets the requirements for social learning. Stakeholders who engage at the local community level along with organisations that are focused on tackling wicked problems with citizen scientists increase their potential to overcome the inhibitors and the barriers to social learning such as the lack of sustained energy of engagement and support efforts that transcend intellectual barriers and create incentives for social learning. This is one of the reasons for the growing motivation for the continual use of information systems at the LCPG level to support their work.

6.2 The value of information systems in creating virtual networks and engagement spaces.

A key question for the future is where should monetary resources be directed to fund such work and how will funders be alerted to places to direct their funds? A key element of any project that wishes to attract such funds is that the transaction costs of monitoring, evaluating and rewarding and inter-acting in the work should be kept low and transparency maximised. When social constructs such as inclusiveness, openness and transparency[87] are applied in relation to citizen

[87] Refer to Chapter 2 on these and other constructs

science in information systems formed in virtual engagement spaces, finding processes that conform to the aforementioned requirements becomes relatively less of a daunting task. A task which is critically important in bringing about socio-ecological benefits to the catchment. Not only will funding to community initiatives involving citizen science create jobs thus alleviating socio-economic challenges faced by local communities, but it will contribute directly to solving some of the most persistent water and environmental issues such as a declining water quality of local streams.

6.3 Social involvement processes and the kind of learning to be encouraged

The initial argument stated in the introduction to this research was that the inability to address some of the most wicked problems facing water managers in the catchment may have a lot to do with the fact that stakeholders are stuck in a process of downloading and are not co-creating, co-sensing and redirecting new thinking, according to terms used by Scharmer (2009) in his Theory U. Scharmer's Theory U argues that such processes facilitate social learning which in turn leads to transformational change. This downloading has been seen to be evident in the meetings of the UEIP where the same problems are constantly being discussed in every meeting. The lack of coordination being the most frequent of the issues confronted in these meetings to the point that workshops for coordination were even conducted to address it as an issue. Such issues of coordination were rooted on stakeholders not knowing how to communicate with each other in a way that brings about cohesion, this was despite that fact that such a large multi-stakeholder group made committed efforts through their meetings to communicate and present information. The lack of essential attendees in this space is also an additional barrier[88]. This was true even for the MCMF where business is seldom participating in the convened space offered by the forum. The LCPG, by contrast benefits the most from the engagement process because of empowerment received from being educated about their environment and the stakeholders themselves educating others using citizen science. By contrast in the UEIP and MCMF one could sense struggles due to existing power relations and the fear of revealing failures and struggles of each organisation despite

[88] In the case of the UEIP, governance was seldom involved in the engagement space, there were only researchers and NGO's who can do little to nothing in mobilizing change outside their own organisations (eg. School at INR).

transparency and openness being essential to progression. In the MCMF, it has been found that 'reporting' of work by each organisation has a short term benefit that only allows stakeholders to report back instead of allowing open and critical discussions that tests and probes the movement forward. This is not lacking within LCPGs such as the MEC. The citizen scientists are encouraged to discuss their struggles at work openly and consequently a safe space for engagement that benefits learning. Hence, if focus is placed on empowering the citizens who seem to be working in a more coordinated way, citizen science especially when facilitated by the sort of information systems discussed in this research, has the potential to provide social learning from the grassroots level to stakeholders at larger multi-stakeholder group arrangements.

However, the institutional and legal structure that supports the engagement process can still be a cause for hindrance to achieving the full benefits of citizen science. The lack of attendance of business and funders into open and public forum spaces of engagement such as the MCMF means that they are not aware of the wicked problems plaguing the catchments and engagement but also business is not being alerted to the work done by local community groups. Hence the electronic or virtual networking opportunities made available through the Mathuba WIKI websites can be used to link up these important stakeholders.

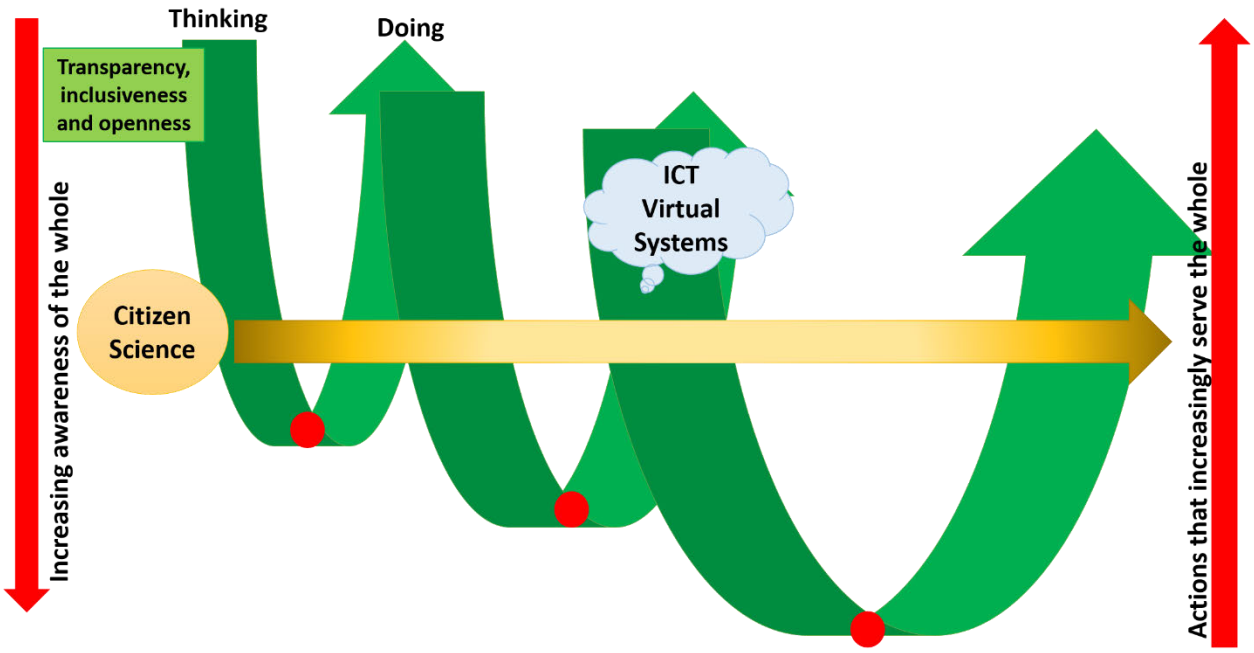

Figure 6.1 Recommendations on improving opportunities for social learning in the uMngeni catchment using Theory U adapted from Scharmer (2009)

A direct approach from experts to citizens is not recommended as it does not directly support a post-normal science approach explained in Chapter 2 and borne out by the results of this research. Furthermore, improving social learning can be accomplished when a focus is placed on supporting and mobilizing groups at the citizen level and in accordance with the constructs that facilitate social learning and which have been examined and discussed in this research as these local community project groups have the highest relative success in meeting the requirements of social learning despite their challenges.

The research has shown that when approaching wicked water problems in the uMngeni it would be wise to engage citizen science with local community members to achieve better water resource management as an outcome. By democratising virtual platforms in the same way that one would to physical platforms, stakeholders in the UEIP and MCMF can better align to the NWA 1998, and more specifically the WRC, Principle 2 where *decisions are informed by both the best available science, research and technology, as well as real-life, local experience*.

Chapter 7: References

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Appendix A

Theoretical Interview Templates

Interview Objective: The purpose of this interview is to learn from the experiences of the key stakeholders and other stakeholders in the catchment in interacting with one another and in dealing with the social and technical problems related to keeping a healthy socio-ecological infrastructure. The responses are hoped to give an indication of the stakeholder's knowledge of social constructs affecting the engagement in the groups that they participate in and in the uMngeni catchment as a whole. This will also be achieved by acquiring the opinions and experience of the stakeholders in using ICT systems in the uMngeni catchment.

As the interview is based on social constructs associated with learning and will be divided into three parts. There are two versions of this interview; those for experts and a template for citizen scientist belonging or associated with LCPG. The versions are almost the same with certain questions being added in one version when compared to the other.

Below is an introduction of the different parts based on the two objectives.

Introduction

Part 1

1. **Question 1: What are the *barriers* and *incentives* to social learning in current spaces of water related stakeholder engagement?**

The major advantage of the first question is that through the interviewee responses it will be revealed that ICTs can help in reducing the barriers that are evident in the stakeholder engagement process and the incentives to social learning. This makes it easier to find the answer through another series of sub questions to the second major research question.

Part 2

2. **Question 2: What are the potential benefits as well as challenges to consider when adopting ICT supported virtual systems as aids in multi-stakeholder water resource engagement?**

By asking a variety of sub questions related to this major question in a post-normal world, two major spaces of learning through information will be expressed in the responses; (1) the social media & citizen science space where the extended community information is made public typified by systems like ”Mathuba” (2) the simulation modelling and scientific information accommodating type of system spaces, in this research, this will be typified by a ”MIKE INFO” type IT tool.

Part 3

3. **Question 3: What can be recommended in order to create a nourishing environment for social learning to thrive in water related multi-stakeholder engagement processes?**

By answering the sub questions under this question, the responses from them will show that the connection between local levels experiences (the extended peer communities) and the top level science is very important in gaining a holistic understanding of wicked problems faced in the management of water in the catchment. The responses although not necessarily created from an experience of using the two emerging technologies focused on in this research, will still show the stakeholders opinions on the idealistic type of information systems to enhancing coordinated collaborations and hence learning. This was done in order to better understand how to answer the second objective more fully.

Interview Template 1: For expert stakeholders engaging in the UEIP/MCMF space

Part 1

a. As a stakeholder working in the field of water related protection, please tell me a little bit about what the uMngeni catchment means to you, how have your thoughts about it been influenced and possibly changed from the past?

   → (Self-identity change that influences empowerment)

b. When you look at the number and variety of problems in the catchment, do you feel that anyone one person or specific group of people knows how the whole system works and can find the answers to questions relating to water?

c. Do you think it is affordable and feasible to get all relevant/important stakeholders of the uMngeni together, face to face in a single meeting session to work on the problems faced in the catchment?

d. Do you feel satisfied with the way the meetings are conducted to cover the issues discussed?

e. Are you satisfied with the river basin plan in the projects you are involved in particularly the UEIP/CMF?

f. Within those meetings, do you feel that you are given enough opportunity to share your opinions, views and suggestions on issues?

g. Do you feel motivated to do so or to take part in the shared action?

h. What has your experience been in observing the interaction between stakeholders this whole time, do you feel some people dominate those meetings than others while some get little to no chances of expressing themselves? And what of the meeting arrangements that you have been involved in do you think allows this?

i. Do you feel like a significant part of the interaction?

j. Given your involvement in the engagement process such as that of the UEIP, do you feel like you now have a holistic idea of the biophysical landscape of the catchment, of who is involved, what their role is and what other projects exist in the catchment? If not, why not?

k. Do you or have you engaged in what could broadly be termed the Citizen Science engagement space? Tell me a little bit more about your experience, the challenges you faced and the successes gained.

l. *Do you feel that such spaces* of grassroots involvement provides an important social learning opportunity as society moves to behave in ways that protect and restore socio-ecological functioning of the catchments you work in, however small?

m. Have you found that when multi-stakeholder groups work off the same information set, that trust develops then finding a consensus or way forward to their complex water related problems is made easier? (What is your experience and thoughts been regarding this)

n. Do you feel that in a catchment such as the uMngeni and Duzi where we face problems such as water quality decline and other persisting socio and ecological problems that gaining sustainability in spite of these is dependent on the ability of stakeholders to participate meaningfully in a collaboration space?

Part 2

a. From your observations of the engagement space; do you think there is a place for top level scientists to connect information systems and their simulation modelling of "what if scenarios" in the multi-stakeholder engagement spaces that form around water in the various sub-catchments which make up the uMngeni catchment? If IT skills are not a limiting factor, do you think this can be a beneficial addition to the engagement through modelling? Why?

b. Do you think the CMF/UEIP or other face to face stakeholder meetings provide enough freedom and time to organise information logically, perhaps in a tables, map or other

document and to then validate this information with others? *(Do you think more support needs to be provided to do this at a later stage?)*

c. In the quest to overcome the challenges of time and discussions of issues in a single working meeting between stakeholders; would you imagine it useful to find out what others in the geographical area are doing ahead of time of these meetings, perhaps by looking at the Google Earth map onto which other groups are placing their work? *(what do you think about using Google Earth platforms onto which other people place their work as a strategy to do this?)*

d. Do think the main challenge to the using such Hi Tech info systems and the ones with modelling characteristics is a lack of information OR a lack of skills OR a lack of appreciation of the benefits OR *ownership* wars or disagreements between the modellers regarding the ones to be used?

e. Do you think that it is possible to achieve the benefits of a high level of influence so much that you can make a substantial and lasting change, without having multi-stakeholder engagement that is substantially assisted by ICT? Why/why not?

f. Do you think these systems can be applied this way to the point that you can generate serious options to the point that you can use them for making wise decisions related to water?

g. Have you noticed that Citizen science and scientists are slowly making it into the scene of science of real or applied science we are used to, how important do you think the participation and contribution is of citizen science in tacking the issues we experience in the water management context?

<u>Part 3</u>

a. Do you believe that the high level ICT systems are necessary to complete the trajectory of stakeholder engagement to the point that serious options can be generated to help wise decisions?

b. If your answer above was affirmative then do you think that it is necessary for stakeholders to agree on a common ICT system that they can all work with, with confidence?

THE ICT

c. Which of the following attributes do you think such a system should have:-

1. Ability to manipulate & display geographic information systems;
2. Ability to manipulate and display time series information and data
3. Ability to store and invoke spread sheets
4. Ability to store documents and pictures
5. Ability to feed the above into simulation modelling systems in a reasonably seamless manner

d. Up until this point I have asked you questions based on the possibility of having singular trained individuals from each organisation or institution having a trained individual or individuals to deal with the technicalities of adding or deleting information from the collectively owned system. (The system is managed by skilled individuals of different organisations)

- What do think of the prospect of this system being collectively managed?
- Who do you think should manage such a system?

(Inclusiveness and transparency, PABSSM adsorptive capacity)

- Who do you really think should have access to the information contained in such potentially rich wholistic information sources?
- And who should provide the data/information and ultimately knowledge richness of this system?

Interview Template 2: For the layperson and expert stakeholders engaging in the LCPG space.

Part 1

a) When you look at the number and variety of problems do you feel that one person (on their own) can know the answer to all the problems everywhere? *(Self-identity that influences ways of integrating)*
b) Is it possible and affordable to get all the stakeholders in the uMngeni together, face to face in a meeting, often, to work on all the problems? *(Whole system Institutional Virtual Spaces, Transparency/Openness and Inclusiveness)*
c) Do you feel satisfied with the way the meetings are conducted to cover the issues discussed in some of the meetings you have attended, the plans executed? *(Meaningful participation, Socially Robust Knowledge, Energy Flow and Tempo)*
d) Within those meetings, do you feel that you are given enough opportunity to share your opinions and views on issues? Perhaps sharing opinions, views and suggestions? ---what has your experience been in observing the interaction between stakeholders this whole time, do you feel some people dominate those meetings than others?

(Meaningful participation and transactional costs of stakeholder involvement, Self-identity that influence connections and power, legitimacy and values, Self-identities which influence connections and power, transactional costs of stakeholder involvement, in kind contributions to ease resource constraints)

e) Do you engage in what could broadly be termed the Citizen Science engagement space? Do you feel that such spaces provide an important social learning opportunity as society moves to behave in ways that protect and restore socio-ecological functioning of the catchments you work in, however small? *(Citizen Science and Citizen Agency)*

f) Given your involvement in the project and engagement, do you feel like you have a holistic idea of the biophysical landscape of the catchment, of who is involved, what their role is and what other projects that exist in the catchment? *(Whole system institutional virtual spaces, Institutional memory).*

g) Have you found that when multi-stakeholder groups work off the same **information set**, that they all trust then finding a consensus way forward to their complex water related problems is made easier? (What is your experience been regarding this) *(Openness and Transparency and inclusiveness, Trust and relationship building, adaptive capacity to engage in PABSSM)*

h) Do you feel that in a catchment such as the uMngeni and Duzi where we face problems such as water quality decline and other persisting socio and ecological problems, finding sustainability in spite of these is dependent on the ability of stakeholders to **participate meaningfully?** *(Meaningful participation)*

i) How do you feel about the ability of certain stakeholders such as the **citizen science** community to post information on biomonitoring and perhaps other activities of the catchment on social media platforms such as Google Earth, websites such as the Minisass map and website where they can generate conversation with other stakeholders who learn about their work?

   What **effect** do you think that has on the individual who posted that information? *(Citizen Science and Agency, self-identity change, whole system institutional virtual space)* → *this question is unique to the citizen scientists, it still written to find the views of the actors on citizen science.*

j) Would you say that you are engaging in what could broadly be termed the Citizen Science engagement space because of your involvement with the Mpophomeni Eco-champions and you Jim with being part of environmental education?

   Also, Do you feel that such spaces provide an important social learning opportunity as society moves to behave in ways that protect and restore socio-ecological functioning of the catchments you work in, however small? *(Citizen science, self-identity change, inclusiveness, social learning, socially robust knowledge)*

k) What difference would you say the use of IT (ie smartphones and Google Earth) has made in your work in the citizen science engagement space and to the citizen scientist

themselves who may use these systems already? *(citizen science, large scale emergent change, institutional memory, transcendence of intellectual and organisational barriers)*

l) Aside from the problems existing in the physical catchment that groups try to solve through their partnerships, collaborations and other engagements, has engaging openly in such spaces in this catchment been challenging in some cases socially? (ie. Participating in meetings and working sessions) If so, how? *(barriers to meaningful participation, appreciative inquiry)*

m) Do you think anyone person knows how the whole system works? *(whole system institutional virtual spaces, cogeneration of information and knowledge)*

n) How would engaging in a space where information about the stakeholders and about how they manage the catchment, what they do, their projects and other information is disclosed openly with everyone make you feel about them? How do you think it might change the relationship dynamics in that exist? *(Bounded rationality, trust, transparency and openness)*

o) What about this? Is there a place for top level scientist0s, information systems and simulation modelling of *"what if "* scenarios in the engagement spaces that multiple stakeholders in society form around water in the various sub-catchments which make up the uMngeni catchment? *(models as metaphors, practice architectures, PABSSM)*

Part 2

h. Has the use of smart phones and the internet enabled you, working with others, to get your work more widely known? (collective action, lower transactional costs of engagement)

i. How do you feel about the fact that the citizen scientist are now using ICT systems in completing their work

j. From your observations of the engagement space; do you think there a place for top level scientists, information systems and simulation modelling of "what if " scenarios in the engagement spaces that multiple stakeholders in society form around water in the various sub-catchments which make up the uMngeni catchment including the Duzi?

k. In all the years you have worked in the CMF/UEIP/other stakeholder arrangement, have you found that the face to face meetings with other stakeholders provide enough freedom and time to organise information logically, perhaps in a tables, map or other document and to then validate this information with others later?

l. In the quest to overcome the challenges of time and discussions of issues in a single working meeting between stakeholders; would you imagine it useful to find out what others in the geographical area are doing ahead of time of these meetings, perhaps by looking at the Google Earth map onto which other groups are placing their work?

m. Do think the main challenge to the use of Hi Tech info systems and modelling are a lack of information/ a lack of skills/ a lack of appreciation of the benefits OR turf wars between modellers?

n. Do you think that it is possible to achieve the benefits of a high level of influence to make a substantial and lasting change, without having multi-stakeholder engagement that is substantially assisted by ICT? *(PABSSM, Whole system institutional virtual spaces)*

o. Have you noticed that Citizen science and scientists are slowly making it into the scene of science of real or applied science we are used to, how important do you think the participation and contribution is of citizen science in tacking the issues we experience in the water management context *(Citizen Science Agency and Social learning)*

Part 3

p) Do you believe that the high level ICT systems are necessary to complete the trajectory of stakeholder engagement to the point that serious options can be generated to help wise decisions?

If your answer to 3 c was affirmative then do you think that it is necessary for stakeholders to agree on a common ICT system that they can all work with, with confidence?

Which of the following attributes do you think such a system should have :

1. ability to manipulate & display geographic information systems;
2. ability to manipulate and display time series information and data
3. ability to store and invoke spread sheets
4. ability to store documents and pictures
5. ability to feed the above into simulation modelling systems in a reasonably seamless manner

Up until this point I have asked you questions based on the possibility of having singular trained individuals from each organisation or institution having a trained individual or individuals to deal with the technicalities of adding or deleting information from the collectively owned system:

q. Mentorship, do you think such systems could be designed to create leaders that are mentors and representatives of a larger population of communities. Eg. Ayanda *(citizen agency, self identity change)*

r. What do think of the prospect of this system actually being collectively managed? Open and transparent in information? *(Collective information management, transparency and inclusiveness, socially robust knowledge)*

s. Who do you think should manage such a system? Do you think resources could be prioritized in having a few such ones as representatives of institutions in multi-stakeholders engagements? *(Collective information management, self-identity changes, transparency and inclusiveness)*