

Towards a “new moment” in Life Sciences Education: Facilitating critical complexity thinkers in South African secondary schools

by
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Declaration

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Abstract

The global polycrisis, particularly ecological degradation and humans' estrangement from nature, is an epistemological crisis that has been created by an industrial, mechanistic and reductionist way of knowledge creation. As our knowing informs our way of being and acting in the world, this study attempts to answer the call for urgent educational reform in promoting a critical complexity approach to Education for Sustainable Development (ESD).

Using the South African Life Sciences curriculum and a theoretical framework developed through literature on complexity theory, systems theory, ecoliteracy and ESD, a teaching and learning experience entitled the *Working with Nature* (WWN) project was developed. Six diversely different secondary schools from the Western Cape of South Africa participated in this project which through participatory action research (PAR), explored the effect that it had on the thinking, values and knowledge of both teachers and learners.

From a thematic analysis on the emergent narratives, it was found that the learning experience did promote integrative thinking and value tendencies and that there was growth in both the explicit-formal and explicit-informal knowledge typologies of the participants. Other key themes that emerged from the experience were diversity values, grit and resilience and contextual thinking. Themes that emerged that were more teacher specific were around process rather than product learning and learner-centeredness.

The implications of this research are vast, however mainly suggest that mainstreaming a critical complexity learning experience is possible and that perhaps this may be the start of a transitioning towards a "new moment" in Life Sciences education, which translates not only into ESD, but also a complexity ethic – creating mindful teachers and learners who engage and participate in the world sustainably. Further studies are necessary in developing strategies for reform and transformation within all education levels towards effectively implementing ESD.

Opsomming

Die globale polikrisis, veral die ekologiese degradasie en die mensdom se vervreemding van die natuur, is 'n epistemologiese krisis wat deur 'n industriële, meganistiese en gereduseerde manier van kenniskepping geskep is. Omdat kennis ons manier van wees en handel in hierdie wêreld lei, poog hierdie studie om die roepe tot dringende opvoedkundige hervorming te beantwoord. Dit doen so deur 'n kritiese kompleksiteits-benadering tot Opvoeding vir Volhoubare Ontwikkeling (OVO) aan te moedig.

Deur gebruik te maak van die Suid-Afrikaanse Lewenswetenskappe kurrikulum, sowel as 'n teoretiese raamwerk wat deur letterkunde oor die kompleksiteitsteorie, sisteme-teorie, eko-letterkunde en opvoeding vir volhoubare ontwikkeling ontwikkel is, is 'n onderrig-en-leer ervaring genaamd die *Working with Nature* (WWN)-projek ontwikkel. Ses diverse sekondêre skole in die Wes-Kaap van Suid-Afrika het aan hierdie projek deelgeneem. Die projek het op deelnemende aksie-navorsing berus en het die effek wat dit op die denke, waardes en kennis van beide die leerders en onderwysers het, ondersoek.

'n Tematiese analise van die ontwikkelende verhale het gevind dat die leer-ervaring neigings to geïntegreerde denke en waardes bevorder het en dat daar 'n groei in beide die eksplisiet-formeel en eksplisiet-informele kennis tipologieë van die deelnemers was. Ander sleuteltemas wat deur die ervaring na vore gekom het was diversiteitswaardes, waagmoed en elasticiteit asook kontekstuele denke. Temas wat as onderwyser-spesifiek na vore gekom het, het rondom prosesse gehandel eerder as produkleer en leerdergesentreerdheid.

Die implikasie van hierdie studie is wyd, maar dit stel hoofsaaklik voor dat dit moontlik is om 'n kritiese kompleksiteitsleer-ervaring deel van die hoofstroomopvoeding te maak en dat dit moontlik die begin van 'n oorgang na 'n "new moment" in Lewenswetenskapopvoeding kan wees. Hierdie oorgang sal beide OVO en etiek rondom kompleksiteit aanmoedig – om indagtige

onderwysers en leerders te skep wat volhoubaar in en met die wêreld besig is. Verdere studies is nodig om strategieë te ontwikkel vir die hervorming en transformasie binne alle opvoedingsvlakke om effektiewe OVO te implimenteer.

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To the **Earth**, for being the most valuable classroom and teacher that there is.

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List of Acronyms and Abbreviations

CAPS	Curriculum and Assessment Policy Statement
CFWWTW	Cape Flats Waste Water Treatment Works
CO ₂	Carbon dioxide
DDT	Dichlorodiphenyltrichloroethane
DNA	Deoxyribose Nucleic Acid
EE	Environmental Education
ESD	Education for Sustainable Development
FET	Further Education and Training
GET	General Education and Training
IPCC	Intergovernmental Panel on Climate Change
MDGs	Millennium Development Goals
NCS	National Curriculum Statement
NGO	Non-government Organisation
NPO	Non-profit Organisation
PAR	Participatory Action Research
REC	Research Ethics Committee
SACE	South African Council for Educators
SD	Sustainable Development
SDGs	Sustainable Development Goals
TBP	Teaching Biology Project
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
WCED	Western Cape Education Department
WEO	World Energy Outlook
WHO	World Health Organisation
WWN	Working with Nature

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Chapter 1

Introduction

1.1 Introduction

“When the young scientist in training has sat on a mountain top, and has completed her first major assignment to ‘think like a mountain’, that is, to dwell and deeply identify with a mountain, mechanistic thinking will never take root in her mind.”

(Harding, n.d.: 4)

There is a pressing need to prepare young minds for a world that is highly complex and uncertain (Morin, 1999a; Montuori, 2014). These young minds are set to face the challenges of the “global polycrisis”, which refers to a set of multiple, interconnected, mutually reinforcing crises that previous generations created in many ways through their mechanistic and reductionist worldview (Morin, 1999b; Swilling & Annecke, 2012; Montuori, 2014).

This study looks to complexity theory, but in particular a “critical complexity” (Preiser, Cilliers & Human, 2013) and a “living systems” (Capra & Luisi, 2014) approach towards viewing and understanding education, its implication and application to education philosophy, pedagogy and curriculum in a South African secondary school context. A humbled effort will be made to provide meaning and understanding to these approaches and their terminologies in subsequent chapters.

Specifically, for this thesis, these approaches were applied to the formation, facilitation and pedagogy of a learning journey entitled WWN. This journey was experienced by Grade 11 learners and teachers from six diversely different schools in the Western Cape of South Africa. This study essentially aims to answer the questions: What would a critical complexity approach to a learning process look like? And how would this approach affect the thinking, values and knowledge of Grade 11 learners and teachers? And then, will this thinking, these values and this knowledge, developed from this learning approach, be more integrative, making these participants mindful of the complexities of socio-ecological systems? This attitudinal

development is important when it comes to transitioning towards a sustainable future (Cilliers, 2008; Swilling & Annecke, 2012; Sund, 2015).

This chapter introduces the background information and motivation of my thesis, giving some initial thought to the overall theoretical approaches and paradigms explored in this study. It then goes on to provide some context to the WWN project, before exploring my role as the researcher in this study. The problem statement is only then outlined in section 1.3, with the corresponding research objectives and rationale of the study being discussed in sections 1.4 and 1.5 respectively. It also touches on the overall research approach, design and methodology in section 1.6 before making the limitations, assumptions and ethical considerations of the research apparent. The chapter ends with a brief outline of this paper and then a chapter summary.

1.2 Background and Motivation

The world appears to be searching for postmodern ways of educating that move beyond mechanistic, “factory-like” education models that came into being during the period of industrialisation (Montuori, 2014). South Africa has seen four educational reforms since its new democracy in 1994 (Jansen & Taylor, 2003; Bantwini, 2010; Department of Education, 2011; Teise, 2013). These reforms have primarily focused on addressing the destruction caused by the previously racist apartheid system and building up a new highly skilled, non-racial workforce of all South Africans. However these reforms have also created many problems for both teachers and learners alike. Curriculum 2005 (C2005) for instance, that was launched in January 1998, followed an outcome-based approach to the curriculum and was filled with inaccessible and complex language, not taking into account the large discrepancies in resources and capacity entrenched within South African schools (Jansen, 1998; Jansen & Taylor, 2003; Bantwini, 2010). Furthermore, the United Nations Educational, Scientific and Cultural Organisation (UNESCO) has highlighted that environmental education (EE) and particularly ESD have been around since the instrumental publication *Our Common Future* from the report of the Brundtland Commission (UNESCO, 2014), and despite curricula efforts with a South African

context, its implementation into the South African curricula over these years has been relatively shallow (Teise, 2013; Irwin & Lotz-Sisitka, 2014).

1.2.1 Complexity theory and critical complexity condition

Since the seminal work done by Edgar Morin (1999a) in *Seven complex lessons in education for the future* there has been relatively little literature written involving complexity theory and its implications and significance for education (Osberg & Biesta, 2010). This is intriguing because general complexity theory is a theory of knowledge creation, a theory of rethinking the fundamental definitions of what knowledge is (Cilliers, 2008), and therefore it is not surprising that it has been regarded as an educational theory (Davis & Sumara, 2008). Moreover, complexity theory is paramount in not only the epistemological branch of philosophy, but also in the ontological and ethical¹ aspects of what it means to be human and act within the world (Cilliers, 2000a,b; Cilliers & Preiser, 2010; Preiser, 2012; Woermann & Cilliers, 2012). What is evident, is that in the last decade, there appears to be increasingly more work being written on complexity theory and education. The journal *Educational Philosophy and Theory* compiled by the Philosophy of Education Society of Australasia released a double issue in 2008 made up of 15 papers written on complexity and education covering the following themes: complexity theory and the philosophy of education, complexity theory and educational research, and complexity theory and the curriculum (Peters, 2008). Despite this, it is apparent that there are many questions that need to be unpacked and there are concretised applications of complexity theory to education that still need to be explored (Mason, 2008a,b; Morrison, 2008; Siu, 2008; Osberg & Biesta, 2010; Sund, 2015).

Critical complexity is a “condition” that is in a stage of infancy within the philosophical discourse which was only first introduced by Paul Cilliers in the last chapter of the book *Complexity, Difference and Identity: An Ethical Perspective* (Cilliers & Preiser, 2010). As there is no one single definition for the term, critical complexity can also be referred to as an ethics of complexity that presents the normative shift on a “general theory of complexity that is based on the lived experience of complexity in

¹ There are three main branches to philosophy, ontology, which deals with the nature of reality, epistemology, the nature of knowledge and ethics, the study of how we should act (Preiser, 2014) (also see section 2.4.2 of this thesis)

the world ... from a mere abstract kind of thinking [of complexity] to the pragmatics of what it means to encounter complexity” (Preiser, 2012: 209).

The complexity worldview and its related critical complexity condition will be discussed in more detail in chapter 2 of this paper, however a call has been made for “educational justification” (Osberg & Biesta, 2010: 2) of complexity theory, of any shape or form, within systems of knowledge creation.

1.2.2 Living systems theory and ecosemantics

The living systems theory, which Fritjof Capra (1997) introduced in one of his seminal works *The Web of Life*, builds on general systems theory and systems thinking and incorporates the “autopoiesis” concept of the two Chilean biologists Humberto Maturana and Francisco Varela (Maturana & Varela, 1987; Capra, 1997; Capra & Luisi, 2014). The concept “autopoiesis” literally means “self-making” and is the key condition to all of life’s self-organising, networked and self-regulating systems (Capra & Luisi, 2014). Capra and Luisi (2014) see complexity theory as not being a scientific theory, but rather as a mathematical theory that builds towards an emergent systems view of life. This thesis adopts the Paul Cilliers’ school of thinking on this aspect, seeing complexity theory as being fully compatible with a living systems theory, but more than that – a theory of ethics and on what it means to be human (Cilliers, 1998, 2000a,b, 2008; Osberg, Biesta & Cilliers, 2008; Cilliers & Preiser, 2010; Woermann & Cilliers, 2012; Audouin, Preiser, Nienaber, Downsborough & Lanz, 2013; Preiser, Cilliers & Human, 2013).

EE, environmental literacy, ecoliteracy literacy, ecoliteracy and ESD are all incredibly useful terms when it comes to transforming education systems if one does not get too stuck on their “eco-semantics” (McBride, Brewer, Berkowitz & Borrie, 2013; Capra & Luisi, 2014; Irwin & Lotz-Sisitka, 2014). They all fundamentally require a complexivist and living systems approach to fully appreciate and understand the complex nature of the world and how to “be” and act within the world that places humans on the trajectory towards creating sustainable futures. Biomimicry is a particular approach to ecoliteracy which holds a promising paradigmatic shift from learning *about* nature to learning *from* nature and ultimately aims to create conditions that are conducive to all of life’s systems flourishing (Benyus, 2002; Janisch &

Weerepas, 2014). It is therefore argued that if approached through a critical complexity lens, all these terms will promote ESD.

It must be acknowledged at this stage, that the living systems theory proposed by Fritjof Capra (Capra & Luisi, 2014), EE (Le Grange, 2004; Carter & Simmons, 2010; Irwin & Lotz-Sisitka, 2014), ecoliteracy (Kahn, 2010; McBride et al., 2013), biomimicry (Benyus, 2002) and sustainable development (SD) paradigms (Swilling & Annecke, 2012) all played a vital role within the theoretical framing of this thesis. The reason these theories, worldviews and approaches have not been given their equal weighting in this chapter, relative to complexity theory, is because the theory of complexity was the golden thread upon which the others interconnected, supported and entangled themselves within.

1.2.3 My motivation and story within the research

“The crisis is at root one of perception”

(Harding, 2006: 28)

When I read *Animate Earth* by Stephan Harding while attending a module at the Sustainability Institute in the Lynedoch Ecovillage just outside of Stellenbosch in South Africa, nothing else seemed to resonate with me more at that time. I found significant similarity between his personal academic experience on neglecting his sensibilities while having to report on the muntjac deer and my academic life in human genetics. That was the reason I became a Life Sciences² teacher – it was an attempt to reconnect myself with other humans and the environment in a more meaningful way. However, teaching in mainstream Eurocentric schools³ exposed many gaps in the way that we as human beings create knowledge, learn knowledge, evaluate our new learned knowledge and then apply that knowledge, (that is, if we are fortunate enough to find that curriculum-driven knowledge applicable to our everyday lives).

² Life Sciences is the latest CAPS name for the subject that is more commonly known as Biology.

³ I have taught in Scotland and South Africa and currently teach at an independent boys' school called Bishops Diocesan College in Cape Town.

Through the exceptional work of the late Paul Cilliers, which I was introduced to in my module at the Sustainability Institute on Complexity and Systems theory, my worldview was radically altered. I realised that our contemporary knowledge creation was as a result of a reductionist approach to scientific inquiry and it was this mechanistic way of viewing and understanding the world that has estranged humans from each other and the environment of which they are part. In order for humans to understand things, we reduce them into their simplest parts, organisms into cells and then atoms, cities into suburbs and then houses, economies into markets and then currency; this is the way that I was taught and the way that I was now teaching. What I realised was sorely missing, not only in education but in humanity as a whole, was a reconnecting of all these atomised, segregated, reduced entities with each other; an ontological, epistemological and ethical awakening that all living and non-living is related in a beautifully self-organising, non-linear, emergent “Web of Life” (Capra, 1997).

Strangely, or perhaps not so strangely, the day before the ex-rector of Stellenbosch University, Professor Russel Botman unexpectedly passed away, my lecturer Professor Mark Swilling was talking to me about Botman’s oratory on the “pedagogy of hope” in knowledge creation, which involves a re-assembling of pieces through transdisciplinarity, not just academic, not just scientific but something beyond disciplines (Swilling, 2014). Around the same time my teaching colleague Cheryl Douglas, who is the programme director of the non-government organisation (NGO) Teaching Biology Project (TBP) and a Life Sciences teacher at Bishops (Diocesan College), and I were trying to challenge the contemporary, reductionist ways of teaching and learning. We were particularly interested in integrating the skills and attitudes that learners need in the 21st century (Gerstein, 2014) into our classrooms. I found all of this information, and so much more, culminated in my looking to see whether it would be possible to infuse complexity thinking into my educational practice in an attempt to reconnect learners to the environment and to reconnect philosophy to science. In doing so, I would hopefully help facilitate emergent complexity thinkers who would gain a deeper understanding of the complex world they live in and a mindfulness towards creating a sustainable future.

1.2.4 A context to the *Working with Nature* project

TBP is an NGO that is a part of the Africa Genome Education Institute, and was founded in 2008 by Life Sciences teacher Cheryl Douglas and Professor Wilmot James who is a Member of Parliament and Federal Chairperson for the political party, the Democratic Alliance. TBP was initially funded by the Netherlands' government, and was originally formed in an effort to upskill Life Sciences teachers in the Western Cape, who in 2008 had just begun teaching biological and human evolution to Grade 12 learners. This was a new, exciting and somewhat controversial period for teachers of Life Sciences, as many had never been taught evolution explicitly in their own schooling as learners. This was primarily because it was not allowed to be taught in schools in South Africa during the apartheid Christian-based education system and was also only given scant recognition by the post-1994 Department of Education (James & Wilson, 2002).

TBP's mandate has now expanded and diversified into something far greater. It is currently funded by the National Lottery Distribution Trust Fund and runs in-service workshops mainly for teachers dealing with various current issues in Life Sciences. Each workshop is limited to approximately 50 teachers and runs over four days, three times a year, at Bishops Diocesan College in Rondebosch, Cape Town (TBP, 2013). The aim of the workshops is to empower teachers to become more effective at what they do, increasing their ability to use Information Computer Technology (ICT) and increasing their content knowledge, scientific methodology and practical skills (TBP, 2013). It is important to note that after English First Language and Mathematical Literacy, Life Sciences has the third largest number of learners taking the subject through to Matric⁴, with 284 298 learners in December 2014 writing the Life Sciences final examination (Department of Education, 2014). This is significant as it means that for the majority of South Africans who finish high school, Life Sciences is the only form of scientific literacy they will get from their education.

WWN can in some ways be regarded as a project-based assignment that was created and disseminated by TBP specifically for Grade 11 Life Sciences' teachers who needed to do a large assignment on the "Human Impact on the Environment"

⁴ Matric is the final year of secondary level education in South Africa.

section of the latest Curriculum and Assessment Policy Statement (CAPS) (Department of Education, 2011). However, it is worth mentioning, that earlier forms of the WWN project actually began in 2011, created by Cheryl Douglas and run by the Bishops Biology Department as “Human Impact on the Environment” market-place-lobbying projects. It was at that time that I became involved at Bishops and in TBP through running their workshops and creating digital material for them and so I familiarised myself with the early versions of the WWN project.

In 2014 Cheryl Douglas was awarded second runner up in the “Educator as Change Agent and Innovator Category” at the Microsoft in Education Global Forum in Barcelona. This was based on a project she facilitated through TBP, in which learners from 12 different schools were paired up and went on field trips investigating human impact at various sites around the City of Cape Town (SchoolNet SA, 2014).

On reflection on these earlier pilot projects, it became apparent that the learners and teachers were still too product driven and had very little appreciation and understanding of the importance of experiencing the process of the project itself and the skills and attitudes that developed out of doing the project. This acknowledgement emerged at the same time that I was generating momentum on understanding the importance of complexity and living systems theory, and that critical learning was to be attained through the process of learning experiences and not the final product. These understandings ultimately culminated in laying down the foundation for the WWN project of this research paper.

1.2.5 Bringing reflexivity into the research

Reflexivity plays an important role throughout this research study, from the moment of first inquiry right through to the analysis and discussion of the findings, and so in an attempt to make the “[reflexive] self” and “research lens as explicit as possible” (Yin, 2011: 270), I attempt to bring myself as the researcher into the report through reflexive boxes as was done successfully in Murray’s thesis (Murray, 2015). It is important to note that I adopt a *reflexive* practice in this paper, which goes a step further than being just *reflective*, as I not only reflect, but also make an attempt to stand outside the self, examining my own assumptions, values, and limits to my

knowledge (Bolton, 2010). I justify this approach to my research through the following academic literature:

- Complexity theory looks beyond the subjectivity/objectivity dichotomy and acknowledges the personal value-laden intricacies of knowledge and knowledge creation (Cilliers, 2000a). I make as clear and explicit as possible my involvement and subjectivity in this research.
- McNiff (2008) shows concern for the exclusion of the “living I” from educational discourse and philosophical research saying in his understanding “... knowledge is generated by a knowing subject, from within a social context, and this is best communicated through narrativised accounts that tell the story of one’s learning” (Mcniff, 2008: 352).
- Social science research cannot be neutral and that it would be more detrimental and dishonest, epistemologically speaking, if the research is separated from the researcher (Kelly, 2009).
- There is a shift from objective to epistemic science⁵ when it comes to systems thinking (Capra, 1997; Capra & Luisi, 2014) and this thinking influences this thesis. However, it is important to understand here that recognising the subjective dimension does not mean forfeiting all scientific rigour. Instead it merely gives “intersubjective validation” (Capra & Luisi, 2014: 82) a place in the scientific method.

1.3 Problem Statement

Using the South African Life Sciences curriculum content on “Human Impact on the Environment” (Department of Education, 2011) and a theoretical framework developed after reading the work of Fritjof Capra, Paul Cilliers, Mary Evelyn Tucker, *inter alia*, I propose a thesis that, through a series of teacher and learner workshops entitled WWN, a form of critical complexity (Preiser, Cilliers & Human, 2013) would be infused into the thinking of the teachers and the Grade 11 learners who participated. This might create emergent critical complexity thinkers within science, who were mindful of the complexities of socio-ecological systems and might thus have a better understanding of the interconnections within these system, as well as

⁵ Epistemic science suggests that epistemology, our “method of questioning” (Capra & Luisi, 2014: 82) is integral in how we view, interpret and explain our scientific study.

the importance and implications of context and place. These workshops might facilitate participants to develop integrative thinking skills and values as well as deepen their knowledge, enabling them to address and navigate their choices ethically towards finding sustainable solutions to unsustainable problems.

1.4 Research Objectives

The objectives of this study were to:

1. Develop a theoretical framework through a literature review for informing a complexity approach and pedagogy to the contemporary Life Sciences CAPS.
2. Help create, facilitate and experience a critical complexity learning process for Grade 11 learners and teachers through a PAR methodology entitled WWN, by using the “Human Impact on the Environment” content of the CAPS and other forms of ecoliteracy as a guiding framework.
3. Investigate through thematic coding of qualitative data, the effect that this collaborative critical complexity learning experience had on the thinking, values and knowledge of learners and teachers from six diversely different secondary schools in the Western Cape.

1.5 Rationale of the Research

“Over the last few decades, the glaciers have been melting faster than education has been changing to meet serious new crises.”

(Greenwood, 2010: 139)

This research paper proposes a postmodern approach to education in South Africa using a developed theoretical critical complexity framework, which may address some of the unsustainable problems that a segmented and reductionist model of education creates. This particular critical complexity, pluralistic approach to education, and linking it to ESD, has not been tried in South Africa before and therefore any outcomes from this research may be a valuable contribution to these fields of study.

It could also be important to a wide variety of stakeholders. Education policy makers and curriculum creators and advisors may see this as a new proposition in

developing an alternative approach to the current Life Sciences CAPS (Department of Education, 2011). This could happen without them having to make radical adjustments to fundamental education structures that are heavily entrenched within the current system and are therefore slow moving. Simultaneously, it may expose the limitations and flaws of these entrenched education structures and so may allow for a smoother transition towards changing these structures in the future. This research could act as a type of intermediary between future sustainable education systems and contemporary modernist, industrial education systems. Therefore this research could be fundamentally considered as a part of the “mainstreaming ESD” discourse (Togo & Lotz-Sisitka, 2013) however employing a critical complexivist approach.

Teachers and learners have the potential of finding this research to be transformative as it may equip them to become complexity thinkers (Preiser, Cilliers & Human, 2013; Montuori, 2014; Sund, 2015), which may enable them to navigate effectively, but more importantly ethically, within the complexity of socio-ecological systems. The PAR methodology enables teachers to benefit from this research because the long-term research engagement may empower them by giving them teaching and learning resources. This then would allow them to take ownership of new and different paradigms of teaching. Learners may also benefit by gaining new skills and attitudes towards learning and the environment on a whole. It is also possible that this research may benefit the participant learners as they prepare for their final Matric Life Sciences examination as the content covered in the research is examinable in Grade 12.

Finally, this research may be beneficial to other researchers in the field of complexity theory, educational theory, ecoliteracy, ESD and sustainability as it will increase the literature and knowledge base on these topics and hopefully will prompt further questioning and future research to be done.

1.6 Introduction to Research Approach, Design and Methodology

This research *approach* is a qualitative, empirical study and its *design* shares features of both an ethnographic study and case study, although, as put forward by Yin (2011), there is no single blueprint or design in doing qualitative research, and so this design is largely a blend of implicit and explicit designs and approaches. Bringing the qualitative research approach and case study design together as Bryman, Bell, Hirschsohn, dos Santos, du Toit, Masenge, van Aardt and Wagner (2011: 117) suggests, would take the typical form of an “intensive study by ethnography or by qualitative interviewing of a single case, which may be an organisation, a group of employees within an organisation, or an individual”. Therefore this research used a qualitative approach, adopting features of both an ethnographic and case study design, which employed predominantly a PAR *methodology*. However, there are three important influences to the research approach, design and methodology that need mentioning:

- It predominantly followed a complexity (see reflexive box 1) and systems approach to research in that it acknowledged that the research itself was a socio-ecological complex system that had certain characteristics, such as: it was an open system made up of many different actors and elements, there were feedback mechanisms within the research design and process, there was a history, there were emergent properties from the rich interactions between the elements of the research and that there were non-linear relationships that were at work within the research (Cilliers, 1998, 2000b, 2008).
- Following along the living systems line (Capra, 1997, 2002; Capra & Luisi, 2014) and the *Santiago theory*, as proposed by Maturana and Varela (1987), cognition as a process of knowing “is not a representation of an independently existing world but rather a continual bringing forth of a world through the process of living” (Capra & Luisi, 2014: 256) (see reflexive box 2). The research approach and description of this research therefore was cognisant that all that was known and understood from this study was not only a separate reduced model of the world, but was also an emergent property of

what was and still is lived and experienced by all the participants and was merely represented, albeit in a limited way, in a written format by me, the researcher.

- The two influences above meant that the epistemology of this research most certainly did not follow along positivist⁶ lines, but instead fell somewhere within a critical realism⁷ epistemology in that it accepted that the research structures, theoretical frameworks and categories used to understand reality were not permanent, and there were non-observable evidences of phenomena that were at work in generating change (Bryman et al., 2011). Ontologically it follows “that reality is a state of constant flux, is subjective and that multiple realities co-exist” (Bryman et al., 2011: 17).

Reflexive box 1: Why did I follow a complexivist approach?

As complexity theory was the basis of the theoretical framework of my thesis and informed my personal thinking on a day-to-day basis, it seemed right that I acknowledged this as having played an important role when it came to designing my research, selecting its methodology, carrying out its methods and then interpreting and discussing the emergent outcomes and stories as a result of the research.

⁶ Positivism is a stance that sees only knowledge which is verified through empirical science, as being authoritative and valid (Bryman et al., 2011).

⁷ Critical realism formed as a critique of positivism and broadly speaking is a philosophical approach of navigating through a “differentiated but cohering discussion of natural and social phenomena” in knowledge production (Hampson, 2012: 78).

Reflexive box 2: What world did I bring forth in my research?

The world that I brought forth in this research was not an independent representation of reality, but rather a communication of my own living reality and experience in teaching and facilitating in a series of workshops. However my own accounts of this research, as well as those of the other participants, were contextual versions of a social reality and were most certainly not definitive in nature. Therefore this research and its methods are not necessarily something to be precisely replicated, or to make predictions, generalisations and fierce conclusions from, as will be discussed further in chapter 3, but rather serve to create a deeper understanding of a story that unfolded in this specific context for all those involved. Some of the methods and findings may therefore be transferrable and applied in new ways to different contexts.

It must be acknowledged that as a researcher, I sit in the global South⁸, but have been influenced and exposed culturally to global North perspectives and ideologies. Therefore, I made a considerable effort, at all times, to follow the profound thinking of Orlando Fals-Borda, a pioneer of PAR, when he said “do not monopolise your knowledge, nor impose arrogantly your techniques but respect and combine your skills with the knowledge of the researched and grassroots communities, taking them as full partners and co-researchers” (Fals Borda, 1995: 11). I attempted to counter-challenge, to some degree, my own assumptions and blind spots by integrating reflexivity throughout this thesis, as was explained earlier in the section on bringing reflexivity into the research. Therefore in a small way, I fulfilled the role of a sustainability researcher in being an academic, facilitator and activist (Pohl, Rist, Zimmermann, Fry, Gurung, Schneider, Speranza, Kiteme, Boillat, Serrano, Hirsch Hadorn & Wiesmann, 2010).

⁸ The global North-South divide is used here in its most common form in terms of socio-economic differences. The global North refers to those countries north of the Brandt Line and includes countries such as North America, Europe and Australasia, whereas the global South refers to Africa, Latin America and Asia.

1.6.1 An overview of the research

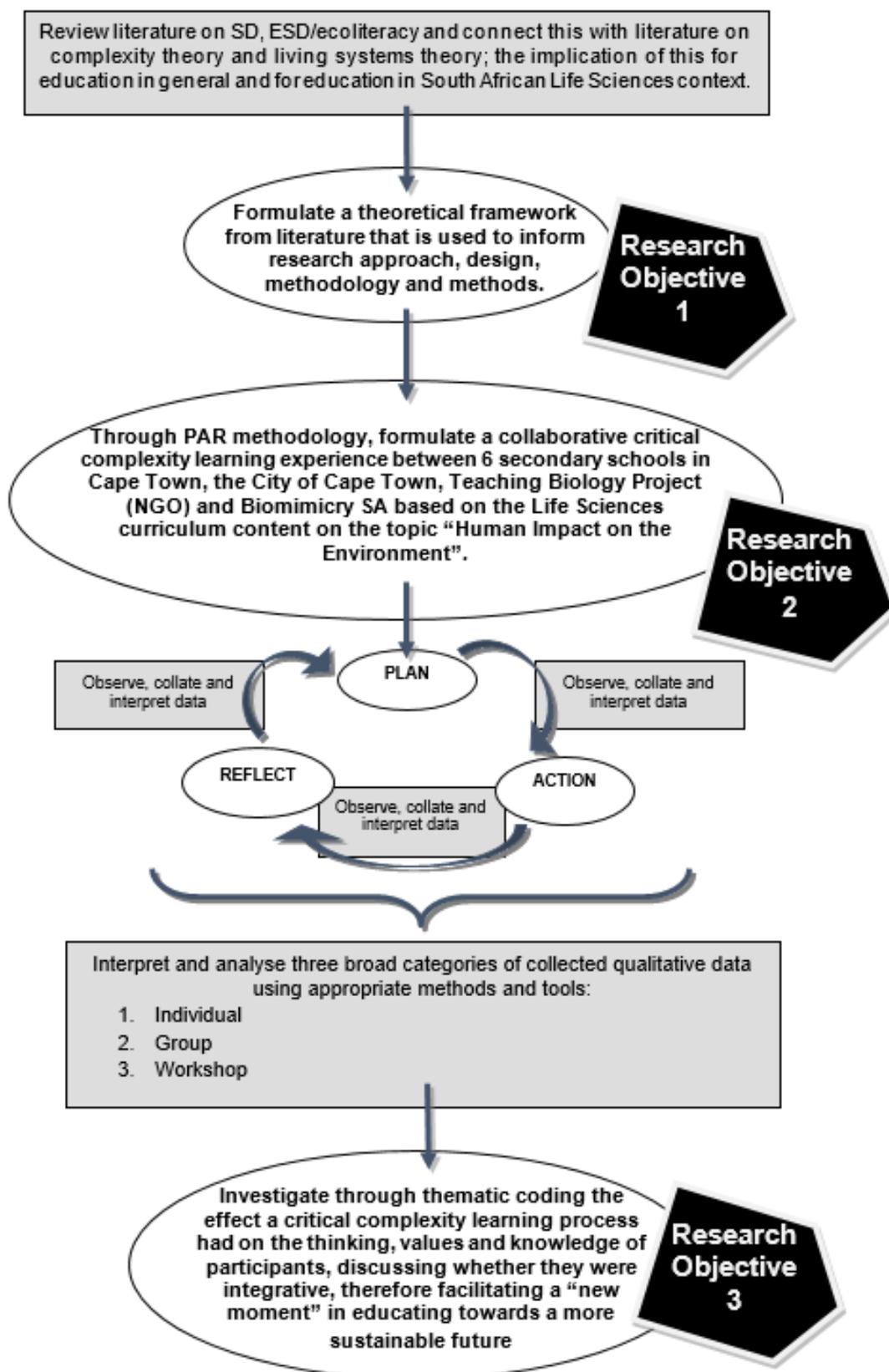
The research began with a comprehensive literature review of academic journals and other forms of contemporary literature. The purpose of this was to establish a theoretical framework that would inform the methods, design and overall lens for the WWN project (research objective 1). Qualitative, empirical, primary and secondary data were then obtained using PAR methodology. Six secondary schools from Cape Town participated in a critical complexity learning experience that was designed for Grade 11 learners using the “Human Impact on the Environment” CAPS curriculum and other forms of ecoliteracy as a guiding framework (research objective 2). Various forms of data collected from participants and from the workshops were then analysed thematically, looking for evidence of integrative thinking, values (Capra, 1997; Capra & Luisi, 2014) and the effect that this experience would have on the participants knowledge (research objective 3). Figure 1 provides an overview of the research.

1.7 Limitations and Assumptions of the Research

There were various limitations and assumptions of the research that need to be briefly introduced here and then further elaborated on in section 3.8 of this paper. The qualitative nature of this research brought in its own set of limitations, especially when compared to a quantitative research viewpoint of validity and reliability (Bryman et al., 2011; Yin, 2011; Stringer, 2014). Subjectivity, replicability and problems of generalisation were all limitations to qualitative approaches and specifically to a PAR methodology (Mouton, 2011; Stringer, 2014). Furthermore sample size and selection methods brought in their own limitations to the understanding and applications of research outcomes and findings (Bryman et al., 2011).

As will become clear in chapter 3, this research makes no attempt to make broad sweeping generalisations on the research findings and assumptions made will be continually reflected upon, exposing the blind spots from the research process that may have developed (Stringer, 2014).

Figure 1: An overview of the research



Source: Author's elaboration

1.8 Ethical Implications of Research

There were ethical implications that were considered for this study as using minors as participants automatically put the study at a medium level of risk. All departmental and university requirements were followed and the study did not in any way contravene the University of Stellenbosch's guidelines on ethical aspects of scholarly and scientific research (Stellenbosch University, n.d.), nor the Policy for Responsible Research Conduct at Stellenbosch University (Stellenbosch University, 2013). Research and ethics approval was granted by both the Western Cape Education Department (WCED) (see appendix 1.1) and the University Research Ethics Committee (REC) (see appendix 1.2).

The research was done making sure that both the environment and the participants benefitted in the broadest possible way. As we were dealing with young adolescents between the ages of 16 and 17, utmost care was taken ensuring that they were treated with decency, respecting their right to the minimization of risks to which people could be exposed in the research process, according to universal standards (Stellenbosch University, 2013). Sessions were carried out by professional South African Council for Educators (SACE) accredited teachers who are obligated to comply with the Code of Professional Ethics of the South African for Educators Act (Republic of South Africa, 2000) or experienced facilitators who have a good rapport with the institutions where they work.

The research was voluntary and this was made explicit to all the participants but in particular to the learners in front of their teachers. Recognition was therefore openly made to the potential power relationships that could have existed between teachers and learners in case the learners were being influenced unwillingly by their teachers to attend the workshops and partake in the research. Written and signed, informed consent was gathered by all the participants as well as the parents of the learner participants (see appendix 1.3). Fictitious names were used in this research paper and so anonymity of the results was kept for all participants.

1.9 Outline of Chapters

Chapter 1: Introduction

Chapter 2: Literature Review: formulating a theoretical framework on critical complexity and its implications for education and SD (research objective 1)

Chapter 3: Research Design, PAR Methodology and Methods (research objective 2)

Chapter 4: Results and Analysis: narratives that emerged (research objective 3)

Chapter 5: Towards a “New Moment” in Life Sciences Education

1.10 Summary

As would be expected from the first chapter of a thesis, the background information, terminologies and context of the research were set. The main challenge that this paper was attempting to address was that of the global polycrisis and the estrangement of humans from nature due to the way that scientific knowledge has been created and then acted upon in the industrial past, in an unsustainable manner (Morin, 1999b; Swilling & Annecke, 2012; Montuori, 2014). From this, the thesis proposed a critical complexity approach to knowledge creation (Preiser, 2012; Preiser, Cilliers & Human, 2013), specifically addressing this challenge by asking three important questions: What would a critical complexity approach to a learning process look like? And how would this approach effect the thinking, values and knowledge of learners and teachers? And then finally, would this thinking, these values and this knowledge, developed from this learning approach, be more integrative, making these participants mindful of the complexities of socio-ecological systems? These question informed the problem statement and its respective research objectives. The rationale of the research gave impetus to the study and this was followed by an introduction to the research approach, design and methodology. The chapter culminated in an overview of the research being discussed and diagrammatically represented (see figure 1) and was then followed by a fleeting discussion on the limitations, assumptions and ethical considerations of the research.

The paper now turns towards its next chapter, which is a selective review of the literature, with the specific objective of developing a theoretical framework for informing a complexivist approach and pedagogy to the contemporary Grade 11 Life Sciences CAPS, thereby mainstreaming ESD into conventional curricula.

Chapter 2

Literature Review

2.1 Introduction

Education systems globally, like many socially constructed systems today, are still mainly entrenched in the mechanistic viewpoint of modernity, with reductionist Newtonian ontology and epistemology at the foundation of scientific knowledge creation (Harding, n.d.; Cilliers, 2000a,b; Heylighen, Cilliers & Gershenson, 2007; Osberg, Biesta & Cilliers, 2008; Audouin et al., 2013). It is this reductionist type of thinking that has in many ways estranged humans from nature (Harding, 2006; Drengson & Devall, 2010). It has created a dangerous belief in “Science” which in turn has nurtured an understanding of the planet as a piece of machinery, with humans as the machine’s operator, who simply adopt a “blind watchmaker’s” attitude to fixing what is, in reality, an immensely complex, interconnected universe (Harding, n.d.). There is much literature on reductionist thinking as being at the root of the global “polycrisis” which seven billion humans now have to face (Cilliers, 1998, 2008; Morin, 1999b; Chu, Strand & Fjelland, 2003; Emmeche, 2004; Harding, 2006, n.d.; Heylighen, Cilliers & Gershenson, 2007; Swilling & Annecke, 2012; Colucci-Gray, Perazzone, Dodman & Camino, 2013).

Despite science’s contribution to technology and improvement in human well-being for some, billions still live in a world of uncertainty, rampant environmental degradation, inequality, injustice and general unsustainable development (Cilliers, 1998, 2008; Chu, Strand & Fjelland, 2003; Emmeche, 2004; Harding, 2006, n.d.; Heylighen, Cilliers & Gershenson, 2007; Swilling & Annecke, 2012; Pretty, 2013; IPCC, 2014; Steffen, Richardson, Rockström, Cornell, Fetzer, Bennett, Biggs, Carpenter, de Vries, de Wit, Folke, Gerten, Heinke, Mace, Persson, Ramanathan, Reyers & Sörlin, 2015). Complexity theory and in particular, critical complexity (Preiser, 2012; Preiser, Cilliers & Human, 2013) as coined by the late Paul Cilliers, provides a hopeful transition in human thinking (Cilliers & Preiser, 2010). It is an important paradigm shift that is required in all knowledge creation and understanding, especially when it comes to understanding social-ecological systems that are innately complex systems (Chu, Strand & Fjelland, 2003; Lui, Dietz, Carpenter, Alberti, Folke, Moran, Pell, Deadman, Kratz, Lubchenco, Ostrom,

Ouyang, Provencher, Redman, Schneider & Taylor, 2007; Cilliers, 2008; Armitage, Plummer, Berkes, Arthur, Charles, Davidson-Hunt, Diduck, Doubleday, Johnson, Marschke, McConney, Pinkerton & Wollenberg, 2009; Audouin et al., 2013).

The objective of this literature review chapter is to create a theoretical framework as an approach to mainstreaming ESD (section 2.5) through reviewing literature surrounding SD (section 2.2), ecoliteracy (section 2.3) and complexity theory (section 2.4).

2.2 Sustainable Development: from prokaryotes⁹ to the SDGs

The United Nations Framework Convention on Climate Change (UNFCCC) is currently gearing world leaders towards COP21 which is being held in Paris in December 2015 (UNFCCC, 2015). According to the United Nations Environment Programme (UNEP), this meeting of global nations may be one of the most important in SD history, as it aims to achieve a legally binding and universal agreement to keeping global warming below 2°C, which is essentially a culmination of 20 years of UN negotiations (UNEP, 2015). The current president of the Republic of South Africa, Jacob Zuma, committed South Africa to Agenda 2030 (IOL News, 2015) at the recent UN Sustainable Development Summit, which was held in New York in September 2015. This section of the thesis, deals with SD from its inception to the development of the sustainable development goals (SDGs).

2.2.1 The lead up to Brundtland

“Sustainable Development is development that meets the needs of present generations without compromising the ability of future generations to meet their needs” (World Commission on Environment and Development, 1987: 43). Almost three decades later and it is still difficult for discourse surrounding the term “sustainable development” not to begin with or move beyond the sentence given by the World Commission on Environment and Development in 1987. The Brundtland report *Our Common Future* provided those significant words, which paradoxically has both seemed to advance sustainability literature to new levels of understanding

⁹ Prokaryotes are single-celled organisms that don't have a membrane-bound nucleus and are thought to be the origins of life on Earth (Margulis & Sagan, 1986; Capra & Luisi, 2014).

of how humans should choose to live in this world, but has also got academics stuck in an ambiguous quagmire in terms of its meaning, plurality and usage (Adams, 1990; Mebratu, 1998; Gallopin, 2003; Sneddon, Howarth & Norgaard, 2006; Capra & Luisi, 2014).

The statement on SD from the Brundtland report, however, does have two important considerations:

1. It recognises the concept of human “needs” (Mebratu, 1998) and therefore indirectly addresses the poverty of the global South (Swilling, 2012).
2. It acknowledges that these “needs” are dependent on a limited, in terms of materials and resources, planet (Mebratu, 1998) and so it infers some form of replenishment or renewal for future generations.

These considerations were in part as a result of the environmentalist movements of the 1960s and 1970s (Adams, 1990; Mebratu, 1998; Swilling & Annecke, 2012). Iconic images such as *Earthrise*, considered to be one of the most influential environmental photos, taken by astronaut William Anders during the Apollo 8 mission to the moon in 1968 (McCarthy, 2012), was only one of the ways in which attitudes and perceptions were changed during this period. Seminal environmental literature such as *Silent Spring* by Rachel Carson (Carson, 1962) and *The Limits to Growth* by Donella Meadows and her team (Meadows, Meadows, Randers & Behrens III, 1972) were all ways of expressing a co-evolutionary realisation of rampant, exponential and selfish destruction to the environment as a result of humans’ insatiable appetite for growth in its many guises. Despite much criticism early after its publication, *The Limits to Growth* has been subsequently supported (Heinberg, 2010)¹⁰ and even expanded on through the publication of the “planetary boundaries” (Rockström, 2009). The political precursor to the Brundtland Commission is often attributed to the World Environment Conference held in Stockholm in 1972 (Farley & Smith, 2014). Environmental literacy from the “Green Movement” in the 1950s and 1960s

¹⁰ It is important to note here that despite receiving much criticism for its scientific methodology, *inter alia* (Adams, 1990), a 30-year update was published which supports many of the original “doomsday” predictions and shows findings to be consistent with what was originally predicted. It also now receives widespread scientific support (Heinberg, 2010) and has issued a “World Scientists’ Warning to Humanity” signed by more than 1600 scientists including 102 Nobel laureates, from 70 different countries (Meadows, Randers & Meadows, 2004).

developed in parallel or preceded other movements surrounding a multiplicity of other global issues from globalisation (Robertson, 1990; Norberg-hodge, 2000; Held & McGrew, 2002; Stiglitz, 2002; Curtis, 2009), neo-liberal economics (Gowan, 2007; Perez, 2009; Gore, 2010; Swilling & Annecke, 2012) to postmodernity (Bauman, 1992; Montuori, 2014).

2.2.2 An evolutionary perspective on sustainable development

Although the term “sustainable development” was first coined in the early 1980s by an authoritative environmentalist and founder of the Worldwatch Institute, Lester Brown (Brown, 1981), the concept has arguably been a part of all living systems since life began on this Earth over some 3.7 billion years ago. This is because nature has an inherent ability to sustain life (Capra, 2002). In most transition and developmental texts the origins of SD ignore the deeper ecological evolutionary perspective and begin analysing the concept from the first socio-ecological hunter-gatherer regimes (Fischer-Kowalski & Haberl, 2007), or from a colonial-influenced conservationist (Adams, 1990), historically religious (Mebratu, 1998) or modern industrialisation viewpoint (Mebratu, 1998; Perez, 2009). As important as these are, many prominent writers in this field also dedicate chapters to the significance that biological evolutionary thinking has had on sustainability (Maturana & Varela, 1987; Capra, 1997; Swilling & Annecke, 2012; Capra & Luisi, 2014).

Classical Darwinism began this epiphany in that it was the first modern scientific text to link all organisms explicitly to a single common ancestor in this beautiful, albeit simplistic, image - the “[G]reat Tree of Life” (Darwin, 1859: 147). However, the drivers of evolution in this case were variation, selection and time, and by selection Darwin meant competition between species and a continual fighting for survival between organisms of the same species (Darwin, 1859). The late biologist Lynn Margulis offers a critical, Neo-Darwinist approach in her evolutionary theory of “symbiogenesis” that describes how eukaryotes evolved from prokaryotes by single-celled organisms forming relationships between one another (Margulis, 2001). This is an important shift in the understanding of evolution in that it acknowledges that “[I]f life did not take over the globe by combat, but by networking. Life forms multiplied and complexified by co-opting others, not just by killing them” (Margulis & Sagan, 1986: 29).

This idea of deep time, a mindfulness of the importance of history, has become a large part of reconnecting the broken relationship between humans and the natural world (Gill, 2002; Tucker, 2014). Immediately we are reminded that humans are a part of, and not separate from, the Earth and that our species, *Homo sapiens*, is largely insignificant when it comes to a temporal understanding of all life forms on Earth, but simultaneously disastrously significant when it comes to our impact on this planet. Tucker's tribute to the significance of an evolutionary perspective is made clear in her text *Our Place in the Universe* in which she writes:

We have, for the first time, a scientific story of the evolution of the universe and Earth that shows us our profound connectedness to this process ... Our consciousness is shifting from valuing hyper-individualism and independence to embracing interdependence and kinship on a vast scale. (Tucker, 2014: 52)

2.2.3 Defining sustainable development, needs and growth

Although defining SD has often been referred to as being too difficult, some argue that our knowledge of sustainability has increased and it is actually the notion of development that is too difficult to define (Sneddon, Howarth & Norgaard, 2006). It can therefore be seen that with the concept of SD comes a reconceptualisation of what "development", "needs" and "growth" means. Entire books and papers could be dedicated to just this and many have¹¹, but in terms of the latter two concepts it's worth mentioning that the Millennium Ecosystem Assessment (2005) makes the link between ecology through ecosystem services and human wellbeing explicit (Millennium Ecosystem Assessment, 2005). This is a clear movement away from a classical humanistic, Maslowian hierarchy of needs. Jules Pretty (2013) provides convincing evidence that a transition to a "green economy" is inevitable. This refers to growth and human needs not based on indicators such as gross domestic product (GDP) but rather on non-material consumption that has been shown to improve life satisfaction and human development after countries reach modest affluent levels (Pretty, 2013). The only question remaining is: will we make this transition with enough time to save our planet (Pretty, 2013)? The SDGs are attempting exactly

¹¹ See (Adams, 1990; Mebratu, 1998; Centre for Urban Policy Research, 2000; Hattingh, 2001; Gallopin, 2003; Hopwood, Mellor & O'Brien, 2005; Sneddon, Howarth & Norgaard, 2006; Blewitt, 2008; Lombardi et al., 2011; Farley & Smith, 2014)

this by having proposed 17 goals for the global community to address by 2030 (UN Division for Sustainable Development, 2015).

UNEP's International resource panel attempts to answer this question by quantifiably providing country-specific and global targets in material resource extraction and use, while reducing environmental degradation through material flow analyses (Fischer-Kowalski & Swilling, 2011; Swilling, Robinson, Marvin & Hodson, 2013). They too focus on future global development in terms of dematerialisation that promotes what is referred to as "decoupling" in two main ways: firstly, resource decoupling means a reduction of the rate at which primary resources are used per unit of economic output, and secondly, impact decoupling means increasing economic activity but decreasing the negative impact that we have on the environment in terms of carbon dioxide (CO₂) emissions, pollution and loss of biodiversity (Fischer-Kowalski & Swilling, 2011; Swilling et al., 2013).

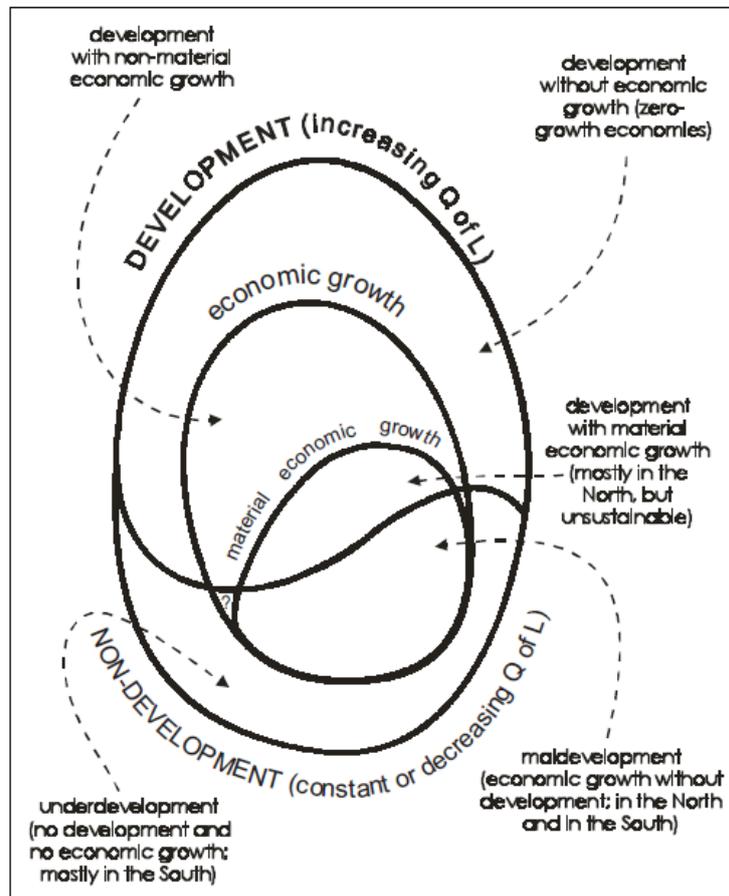
Taking the above discourse into consideration, Gallopin's egg (figure 2) demonstrates four useful clarifications on the term "development" (Gallopin, 2003):

1. Development is improvements in human well-being but at the cost of material economic growth.
2. Maldevelopment means reduced human well-being but with improvements in material economic growth.
3. Underdevelopment is when there is no improvement in human well-being and there is reduced material economic growth.
4. SD is an increase in quality of life for all humans with no material economic growth.

As useful as this is in terms of understanding development, Gallopin's view on SD is still very Eurocentric and more appropriate to the global North. As for most developmental states, which according to Swilling and Annecke (2012): "is not about the 'state in the developing world'... [but rather] a wide range of state formations in mainly developing countries" (Swilling & Annecke, 2012: 83–84), (re-)industrialisation in terms of non-material development is unlikely in the short term. So for the purposes of this thesis, I therefore combine Capra's (2014) ideas on a sustainable community with the US-based Centre of Urban Policy Research's ideas on

sustainable livelihoods to formulate a somewhat more workable, context-specific definition.

Figure 2: Gallopin's egg showing the different "guises of development" (Gallopin, 2003: 27)



Source: Gallopin (2003)

SD is therefore about "... communities [that] evolve their patterns of living over time in a continual interaction with other living systems, both human and nonhuman ... It is a dynamic process of coevolution rather than a static state" (Capra & Luisi, 2014: 353), and involves "... processes of social and ecological reproduction situated within diverse spatial contexts. We understand processes of social and ecological reproduction to be non-linear, indeterminate, contextually specific, and attainable through multiple pathways" (Centre for Urban Policy Research, 2000: 7).

As fuzzy a definition as this may be, it really emphasises the idea that SD and sustainability are complex concepts that require complex thinking in order to navigate towards its deeper-level understanding.

2.2.4 Approaches to sustainable development

There is a diverse continuum within SD approaches that range from a weak, shallow anthropocentric perspective through to a strong, deep, ecocentric perspective (Mebratu, 1998; Gallopín, 2003; Hopwood, Mellor & O'Brien, 2005; Blewitt, 2008; Farley & Smith, 2014). On the shallower end of the spectrum lie neo-liberal economists and to some extent ecological modernisers who are humanistic towards SD, looking at “business as usual” with a “brighter shade of green” made possible through predominantly technological advancements (Hopwood, Mellor & O'Brien, 2005; Robertson, 2007; Korhonen, 2009). Its discourse is primarily on mitigation and efficiency through “techno-fixes” and is criticised mainly for still not acknowledging planetary boundaries and limits to growth (Swilling, 2012). Deep ecology (Devall, 2001; Drengson & Devall, 2010) and Gaia Theory (Harding, 2006, n.d.; Lovelock, 2007; Tucker, 2014) on the other hand deal with an ecocentric value system that places its centrality on the environment and nature; humans are a part of but in no way superior to the natural environment. At the essence of Gaian Theory, James Lovelock and Lynn Margulis see the Earth as an alive entity with interconnections between living and non-living parts (Harding, n.d.). These viewpoints look for a more radical transformation in terms of equality and the environment (Hopwood, Mellor & O'Brien, 2005). As James Lovelock implores:

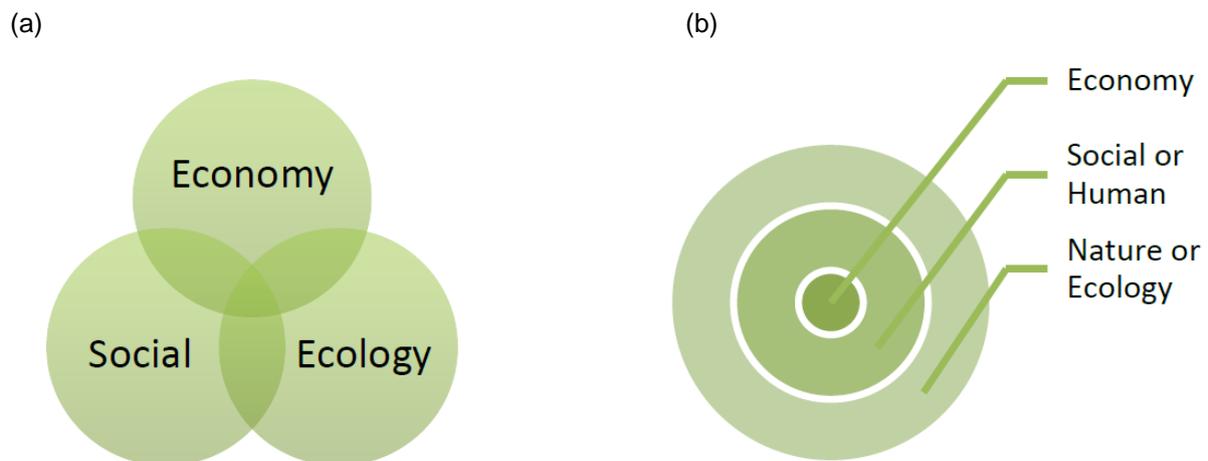
I ask that we put our fears and our obsession with personal and tribal rights aside, and see that the real threat comes from the harm we do to the Living Earth, of which we are a part and which is indeed our home. (Lovelock, 2007: 14)

2.2.5 Modelling sustainable development

Adapting ideas from both Mebratu (1998) and Farley and Smith (2014), there are two common models that are useful when referring to and dealing with SD: The first is the dominant triple-bottom line or three pillars of sustainability in which the economy, society and environment are equally placed, “mutually reinforcing but essentially autonomous” (Farley & Smith, 2014: 149). This is usually depicted through a Venn diagram (figure 3a) where the three circles overlap showing the space of SD (Smith, 2011). The second is the nested model (figure 3b), in which the economy is embedded within society which in turn is embedded within the environment, what Farley and Smith (2014) refer to as neo-sustainability. Of course there are variations

on these two models, the nested model for instance has been adopted as a national framework for SD in South Africa, but it underpins the entire model with a “governance” component (Department of Environmental Affairs & Tourism, 2008). However, this makes the assumption that there is ethical governance contributing to the model and once again reinforces the social aspect of sustainability over and above the environment (Noel, 2013).

Figure 3: Two diagrammatic models of sustainable development: (a) the dominant triple bottom line and (b) the neo-sustainability nested models



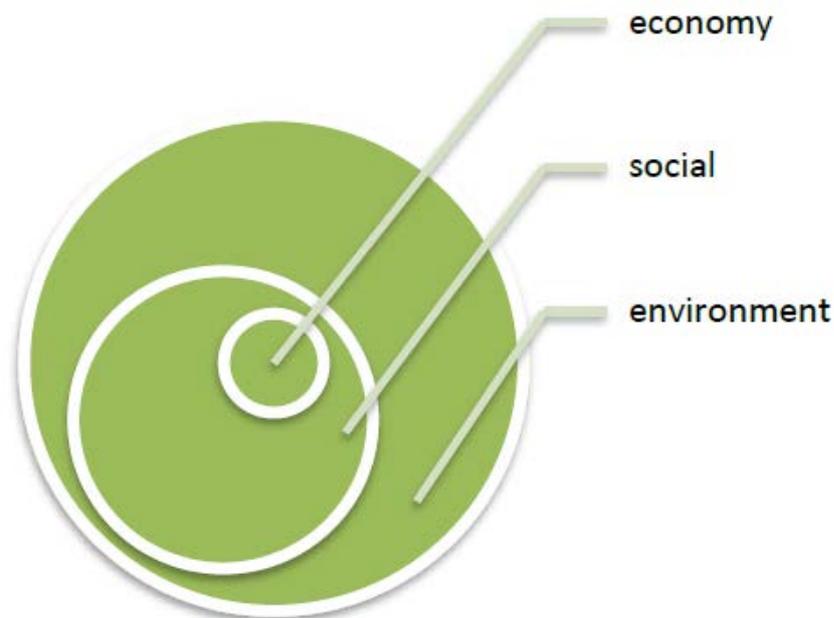
Source: Blom (2014)

The critique of the triple bottom line model is that it lies more towards the weaker side of the sustainability continuum. This is because there is no “special place for the environment” (Farley & Smith, 2014: 149) in this perspective. Despite Smith (2011) suggesting that it calls for transdisciplinarity and integration between the three parts, Hattingh (2001) shows that this model lends itself to the logic of trade-offs, possibly at the expense of the environment if the other two, the social and economy, are shown to benefit.

This thesis follows the ecocentric nested approach to SD as it acknowledges that without the environment there is no society and economy to speak of and that humans are therefore wholly dependent on the environment (Farley & Smith, 2014). In particular, as will be demonstrated in later chapters, it positions itself more towards a complexity theory (Cilliers, 2008), living systems thinking (Capra & Luisi, 2014) and a Gaian perspective (Lovelock, 2007) on SD. Following the complexity

theory viewpoint, caution must be taken when dealing with any models as they are certainly not representations, nor even approximations of reality, that can be applied to all contexts (Preiser, Cilliers & Human, 2013). However, this does not imply that models are purposeless or not useful, instead it means that the limitations of these models must be accepted equally when it comes to their implications for real complex living systems (Cilliers, 2000b). For this reason, this paper would like to delve one step deeper and acknowledge and adopt a neo-sustainable model developed by Murray (2015) (figure 4), which attempts to give voice to the complexity of SD: “The circles have been drawn in a nested, off-centre form to depict both the systems/complexity view and messiness of the inter-relationships between the environment, the social world and the economy” (Murray, 2015: 47).

Figure 4: The sustainability model adopted for this thesis



Source: Murray (2015)

2.2.6 Why sustainable development? The global polycrisis

So far the history of SD, its complexity in formulating definitions, models and approaches have been addressed. However the crucial question really is – why SD? The best way of answering this question is to refer to what Edgar Morin calls the “polycrisis” (Morin, 1999b: 73), a term which has morphed into the “global polycrisis”

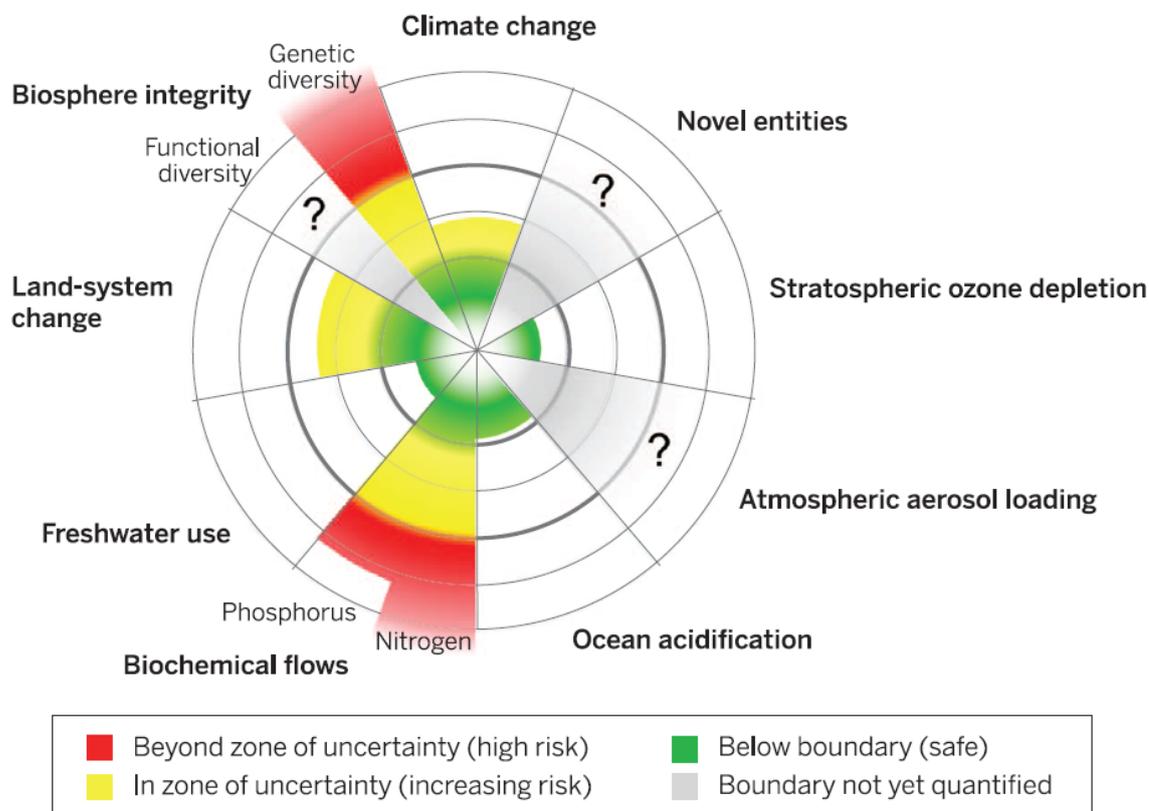
and has been introduced powerfully into the sustainability talk by Swilling and Annecke (2012: 26). They propose seven documents that have changed the view of our world, showing the devastating effects that humans have on all living things, including other humans (Swilling & Annecke, 2012). These include:

1. The United Nations (UN) *Millennium Eco-system Assessment*, which confirms, *inter alia*, that humans have degraded 60% of eco-systems upon which humans themselves depend on for survival (Millennium Ecosystem Assessment, 2005)
2. The *Intergovernmental Panel on Climate Change* (IPCC) report that confirms that not only is global warming a harsh reality, particularly for the poor, but that it is to a large degree anthropogenic (IPCC, 2007). In fact, the latest IPCC report is 95% certain that humans are the cause of the current global warming event (IPCC, 2014).
3. The *2008 World Energy Outlook* (WEO) which recognises that, although there is still debate around the exact time, the world will reach “peak oil”, and that will be the end of the cheap oil era (International Energy Agency, 2008). The most recent WEO special report *Energy and Climate Change*, which was released on 15 June 2015, focuses its attention towards COP21 in Paris (International Energy Agency, 2015). Its message is clear and urgent and calls for ambitious Intended Nationally Determined Contributions (INDCs) of countries, if the inevitable transition towards renewable energy is to occur without exceeding a mean global temperature rise above 2 °C by around 2040 (International Energy Agency, 2015).
4. The United Nations Development Programme (UNDP) *Human Development Report* for 1998 simply highlighted the massive inequality that existed between the richest and poorest of people (UNDP, 1998). The latest 2014 report, which focuses on vulnerability, shows that there has been some reduction in inequality due to increased health in several countries, however “horizontal inequality” is still widespread, particularly within education (UNDP, 2014).
5. *The Challenge of Slums*, which was a report released by UN-HABITAT, stated that one-third of the world’s total urban population live in slums; this equates to one billion people (United Nations Centre for Human Settlements, 2003).

6. The most comprehensive report on global agriculture entitled *Agriculture at the Crossroads* raises huge concerns for global food insecurity due to industrial and chemical intensive agriculture that has degraded 23% of all used land (Watson, Wakhungu & Herren, 2008).
7. Lastly, the *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth* report, which has been previously mentioned, showed that in 2005 there had been a 36% increase in global resource dependency since 1980 (Fischer-Kowalski & Swilling, 2011).

This all paints a sad picture for humanity. Can we really say that we've "progressed"? A further, more current, elaboration on the global polycrisis is perhaps the work done by the *Planetary Boundaries* research team (Rockström, 2009; Steffen et al., 2015). Its message is clear and simple: the relatively stable 11,700 Halocene epoch is over and we have now entered into what is being referred to as the Anthropocene, because the world is currently being altered more severely by humans than it ever has been before (Steffen et al., 2015). The team of scientists have mapped nine planetary boundaries and have quantified the safe operating zone for humanity (figure 5). They have empirically shown that society has already crossed the safe operating zone in four out of the nine boundaries, namely: Nitrogen and Phosphorous biogeochemical flows, land system changes, biosphere integrity and climate change (Steffen et al., 2015).

What does this all mean for humanity? And more importantly for this thesis, what does this mean for the education of humanity today and in the future? The next section attempts to look towards the future of SD, paying specific attention to the SDGs for 2030, and in particular at ESD that will be brought into this review in section 2.3.

Figure 5: The updated Planetary Boundaries 2.0 (Steffen et al., 2015)

Source: Steffen et al., (2015)

2.2.7 The future of sustainable development

Based on transition theory, Swilling and Annecke (2012) describe how the economist Charles Gore overlaps the industrial socio-technical transitions (Perez, 2009) within the Kondratieff cycles to create what Gore (2010) calls the long-term development cycle that typically lasts 50 – 60 years. Swilling and Annecke (2012) then convincingly propose that the next long-term development cycle, through irruptive triggers such as the greening of the industrial economy due to the current polycrisis, could be a transition from the industrial (5th wave) to the sustainable (6th wave) epoch (Swilling & Annecke, 2012). The proposed timeframe suggests that we are currently in the Kondratieff spring of the sustainable socio-ecological regime (Swilling & Annecke, 2012) and coincidentally, or perhaps due to Gaian co-evolutionary

thinking¹² (Hawken, 2007), this ties up with the UNDP's expiration of the Millennium Development Goals (MDGs) and the introduction of their new 15-year SDGs (UNDP, 2015).

This year, 2015, the world community have negotiated 17 goals and 169 targets (UN Division for Sustainable Development, 2015), despite predictions that there would be issues of quantifying and narrowing down the targets into something manageable (Brende & Høie, 2015). Jeffrey D Sachs, an economist and director of the Earth Institute, seems to think that the three-pillar approach, with the introduction of good governance at all levels, should be applied to the SDGs (Sachs, 2012), however the three-pillar approach would be problematic as already critiqued in section 2.2.5 of this paper. Griggs, Stafford-Smith, Gaffney, Rockström, Öhman, Shyamsundar, Steffen, Glaser, Kanie and Noble (2013) support this approach as being problematic by proposing a unified framework for a transition from MDGs to SDGs with a nested sustainability approach, built upon the limitations proposed by the planetary boundaries as a new chosen paradigm. Their definition of SD is one of the Anthropocene: "Development that meets the needs of the present while safeguarding Earth's life-support system, on which the welfare of current and future generations depends" (Griggs et al., 2013: 306)

Goal number one is "thriving lives and livelihoods" and this includes universal access to education (Griggs et al., 2013). The future of the planet seems to be set on a transition towards a sustainability trajectory (Swilling & Annecke, 2012) as there is no other way of adequately addressing the gross negligence and destruction that humans have had on the environment. If we are going to make this transition, it is essential that education plays a vital role in shaping the knowledge and understanding of today's and tomorrow's people. Education is embedded into this SD agenda and so the next section will explore the literature specifically on ecoliteracy that enables a complexivist view on ESD.

¹² Sustainability co-evolution is mentioned often in SD literature (Altieri, 2007; Morrison, 2008; Capra & Luisi, 2014) and really refers to a collective evolution of two or more populations, due to close interconnectivity and mutualistic selective forces (Cairns, 2007). The suggestion made in the paper therefore follows Paul Hawken's viewpoint that there are changes occurring in the collective thinking of humans, that there is co-evolution happening due to the interconnectivity between humans, and between humans and Gaia (Hawken, 2007).

2.3 Education for Sustainable Development through Ecoliteracy

“By then, there was only one role left in the great scheme of things, so the Creator and Mantis assigned this place to the Bushman – that of Hunter-Gatherer. The Bushman fulfilled his designated role faithfully, living in close harmony with the animals, birds and the plants upon the earth.”

(Greaves, 1988)

This section begins by reviewing a brief history of EE whilst at the same time making sense of the terms EE (Carter & Simmons, 2010; Irwin & Lotz-Sisitka, 2014), environmental literacy (Carter & Simmons, 2010; McBride et al., 2013), ecological literacy (McBride et al., 2013), ecoliteracy (Capra & Luisi, 2014), and ESD (Manteaw, 2012; Locke & Russo, 2013; Capra & Luisi, 2014). I then go on to argue that although removing the ambiguity of terms and terminology can be useful (Le Grange, 2002; McBride et al., 2013), getting too stuck in the semantics is not entirely helpful when what we need is urgent transformation in education systems that puts learners on the trajectory towards creating their sustainable futures (Morin, 1999a; Lotz-Sisitka, 2009; Clarke, 2012; Montuori, 2014). Essentially all the above-mentioned definitions will foster a form of ecoliteracy on some level, which in turn is intricately linked to ESD and, as argued by Clarke (2012), humans are all functionally ecoliterate (Clarke, 2012). The questions applicable to this thesis are:

- how can we seriously implement these approaches into our curricula and pedagogy (Thomas, 2010; Barlow & Stone, 2011; Widhalm, 2011), especially when our education systems are still planted in a modernist, enlightenment and reductionist paradigm?
- And what are useful frameworks to gain a sensibility as to whether this implementation has indeed made a difference to the way that learners participate in the world around them (Barnes & College, 2013; McBride et al., 2013; Capra & Luisi, 2014; Gerstein, 2014)?

Reflexive box 3: Sounds of Nature

As a young boy I clearly remember being read those words that I quoted in the opening lines of this section, from Nick Greave's *When Hippo was Hairy*, for these were the folktales that many a young, middle-class, English-speaking South African boy heard growing up. I wonder what role this played in making me ecoliterate? When reviewing the history of EE and ecoliteracy both globally and locally, it seems likely that billions of other children, past and present, have had their own forms of culturally-tailored, informal environmental literacy to which they were exposed, whether it be through indigenous folklore or traditional bedtime stories. And so the real question is ... what was and is happening to facilitate ecoliteracy in formal education?

I managed to stumble across a poem I wrote at school when I was 13 years old entitled: *Sounds of Nature*, in which I clearly express awe at the diversity of nature through the various sounds that animals that crawl, fly, burrow, prowl and swing make. I think there is very little doubt that my ecoliteracy, albeit Eurocentric and romantic, began at a young age.

2.3.1 The history and the evolution of ecoliteracy

EE, environmental literacy, ecoliteracy and ESD, being as interwoven as they are, could theoretically all be traced back to the first recorded time that humans showed an emotional and physical awareness of their environment and how to “be” a part of it. Following on from section 2.2.2, and taking on an evolutionary perspective, it is difficult to get a real sense of when humans first realised their relationship to nature, because traits like “consciousness”, “knowledge” and “behaviour” don't fossilise (Raath, 2012). However if we follow a living systems theory in that all life has an innate ability to sustain life (Capra & Luisi, 2014), perhaps there is value in looking as far deep into time as when our early hominid common ancestors, such as *Australopithecus afarensis* or “Lucy”, lived over three million years ago. Not surprisingly, this is out of the scope of this thesis and so it forces us to begin where most literature on EE begins.

2.3.1.1 The global context

It is known through archaeological evidence that ancient civilisations, such as the Greeks, Egyptians and Chinese, actively taught EE and that societies in Africa have been known to teach knowledge and practices of sustainable ecosystems well before colonisation (Irwin & Lotz-Sisitka, 2014). During the period of Enlightenment, Jean-Jacques Rousseau stressed the importance of educating about the environment, while following this in the late 19th century, the Scottish sociologist Patrick Geddes, was the first to acknowledge the importance of EE in the urban environment and therefore is considered the father of EE (Irwin & Lotz-Sisitka, 2014; Murray, 2015). During the Green Movement, a definition of EE was published by Professor William B Stapp in 1969: “Environmental education is aimed at producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of how to help solve the problems, and motivated to work toward their solution” (Stapp, 1969: 34).

It was not more than three years later, when the UN had its first international conference in Stockholm in 1972, whereby EE was explicitly recognised as a tool for addressing environmental issues, and furthermore UNEP was tasked to establish a universally accepted definition and framework (Carter & Simmons, 2010). The first international workshop on EE was held in Belgrade in 1975, which then went on to ignite the international meeting and formulation of the most popular declaration of EE, the contested Tbilisi Declaration in 1977 (UNESCO, 1977; Lotz-Sisitka, 2009; Carter & Simmons, 2010). This intended to be value neutral towards the environment (Le Grange, 2002), and outlined objectives and principles of EE without providing frameworks on how to achieve them (Locke & Russo, 2013). From then on, there was an explosion of global declarations and conferences, policies and initiatives that were undertaken surrounding the polysemous¹³ EE (Le Grange, 2002; Lotz-Sisitka, 2009).

¹³ “Polysemous” is a term often used in EE discourse to describe words that have many meanings (Le Grange, 2002; Murray, 2015).

2.3.1.2 The South African context

Interest in EE in South Africa began in the 1960s as a result of the growing global awareness in environmental issues, however it was not until the mid-1980s that the country began integrating it into society and politics (Irwin & Lotz-Sisitka, 2014). Due to political reasons, the apartheid-governed country at the time did not sign into the Tbilisi Declaration, but in 1984 the first national journal for EE was published and in 1985 the first university graduate and postgraduate courses were offered on EE (Irwin & Lotz-Sisitka, 2014; Murray, 2015). From the late 1980s through to the present there have been many initiatives in trying to implement EE into the national curriculum (Le Grange, 2004). Before the democratically elected South African government came into power, a White Paper on EE was issued with the intention of incorporating it into the curriculum (Le Grange, 2002). Post the 1994 elections there was a plethora of new policies that were being institutionalised, one of which included the right of every South African to a healthy environment as a part of the new constitution (Le Grange, 2002). A significant aspect of this political period was the government White Paper issued in 1995 on education and training, in which EE was said to be:

... an inter-disciplinary, integrated and active approach to learning, [which] must be a vital element of all levels and programmes of the education and training system, in order to create environmentally literate and active citizens and ensure that all South Africans, present and future, enjoy a decent quality of life through the sustainable use of resources. (Department of Education, 1995: 18)

Despite a number of reforms to the South African curriculum over the past 30 years (Jansen, 1998; Jansen & Taylor, 2003; Bantwini, 2010), these EE inclusions have been carried forward as a core principle in all subjects in both the General Education and Training (GET) band, which is from Grades R-9, and the Further Education and Training (FET) band, which is from Grades 10-12 (Le Grange, 2004; Department of Education, 2011; Irwin & Lotz-Sisitka, 2014). As can be seen in table 1, the latest CAPS includes the social aspect alongside the environmental, a clear movement towards a “sustainability” agenda (Teise, 2013). An obvious example of explicit ecoliteracy content that is covered in CAPS is the “Human Impact on the Environment” section that is part of the Grade 11 and 12 Life Sciences curriculum

(Department of Education, 2011). The content and issues in this section, shown in the table 1 below, are not only of an environmental nature but also incorporate a wide range of social and economic concepts and themes, which make it an ideal framework to use for ESD.

Table 1: “Human Impact on the Environment” CAPS content for Grade 11 and 12 Life Sciences

Topic	Content
Atmosphere and Climate Change	<p>Causes and consequences of the following (relate to conditions and circumstances in South Africa):</p> <ul style="list-style-type: none"> • Carbon dioxide emissions • Concept of ‘carbon footprint’ and the need to reduce the carbon footprint • Deforestation • Greenhouse effect and global warming: desertification, drought and floods • Methane emissions • Ozone depletion.
Water Availability and Quality	<p>Causes and consequences of the following (relate to conditions and circumstances in South Africa):</p> <ul style="list-style-type: none"> • Construction of dams • Destruction of wetlands • Poor farming practices • Droughts and floods • Exotic plantations and depletion of water table • Boreholes and effects on aquifers • Wastage • Cost of water • Water for domestic use, industry, agriculture and mining: pollution, diseases, eutrophication and algal bloom • The effect of mining on quality of water • Thermal pollution • The need for water purification and recycling • Alien plants, e.g., <i>Eichornia</i>
Food Security (link with population ecology dynamics)	<p>Causes and consequences of the following (relate to conditions and circumstances in South Africa):</p> <ul style="list-style-type: none"> • Human exponential population growth • Droughts and floods (climate change) • Poor farming practices: monoculture, pest control, loss of topsoil and the need for fertilisers • Alien plants and reduction of agricultural land • The loss of wild varieties: impact on gene pools • Genetically engineered foods • Wastage
Loss of Biodiversity (the sixth extinction)	<p>Causes and consequences of the following (relate to conditions and circumstances in South Africa):</p> <ul style="list-style-type: none"> • Habitat destruction: farming methods, e.g., overgrazing and monoculture, golf estates, mining, urbanisation, deforestation, loss of wetlands and grasslands • Poaching, e.g., for rhino horn, ivory and ‘bush meat’ • Alien plant invasions: control using mechanical, chemical and biological methods • Indigenous knowledge systems and the sustainable use of the environment e.g., devils’ claw, rooibos, fynbos, the African potato (<i>Hypoxis</i> and <i>Hoodia</i>)
Solid Waste Disposal	<p>Causes and consequences of the following (relate to conditions and circumstances in South Africa):</p> <ul style="list-style-type: none"> • Managing dumpsites for rehabilitation and prevention of soil and water pollution • The need for recycling • Using methane from dumpsites for domestic use: heating and lighting • Safe disposal of nuclear waste

Source: Department of Education, (2011: 51–53)

2.3.2 Environmental literacy, ecological literacy, ecoliteracy and ESD

The terms environmental literacy, ecological literacy, ecoliteracy and ESD have evolved into central tenets of the EE discourse (Barnes & College, 2013; McBride et al., 2013; Hofman, 2015). The selective pressure in the evolution of these terms can be seen as the global transition towards an era of SD (Le Grange, 2003; UNESCO, 2005; Locke & Russo, 2013). Preservation and conservation of the environment (Carter & Simmons, 2010; Locke & Russo, 2013) have made a transition towards the integration and collaboration of society embedded within the environment, in a manner in which both can flourish (Barnes & College, 2013). Murray (2015) provides a useful timeline of the history of EE comparative to that of SD which supports this transition.

Just as illiteracy preceded literacy, environmental illiteracy came before environmental literacy (McBride et al., 2013). It is a term most often attributed to the change in human perceptions that have emerged due to environmental texts, such as *Silent Spring* (Carson, 1962) or Aldo Leopold's *A Sand County Almanac* (Leopold, 1949). On the other hand, to become *ecologically* literate means that one has to gain scientific knowledge about ecology, which is the study of ecosystems (McBride et al., 2013) and finally to become *ecoliterate* means to gain a deeper “understanding of basic principles of ecology, or principles of sustainability, and living accordingly” (Capra & Luisi, 2014: 353). What does this all mean for ESD? In light of the global polycrisis (see section 2.2.6 for elaboration), which extends beyond being simply an environmental problem, ESD is a development within EE (Le Grange, 2003) that addresses both the social and environmental problems as embedded systems and therefore, as put succinctly by Locke and Russo (2013):

[Ecoliteracy] is a logical component of education for sustainable development as its focus on the various interactions of different elements in the environment includes human activity which is essential to the achievement of a self-sustaining community that preserves its resources for future generations. (Locke & Russo, 2013: 4)

Some important aspects about ESD is that it is rooted in transdisciplinarity (Hampson, 2012; Michelsen, 2013), systems and complexity thinking (Capra & Luisi, 2014) and so then pushes education to make deeper level changes in teaching and

learning philosophies, methodology and content (Lotz-Sisitka, 2009). Despite UNESCO dedicating a decade to ESD 2004 (UNESCO, 2005), it still remains ambiguous to practitioners (Hasl f, Ekborg & Malmberg, 2014) and invisible not only in the global North but also to continents in the global South (Manteaw, 2012).

2.3.3 Going beyond the ecosemantics

As important as it is in defining these terms in order to develop appropriate pedagogical methodologies and frameworks (Hampson, 2012; McBride et al., 2013), it is also important not to let the semantics get in the way of their value towards creating a sustainable future, as each term offers a unique framework, but simultaneously each framework is interconnected and interchangeable (McBride et al., 2013). Taking into consideration the evolution of these terms in academic literature in the context of their time, it is apparent that it is the social emphasis that grows within these concepts as one moves from EE's beginnings through to ESD. This is because of the more interconnected, relational way of thinking about humans and society nested within nature, which has its roots in living systems and complexity thinking. Before the concept of SD from *Our Common Future*, EE was fashioned in a reductionist, Cartesian dualism with humans and nature still separate from each other. Ecoliteracy is therefore a form of EE but with a living systems lens, which is necessary in making a transition towards ESD. In light of this, whether it be EE or ESD, the focus should be less on what we teach for sustainability and more about how we teach for sustainability (Thomas, 2010; Hofman, 2015) and this has to do with the lens within which teachers view the world (Hofman, 2015). As this thesis is underpinned by complexity theory, it assumes the term ecoliteracy in its broadest, most "fuzzy" way¹⁴ for moving education towards an epoch of sustainability because, as Capra & Luisi, (2014) put it: "[t]he survival of humanity will depend on our ecological literacy – our ability to understand the basic principles of ecology and to live accordingly." (Capra & Luisi, 2014: 356)

¹⁴ Capra & Luisi, (2014) use the terms ecoliteracy and ecological literacy interchangeably. In order to move beyond the ecosemantics (Hampson, 2012), this thesis broadens the term even further to encapsulate EE and environmental literacy.

2.3.4 Teaching ecoliteracy

In order for there to be a transformation from contemporary industrial education into ESD, ecoliteracy needs to be the focus of teaching and learning methodologies and processes. Furthermore the lens through which science is engaged, as a process of knowledge creation, needs to change from a Newtonian reductionist process, to a complexity living systems process – this will be covered in more detail in section 2.4. The questions therefore are: How do we teach ecoliteracy? How can teachers generate what E O Wilson called “biophilia”, this affinity for life and Earth (Wilson, 1984)? And what frameworks are used for teaching ecoliteracy?

Before ecoliteracy frameworks are explored, David Orr, a co-founder of ecoliteracy, provides a sobering reminder to teachers and education administrators:

For those calling [themselves] environmental educators, it is sobering to note that the only people who have lived sustainably in the Amazon rain forests, the desert Southwest, or anywhere else on earth could not read (which is not to say that they were uneducated). And those in the United States living closest to the ideal of sustainability, the Amish for example, do not make a fetish of education, seeing it as another source of deadly pride. On the other hand, those whose decisions are wreaking havoc on the planet are not infrequently well educated, armed with B.A.'s, B.S.'s, LL.B's, M.B.A's, and Ph.D.'s. (Orr, 1992: 149)

Gaining ecoliteracy means being educated for living a sustainable livelihood (Capra, 1997; Capra & Luisi, 2014) and does not mean gaining conventional qualifications, nor does it mean simply having knowledge about certain issues such as climate change (Anyanwu, Le Grange & Beets, 2015). A starting point to understanding how ecoliteracy is taught and learned is by looking at educational institutions and organisations around the world that educate ecoliteracy as their core philosophy, and have therefore based their teaching and learning methodologies within ecoliteracy frameworks. Table 2 provides an overview of some leading institutions and organisations where ecoliteracy is the primary focus of their programmes and curricula. There is little doubt that these “eco-institutions” improve the ecoliteracy of their participants. Ozsoy, Ertepinar and Saglam, (2012) have done quantitative studies with 316 elementary students in Turkey, of which 156 were exposed to the

eco-schools programme¹⁵. Their ecoliteracy levels were then measured through an environmental literacy questionnaire and the results showed that there was a significant difference in ecoliteracy between those that participated in the eco-schools programme and the control group (Ozsoy, Ertepinar & Saglam, 2012).

Table 2: Education related institutions/organisations that teach ecoliteracy

Institution/organisation	Phase	Place	Website
A Rocha International	Primary and Secondary	Worldwide, 20 countries	http://www.arocha.org/en/#
Barefoot College (NGO)	Rural education initiative	Tilonia, India	http://www.barefootcollege.org/
Centre for Ecoliteracy (NPO)	Primary and Secondary	Berkley, USA	http://www.ecoliteracy.org/
Eco-Schools International	Early years, Primary and Secondary	Worldwide, 58 countries, 46 000 schools	http://www.eco-schools.org/
EARTH University	Tertiary	San José, Costa Rica	http://www.earth.ac.cr/
Green School	Early years, Primary and Secondary	Bali, Indonesia	http://www.greenschool.org/
Green Schools (NPO)	Primary and Secondary	Massachusetts, USA based	http://projectgreenschools.org/
Island School	Primary and Secondary	Eleuthera, The Bahamas	http://www.islandschool.org/
School of Environmental Studies/Zoo School ¹⁶	Secondary	Minnesota, USA	http://www.district196.org/ses/
Schumacher College	Tertiary	United Kingdom	https://www.schumachercollege.org.uk/
Second Nature	Tertiary	Boston, USA	http://www.secondnature.org/
Sustainability Institute	Tertiary	Lynedoch, South Africa	http://www.sustainabilityinstitute.net/
Youth Initiative Program	Tertiary	Järna, Sweden	http://yip.se/

Source: Author's elaboration

This list provided in table 2 is by no means comprehensive and there are many other organisations, schools and universities that are integrating ecoliteracy into their everyday, conventional curricula (Togo & Lotz-Sisitka, 2013; McGibbon & Van Belle, 2015; von Blottnitz, Case & Fraser, 2015). David Greenwood gives a compelling account of the difficulties and struggles that teachers, in particular, face if a plugin approach to ecoliteracy is adopted (Greenwood, 2010). Firstly he suggests that teachers should critically analyse their professional work and not be surprised to find that it does not promote sustainability and sustainable livelihoods. He then warns teachers against being overly optimistic for making small changes to the curriculum

¹⁵ See <http://www.eco-schools.org/> for more information on the eco-schools international programme.

¹⁶ For a comprehensive critique of the Zoo School see Richard Kahn's *Critical Pedagogy, ecoliteracy, & Planetary Crisis* (Kahn, 2010).

in lieu of promoting sustainability, concluding that teacher education bureaucracy is too controlled and that changes at the practical level need to be combined with top-down structural and process changes to make any real difference (Greenwood, 2010).

This does not follow along the thinking of Paul Hawken's ideas from *Blessed Unrest* that grassroots movements, no matter their form or size, co-evolve with the collective, making large contributions ultimately to changing global systems (Hawken, 2007). As this thesis is rooted in complexity theory, which considers the non-linear interactions between individual parts of a system, it acknowledges within the complexity framework, the "butterfly effect" in which small perturbations in a system can have large effects and vice versa (Heylighen, Cilliers & Gershenson, 2007). So making changes within any current system that bring about transitions towards sustainable living and thinking, is transformative in its own right therefore providing impetus to mainstreaming ESD into everyday curricula. As explained so eloquently by John Hunt in the *art of the idea and how it can change your life*, he metaphorically likens the *status quo* system to a fortress with all its bureaucracy and those who guard it as "Thought Policemen" who are the protectors of "conventional wisdom"(Hunt, 2009). Hunt writes: "Their fortress is ringed with a moat of logic, and experience peers out from every turret" (Hunt, 2009: 69). When new ideas or changes are made, it's as if there is an attack on the fortress and by the time the fortress collapses, due to the new ways of thinking, the "Thought Policemen" realise that what they were protecting so fervently was long gone anyway (Hunt, 2009).

2.3.5 Ecoliteracy frameworks

There have been numerous frameworks that have been suggested in academic literature on approaching ecoliteracy in the classroom or, even better, outside the classroom. Even before ecoliteracy had evolved into its current state, EE saw its broader approach as "education about, in/through and for the environment." (Le Grange, 2002: 83). The education "about" is the gaining of knowledge of the environment, and aims to fulfil the "knowing" aspect. This could, for instance, be accomplished in a classroom through conventional teaching and scientific methodologies. Education "in/through" is about *being* in nature, or using nature to facilitate the teaching "about". The "for" the environment would traditionally have

been about conserving the environment, although through an ecoliteracy, living systems, perspective, this could be broadened to education *for* sustainability.

Moving on to a living systems approach, Widhalm, (2011) follows the thinking of Capra's networks and patterns (Capra, 1997) and the concept of "autopoiesis" which originally comes from the *Santiago Theory* by Maturana and Varela (Maturana & Varela, 1987; Capra & Luisi, 2014). "Autopoiesis" from its Greek roots, literally means "self-making" and is considered to be the criterion of all living things (Capra & Luisi, 2014). As living systems are relational and made up of networks, they are said to have the following characteristics (Capra, 1997; Widhalm, 2011):

- *Self-bounded* – there are boundaries to every living system, however they are not closed and open to exchanges beyond their boundaries.
- *Self-generating, self-renewing, self-perpetuating* – living systems have components that are continually producing new parts or replacing old or damaged parts.
- *Structural coupling* – there is place for novelty and creativity within the network due to relationships between parts of the system.

Using these characteristics above, Widhalm (2011) suggests that a living systems education should be "open to multiple ways of knowing" and that the "lived experience" is the most crucial part of knowing (Widhalm, 2011: 6). Following on this is the acknowledgment that living education systems are "loving systems" and that relations, contact and identity are important in this regard. Francis-Morgan (2013) found that introducing "learning gardens" into schools "cultivated a sense of place" (2013: 2) for the learners, which further reinforces this idea of identity being an important part for learners and living education systems.

Reflexive box 4: What does it mean to be living?

On reading *A Systems View of Life* and Capra's earlier works, I found it fascinating that he, along with many other esteemed theorists, was grappling with trying to answer hard core universal questions, such as 'what is life?'

As a Life Sciences teacher, the first topic we teach our new Grade 8s who come into high school is "The Characteristics of Life". To make it easier for them to learn the characteristics, we provide an acronym for them, which is MRS C GREN (D). This stands for eight, arguably nine, different characteristics of life that are: movement, respiration, sensitivity to stimuli, cells, growth, reproduction, excretion and nutrition. Death is always a contentious one that is up for debate amongst some teachers. Now I understand that it may be difficult to teach a concept such as "autopoiesis", but it has highlighted how reductionist our pedagogy actually is. Furthermore I understand why learners can debate, to some legitimacy when using this framework, why things such as fire and water can therefore be classified as living. This framework for teaching "life's characteristics" has been changing recently, and you'll now find online and in textbooks information leaning more towards processes, such as homeostasis and evolution, rather than structures when it comes to "defining life". Nevertheless, why are we not leaving the learners with these deeper questions and letting them explore their own unique understanding of life through experiences and interconnections, instead of criteria and tick boxes?

On a more practical level, Barlow and Stone (2011) suggest strategies that are important for leadership, decision-making and changing social systems. These are self-explanatory and could just as easily be applied to a teaching context and include the following: nurture communities, cultivate networks, work at multiple levels of scales, recognise openings of breakthrough of novelty, cultivate systems capacity for self-organisation, facilitate – don't expect to direct – living systems, plan on change taking time, be prepared to be surprised (Barlow & Stone, 2011: 4–7).

It is not surprising that these strategies proposed by Barlow and Stone (2011) correlate with the Centre for Ecoliteracy's five vital practices that integrate emotional,

social and ecological intelligence into education, which will enable learners to become more ecoliterate (Goleman, Bennett & Barlow, 2012):

1. Developing empathy for all life forms
2. Embracing sustainability as community practice
3. Making the invisible visible
4. Anticipating unintended consequences
5. Understanding how nature sustains life

Turning focus now to grey literature, Dr Jackie Gerstein is a passionate American teacher who blogs about 21st century education and teaching. Her “user-generated education” blogsite has a useful framework for teachers to identify the skills and attributes that are required in today’s learners (figure 6) (Gerstein, 2014). These interplay closely with the strategies and characteristics of living systems’ thinking (Capra, 1997; Barlow & Stone, 2011; Widhalm, 2011; Capra & Luisi, 2014). Five skills and attributes are considered in more detail below (Gerstein, 2014):

1. *Collaboration across networks* would be fostered within learners if networks between diverse living and non-living within education were made important and brought into curricula and class activities. This would relate to another point that Francis-Morgan (2013) makes about “fostering interconnectedness”, in that collaborating within systems places emphasis on the interconnections and what emerges from those relationships and not the individual parts.
2. *Agility and adaptability* recognises the non-linearity of systems and the ability to adapt to the unintended consequences that may emerge within a system.
3. The ability to adapt is directly related to the degree of diversity within the system, the many different relationships, and the many different approaches to the same problem. Increased diversity will instil *resilience* within systems.
4. *Curiosity and imagination* is about allowing space for novelty and creativity to emerge, particularly again as a result of a diverse set of networks and relationships.
5. *Empathy and global stewardship* speak to action and the ethics that come with making decisions or taking initiative. This is particularly pertinent to complexity theory and therefore will be demonstrated further in the next section 2.4.

Figure 6: Skills and attributes of today's learners



Source: Gerstein (2014)

2.3.6 Becoming ecoliterate through biomimicry

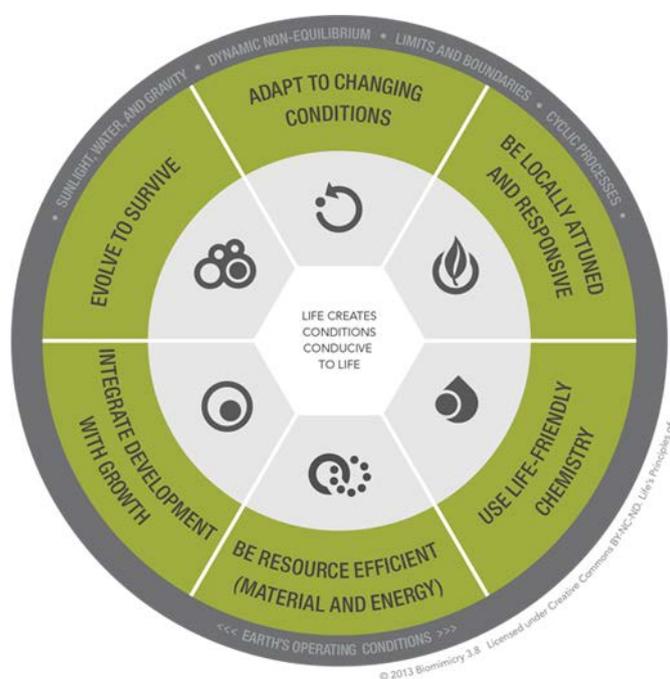
It can be seen that there are various approaches within approaches, and frameworks within frameworks when it comes to ecoliteracy. Barnes and College (2013) attempt to address the difference between simply being aware of nature and actually living and acting for nature, proposing that “[i]ndividuals will, however, be more likely to take actions to protect, restore, and celebrate the Earth based on inspiration from and love for the Earth” (Barnes & College, 2013: 4).

Getting inspiration *from* the Earth is precisely where the relatively new field of biomimicry enters the discourse. The term literally means to imitate life and it is the practice of learning from and then emulating life’s genius by creating more sustainable designs (Benyus, 2002). The basis of this approach is an evolutionary one, as it argues that life has been performing design experiments on Earth for 3.8 billion years and the result is a flourishing planet that knows best. Biomimicry’s focus question is: “can we design human products, processes and systems that are well-adapted to life on Earth?” (Janisch & Weerepas, 2014). It then looks to nature

as a model, measure and mentor for design (Benyus, 2002). Biomimicry follows a set of “Life’s Principles” (see figure 7) and has three levels of engagement for creating conditions that are conducive to life: The first level is mimicking natural forms, shapes and patterns that may or may not result in creating a more sustainable design or solution; if not, a deeper level can be taken in which the processes of nature are mimicked, and then finally the third and deepest level of biomimicry is mimicking ecosystems that work to restore Earth rather than deplete it (Janisch & Weerepas, 2014).

Biomimicry takes one step further than most ecoliteracy frameworks in that it seems to place more emphasis on the action and the doing through its design challenges (Janisch & Weerepas, 2014). The Centre for Ecoliteracy sees biomimicry as a tool for ecological design along with ecological engineering and industrial ecology (Orr, 2007), however in terms of ESD, biomimicry is entirely complementary to the living systems paradigm and can be used as another educational framework for enabling learners to become more ecoliterate.

Figure 7: The biomimicry design lens uses “Life’s Principles”



Source: *Biomimicry 3.8* (2013)

2.3.7 Teaching strategies for ecoliteracy frameworks

Various suitable teaching strategies have been proposed for teachers adopting an ecoliteracy framework, such as implementing place-based learning, project-based learning, interdisciplinary learning and Socratic inquiry in lessons (Centre for Ecoliteracy, 2015). The Biomimicry Educators Network has its own strategies, such as the “challenge to biology” that incorporates biomimicry as a methodology (Biomimicry Education Network, 2012). McBride et al. (2013) further this by suggesting more specific strategies for teachers, such as using case studies, sustainable living management projects, immersing students into socio-ecological contexts and incorporating visualisation and creative workshops into schools. Four of these strategies are of particular importance to this thesis.

Place-based learning is a strategy that has emerged due to a growing feeling that a “solid sense of place is lost” in most of society today (Lindholdt, 2012). It involves students participating in the lives of their communities outside of their classrooms (Greenwood, 2010; Francis-Morgan, 2013; Centre for Ecoliteracy, 2015). It is this type of learning that emphasises the boundaries that are constructed around socio-ecological systems and the importance of context in them (Chu, Strand & Fjelland, 2003; Haggis, 2008; Capra & Luisi, 2014).

There has been growing attention on the concept of project-based learning¹⁷ over the past decade (Thomas, 2010; Reimers, 2013). It is central to themes within the curriculum and involves answering challenging questions that require complex thinking skills and also often lends itself towards interdisciplinarity (Du, Su & Liu, 2013; Centre for Ecoliteracy, 2015). When combined with elements of “experiential learning”, which involves moving out of the classroom and learning in the “real world” (Centre for Ecoliteracy, 2015), it could be argued that this forms a type of transdisciplinary learning as there is a movement beyond disciplines that includes society as a beneficial component of the project (Max-Neef, 2005; Lotrecchiano, 2010).

¹⁷ This is sometimes referred interchangeably to problem-based learning (Thomas, 2010).

Socratic inquiry is a type of teaching and learning strategy in which critical thinking and listening skills are paramount (Centre for Ecoliteracy, 2015). In Socratic inquiry, the role of the teacher shifts from teaching through direct instructions and moves towards facilitating discussions between learners, which promotes tolerance of a more diverse set of opinions (Centre for Ecoliteracy, 2015). Methods of incorporating Socratic inquiry into pedagogy include appreciative inquiry processes (Leng, Ali, Zah, Rosnaini & Roselan, 2010; Centre for Appreciative Inquiry, 2015), Goethean observation, rapid sensing and sound mapping (Janisch & Weerepas, 2014), the last three being aspects of the biomimicry approach to “quieting” cleverness (Benyus, 2002: 287). These strategies again reinforce the ecoliteracy framework of education expanding all the senses of the head, heart, hands and spirit (McBride et al., 2013).

Biomimicry involves strategies such as the “challenge to biology” in which the teacher facilitates learners to define the challenge that they would like to solve, and then ask the question: “how does nature solve such a challenge?” This approach then requires learners to explore nature, and create a design based on their explorations which they will finally evaluate and adapt it if it doesn’t fulfil “Life’s Principles” (Biomimicry Education Network, 2012).

It is apparent from all these teaching strategies that collaboration between participants is vital, that this type of participatory pedagogy isn’t hierarchical from the teacher down to the learners, but rather cyclical in exchanging information and ideas, and that it’s not only about the understanding but also about the experiencing of nature that is vital. "Accordingly, the appropriate way of approaching nature, to learn about her complexity and beauty is not through domination and control, but through respect, co-operation, and dialogue" (Capra, 1997: 187).

2.4 Complexity Theory and Education

Human thinking and understanding of the world is tightly coupled to the way in which humans interact and experience the world. Until the early 20th century, classical and mechanical Newtonian science was the foundation of human thinking and understanding answering the when, where, what, how and why questions on human

consciousness (Heylighen, Cilliers & Gershenson, 2007; Swilling & Annecke, 2012; Colucci-Gray et al., 2013; Capra & Luisi, 2014). It was demonstrated in the previous section that there were numerous frameworks that could be implemented at multiple levels: from informing government national curricula right through to the pedagogical level, helping the individual teacher foster ecoliteracy in learners. What is evident is that adopting an ecoliteracy framework of any kind requires a fundamental change in the thinking and worldview of individuals and collectives. This section therefore deals with proposing that a critical complexity lens to knowledge is the starting point in making fundamental changes to ESD. This is reached after an evolutionary view of knowledge, thinking and complexity are reviewed, which leads onto detailing certain “family resemblances” of complexity theory and then finally looking at some implications that this way of thinking has for education curriculum and pedagogy.

2.4.1 The scientific reductionist (r)evolution

“So even though our body has been grounded more comfortably in nature, thanks to the move towards complexity that is evident in biology and physics, our mind and our sensitivity still await such a ‘scientific’ grounding.”

(Emmeche, 2004: 43)

As was the case with the sections on SD and ecoliteracy, an evolutionary perspective on complexity theory is important in understanding how complexity theory came into being “perhaps the most essential characteristic of our present society” (Heylighen, Cilliers & Gershenson, 2007: 117). It will also shed light on how modernist Newtonian scientific thinking, as a means of generating understanding and knowledge of a complex world, is at the root of an epistemological crisis, which plays a significant role in the way that humans see, understand and therefore act in the world around them.

During antiquity, the way that humans understood the world around them was through “mythical thinking”¹⁸ (Preiser, 2014). This way of making sense of the world,

¹⁸ It is important to make clear that even though the evolutionary structure of this section may suggest that “mythical” thinking is archaic and perhaps primitive compared to “critical” and “postmodern” thinking, this is quite the contrary. This thesis adopts the outlook that all these diverse worldviews are

by an external spiritual realm, dominated right up until the Renaissance, when the likes of Da Vinci and Copernicus began the age of “critical thinking” (Preiser, 2014), that laid the foundation towards the 18th century Enlightenment. During this time the term “science”, coming from the Latin *scientia* meaning “knowledge”, emerged from a break up between two branches of philosophy: the study of theories of nature, which became known as natural sciences, and the study of theories of society, which became known as the social sciences or humanities (Swilling, 2003; Swilling & Annecke, 2012). This was a time when humans began thinking “scientifically” as we understand the concept today. From an Aristotelian causality, Cartesian rationality and dualism through to Newtonian empiricism, a predominantly reductionist thinking has evolved (Heylighen, Cilliers & Gershenson, 2007; Capra & Luisi, 2014). Through “mutations” such as objectivism, determinism, predictability and rationalism (Cilliers, 2000a; Heylighen, Cilliers & Gershenson, 2007; Colucci-Gray et al., 2013), our current ideas and understanding of progress, growth and development were “naturally selected” and the epoch of industrialisation, modernism and mechanistic thinking was born (Emmeche, 2004; Heylighen, Cilliers & Gershenson, 2007; Cilliers, 2008; Swilling & Annecke, 2012; Colucci-Gray et al., 2013).

2.4.2 The philosophy of reductionism

In understanding reductionism’s philosophical roots, there is a need to examine its:

- ontology – the nature of being or the “fundamental categories of reality” (Heylighen, Cilliers & Gershenson, 2007: 117)
- epistemology – the nature of knowing or knowledge and reasoning about that reality, and its
- ethics – the way in which action is taken once knowing through the process of reductionism (Heylighen, Cilliers & Gershenson, 2007).

Scientific reductionism, also often referred to as Newtonian or Scientific Method thinking (Emmeche, 2004; Heylighen, Cilliers & Gershenson, 2007; Swilling & Annecke, 2012; Capra & Luisi, 2014), is based on a materialistic ontology that believes that the whole or the system that is being examined can be broken up into

present at any one time in current day thinking, and neither one of them is better than the other (Preiser, 2014).

simple parts, atomised, and that once you understand the simple parts you can make predictions and inferences about the whole (Heylighen, Cilliers & Gershenson, 2007). Heylighen, Cilliers and Gershenson (2007: 119) further suggest that Newtonian epistemology is “based on a reflection-correspondence view of knowledge”, that our knowledge is an imperfect reflection on the matter of which we are studying and that science’s role is seen as a way of understanding this “reality” as precisely and objectively as possible. It is worth noting that, contextually, this way of thinking co-evolved with modernity, which was the establishment of structure and order to “eliminate the haphazard and annihilate the spontaneous” (Bauman, 1992: 11), where perfection was the goal along with homogeneity, orderliness, progress and structure all being important in establishing the three century long “Cosmopolis” (Bauman, 1992: 14).

Chu, Strand and Fjelland (2003) explore the ontology and epistemological aspects of scientific thinking by suggesting that scientific theories need to have a predictive component, an explanatory component and a control component. Clayton and Radcliffe (1996) also expand on scientism saying that the nature of science seeks three things in particular:

1. Replicability, where different observers are able to replicate results and therefore reinforce epistemological objectivity.
2. Refutability, whereby “good experiments are those that decide between competing hypotheses” (Clayton & Radcliffe, 1996: 15). This is an ironic idea as it brings in the subjectivity of the scientists themselves, because “scientists, being human, are subject to the same unconscious prejudices and biases, failings and moral conflicts as everyone else” (Clayton & Radcliffe, 1996: 9). Therefore refutability is decisive and corroboration is not.
3. And finally reductionism, which people find more coherent and convincing.

Newtonian science caused a major rift to develop between science and the humanities (Heylighen, Cilliers & Gershenson, 2007; Swilling & Annecke, 2012). In an epistemological sense, science was placed on a pedestal above all things (Heylighen, Cilliers & Gershenson, 2007). This meant that there was a loss of ethics in the paradigm of Newtonian science, as there was a shifting of responsibility onto objective scientific findings, models and equations (Cilliers, 2000b, 2008; Preiser,

2012; Colucci-Gray et al., 2013; Michelsen, 2013; Preiser, Cilliers & Human, 2013). Choices made on socio-ecological systems were not only made in isolation from one another, but were based on scientific conclusions with little space for values and attitudes that ontologically and epistemologically speaking are too subjective (Cilliers, 2000b, 2008).

2.4.3 An epistemological crisis: Humans vs nature

This Cartesian, dualistic way of thinking not only split up the relationship between science and the arts but also had a fundamental effect on the relationship between humans and the environment. Nature was seen as something that was mechanical, lesser and separated, that through dissection and analysis could be understood, predicted, manipulated, and therefore could be used for the needs of a growing human population. It was reductionist science and its corresponding way of thinking that estranged humans from their natural environment; houses were built to keep “*homo industrialis*” (Benyus, 2002: 1) separated from the dangers and evils that lurked outside. “The everyday world shrank to what scientists had ‘discovered’ and were able to exploit” (Cilliers, 2008: 41), therefore it was, and is still being exploited by humans for humans at an unprecedented level as evident by the growing global polycrisis.

The paradox lies in the realisation that, despite the seeming horrors of reductionism thinking, the scientific revolution has also transformed society, and to a lesser extent the environment, for the better and this needs to be acknowledged as being important in this thesis. The Anthropocene is an era in which the average human has better health care and education, with an increased mean life expectancy and almost a doubling of GDP per capita since the begin of the modern period (Pretty, 2013).

2.4.4 Moving towards a living systems theory

“Systems thinking is contextual thinking, which is environmental thinking”

(Capra, 1997: 37)

The assumptions made by Newtonian scientific thinking of objectivity and determinism were challenged in the mid-20th century by the likes of quantum

physics, relativity theory and non-linear dynamics (chaos theory), and then later on by systems theory, fractal mathematics, computer science and cybernetics (Heylighen, Cilliers & Gershenson, 2007). As put by Swilling and Annecke (2012), “The problem was that Newton’s constants did not stay constant.” (Swilling & Annecke, 2012: 9) Systems theory thinking was the first to coin the term “holism” and it began by acknowledging that the whole tended to be greater than the sum of its parts (Heylighen, Cilliers & Gershenson, 2007).

Systems theory (or general systems theory) was particularly inherent in the epistemological discipline of biology, where cells to organisms became the living examples of how all systems, including social systems worked, embedded with networks and relations (Clayton & Radcliffe, 1996; Emmeche, 2004; Heylighen, Cilliers & Gershenson, 2007; Capra & Luisi, 2014). Two branches of biological sciences, vitalism and organismic, opposed the reduction of living organisms to pure physics and chemistry (Capra, 1997) and therefore it’s no wonder that many prominent systems, cybernetics and complexity thinkers have been biologists in some form, from Ludwig von Bertalanffy, Humberto Maturana, Francisco Varela to Robert Rosen and Claus Emmeche (Emmeche, 2004; Osberg, Biesta & Cilliers, 2008; Preiser, Cilliers & Human, 2013; Capra & Luisi, 2014).

Ludwig von Bertalanffy was instrumental in formulating particularly the general systems theory and the differences between open and closed systems, and he defines a system as a “set of unities with relationship among them” (von Bertalanffy in Preiser, 2014), or looking at it in another way, a system is a “whole which functions as a whole by virtue of the parts which constitute them” (Rapoport in Preiser, 2014). It was the second law of thermodynamics that particularly puzzled von Bertalanffy, as well as many other scientists, because ever-increasing entropy was not the case in an evolutionary perspective of increased complexity¹⁹ and complex organisation over time (Capra & Luisi, 2014). Therefore he proposed that

¹⁹ For further reading and interest, Claus Emmeche (2004) makes a strong argument against looking at increasing complexity as a function of biological evolution, saying that primitive organisms such as bacteria may not be multicellular and made up of many parts, but who’s to judge that their role in the ecosystem isn’t as complex as other multicellular organisms?

there were open and closed systems and that living biological systems in particular were open (Clayton & Radcliffe, 1996).

In open systems there is upward and downward causation (Heylighen, Cilliers & Gershenson, 2007), with both positive and negative feedback loops providing regulatory control (Clayton & Radcliffe, 1996). Systems theory consists of a downwards analysis of reduction, or an upwards analysis of holism and emergence, with a completely different ontology to Newtonian science, in that its building blocks are not materialistic parts but rather abstract relations (Heylighen, Cilliers & Gershenson, 2007). A final note on systems, which relates to the limitations of Newtonian science and the concept of “boundaries”, is that because living systems are intrinsically open, having to interact with a complex environment within which they are embedded (Heylighen, Cilliers & Gershenson, 2007), it may explain why Newtonian models were so successful in predicting closed systems, within laboratories, but were paradoxically so limited when it came to socio-ecological systems, in that they were actually dealing with what Chu describes as “nearly closed” systems (2003: 23) that are open systems of thermodynamics.

Cybernetics was another major influence in the emergence of complexity theory (Clayton & Radcliffe, 1996; Morin, 1999a; Heylighen, Cilliers & Gershenson, 2007; Capra & Luisi, 2014,) in particular second-order cybernetics, which demonstrated that all knowledge is subjective with multiple realities (Heylighen, Cilliers & Gershenson, 2007). This notion, as well as the adaptive nature of natural and social systems, biological evolution, non-linear dynamics, self-organising social systems, “autopoiesis” and patterns of organisation in living systems (Capra & Luisi, 2014) gave rise to the “new science of complex systems with a ‘postmodern’ philosophy” (Heylighen, Cilliers & Gershenson, 2007; Montuori, 2014).

2.4.5 Identifying complexity theory

It is a well-known critique of complexity theory that the theoretical concept lacks clarity, is vague and ill-defined (Chu, Strand & Fjelland, 2003; Heylighen, Cilliers & Gershenson, 2007). This thesis will not provide clarity on these matters, because there is a thought that suggests that this is precisely where the value of complexity lies, as definitions themselves are reductionist tools (Emmeche, 2004; Cilliers, 2008).

However, in order to grasp the concept a little more firmly, first the philosophy of complexity will be briefly discussed, as it was with Newtonian and systems thinking in the previous sections, and then a few types of complexity will be reviewed before finally providing certain “family resemblances” of complexity, so that, hypothetically speaking, if “complexity” had to walk past a window, it would be recognised.

Complexity theory has an ontology that is not necessarily “real” in terms of scientific rationality, as Edgar Morin puts it, “... complexity is invisible in the disciplinary division of the real” (Morin, 2005: 6). One of the most distinguishing factors of complexity theory is that it deals neither with order nor with disorder, but rather with what is often referred to as the “edge of chaos” (Clayton & Radcliffe, 1996; Chu, Strand & Fjelland, 2003; Emmeche, 2004; Heylighen, Cilliers & Gershenson, 2007; Cilliers, 2008), which is “where the system is in dynamic tension between flexibility and stability” (Clayton & Radcliffe, 1996: 23).

Complexity theory demands a rethinking of epistemology and ethics as it is about acknowledging that all knowledge is essentially subjective, and therefore it has limitations, power, hierarchy, boundaries, context, measurement, levels of complexity and modelling, which all need to be considered before making decisions based on that knowledge (Chu, Strand & Fjelland, 2003; Cilliers, 2008). Following on from this, it doesn’t mean giving into the relativistic argument saying that “things are complex” and simply leaving it at that; on the contrary, complexity requires engagement and most importantly action (Cilliers, 2000b, 2008; Preiser, 2012; Woermann & Cilliers, 2012). Cilliers distinguishes between things that are “complex” and things that are “complicated” and suggests that we shouldn’t look for complex in complicated, and that reductionism modelling works well in understanding and predicting systems that are complicated (Cilliers, 2000b, 2008). Therefore an argument that is often proposed is that “‘complex’ is merely a term we use for something we cannot yet model” (Cilliers, 2000b: 31), but Cilliers is quick to point out that would mean modelling the entire planet and even universe, which is unlikely (Cilliers, 2000b). Furthermore if there is nothing metaphysical about complex systems, modelling them will not relinquish the need for ethical responsibility (Cilliers, 2000b). The ethics of complexity is about the necessity of alternatives within systems, that there are many possibilities and pathways within a system that

can give rise to many different outcomes (Cilliers & Preiser, 2010; Woermann & Cilliers, 2012; Preiser, Cilliers & Human, 2013). Therefore it is positioned in such a manner that choices are imperative²⁰.

Paul Cilliers has usefully made ten general characteristics of complex systems (Cilliers, 1998) supporting the antithesis made by Emmeche (2004) who states: “Complexity does not denote any common or generic phenomenon, the term rather denotes a diverse set of concepts with certain ‘family resemblances.’” (Emmeche, 2004: 33). For this thesis, the most relevant and important characteristics made by Cilliers (Cilliers, 1998, 2000b, 2008) are briefly described and have been interwoven into two important characteristics discussed by Chu, Strand and Fjelland (2003) to create the following “family resemblances” of complexity:

- Complex systems consists of many different parts and each part in itself can be simple and should be treated as such.
- Complex systems are embedded and radically open systems that exchange energy and information between parts and the systems that they are embedded into. They are living systems and therefore operate far from equilibrium. This radical openness of the system affects the richness of the connections within the system.
- The interconnectedness and interactions between parts of the system are rich, dynamic and non-linear. This means that interactions change over time, that they are temporal as well as spatial, and that cause and effect are not proportional, therefore a large effect may be a result of a small cause and vice versa.
- They are self-organising systems that have direct and indirect feedback loops regulating the various pathways between the parts of the system.
- Complex systems have memory that is held within the system as a whole. This means that there is history and links to what Chu, Strand and Fjelland (2003) describe as being a very important generator of complexity, that being “contextuality” (Chu, Strand & Fjelland, 2003). Every system has a context

²⁰ This fortuitously interconnects beautifully with Rachel Carson’s final chapter of *Silent Spring* entitled “The Other Road” (Carson, 1962: 277), which is based on Robert Frost’s famous poem and is about the life threatening importance of choice of humans in socio-ecological systems.

that can be understood by its history and so similar causes in diverse contexts will have different outcomes.

- Finally, one of the most important characteristics of a complex system is that it has “emergent” properties (Clayton & Radcliffe, 1996; Emmeche, 2004; Heylighen, Cilliers & Gershenson, 2007; Cilliers, 2008) that arise from the interactions within the system and are not as a result of inherent characteristics of the individual parts of the system itself (Cilliers, 2008). Morin (2005) uses the example of water as a system, which has certain qualities and behaviour that its constituents, hydrogen gas and oxygen gas, alone don't possess.

2.4.6 The ethical condition of critical complexity

There are various uses, meanings and therefore types of complexity; from Claus Emmeche who makes the distinction between “descriptive” and “ontological” complexity (Emmeche, 2004), to Edgar Morin's “restricted” and “general” complexity (Morin, 2005). Morin argues that “restricted complexity” is the more contemporary understanding of complexity, where systems are considered complex with all the interrelatedness, however remains still within “the epistemology of classical science” (Morin, 2005: 10) and therefore is essentially reductionist. He further argues that “general complexity” is a deeper level of complexity and refers to an epistemological rethinking of complexity (Morin, 2005). This rethinking means acknowledging the limits to complex systems but requires a new language that moves beyond the Enlightenment ideals of knowledge as we know it (Osberg, Biesta & Cilliers, 2008).

In 2010, Cilliers published the concept of “critical complexity” for the first time in the last chapter of the book *Complexity, Difference, Identity: An Ethical Perspective* (Cilliers & Preiser, 2010). Since then this “brand of complexity” (Preiser, 2012: 209) has only been published in two articles (Audouin et al., 2013; Preiser, Cilliers & Human, 2013) and so publicly is in the early stages of its development, meaning and application. Preiser (2012) provides a comprehensive overview of the term in her thesis, in which she provides the background workings of the critical complexity condition as it was developed by Paul Cilliers until his untimely death in 2011 (Preiser, 2012).

Reflecting critically on our way of being in the world is argued as being a normative problem and so critical complexity is the “normative turn” on a general theory of complexity that is based on the lived experience of complexity in the world (Preiser, 2012: 209). It can therefore be thought of as an ethics of complexity that is experienced in the world (Preiser, 2012; Woermann & Cilliers, 2012). In her thesis Preiser (2012) argues that complexity should be re-defined as a condition rather than a problem and that there are three imperatives when encountering complexity in the world: the provisional imperative, the critical reflexive imperative and the world disclosing imperative (Preiser, 2012). These views of an ethics of complexity are very much specific to the Paul Cilliers’ school of complexity theory and the foundation of this thesis (Cilliers & Preiser, 2010; Preiser, 2012; Woermann & Cilliers, 2012). Therefore, instead of “general complexity”, the notion of “critical complexity” is used (Preiser, Cilliers & Human, 2013).

Critical complexity is a post-reductionist attempt to go beyond the reductionist-complexity discourse, as it looks towards a self-reflexive type of reductionist thinking, which ironically is the basis of forming a critical understanding of complexity. It can be seen therefore as being distinctive from, but also a development on, Niklas Luhmann’s “complexity reduction” (Emmeche, 2004; Swilling & Annecke, 2012) as it is pointed out that we cannot avoid reductionism when trying to make sense of complex socio-ecological systems – what we can do is use various techniques and framing strategies when undertaking such reductionism (Audouin et al., 2013). This means critical complexity follows a logic of reductionism but at the same time understands the choices that are made in reducing the system in question (Audouin et al., 2013), and “alludes to the kind of thinking that takes place in the force field where the tension between differences are upheld, brought together and kept apart at the same time” (Preiser, Cilliers & Human, 2013). Most importantly, critical complexity

... offers us a way with which to think together different paradigms without reducing them to one another or dismissing one for the other, so that we can be in a position to explore different and novel ways of being in a world [and] ... what it means to be human. (Preiser, 2012: 210)

2.4.7 The performative tension

Postmodernity saw two main problems with how modernity viewed knowledge creation. The first was this idea that knowledge was gained in a linear fashion, and the second was that science tended to act as the dominant spokesperson on the great narrative of knowledge creation (Emmeche, 2004). However, at the same time, this postmodern philosophy brought with it the fundamentalism and relativism dichotomy (Cilliers, 2000a, 2008) and the ethical paradox that with increased individual responsibility and moral choices came a loss of universal guidance (Bauman, 1992). Complexity theory has made the attempt to move beyond the modernity, postmodernity discourse (Cilliers, 1998; Heylighen, Cilliers & Gershenson, 2007). Critical complexity, in particular, sits nested between these two worldviews on this performative tension between the logic of reductionism and complexity (Preiser, Cilliers & Human, 2013). As Claus Emmeche (2004) summarises:

I think that in complexity studies one can find elements of both kinds of "ethos": both unification and plurality, both a striving to find a general theoretical framework to understand any complex system, and a more modest stance that emphasises sensitivity to the concrete issues of entangledness, diversity and heterogeneity. (Emmeche, 2004: 34)

This performative tension is where the crucial difference between systems theory and complexity theory can be found. It is important to acknowledge that Capra and Luisi (2014) see complexity theory as not being a scientific theory, but rather as a mathematical theory that builds towards an emergent systems view of life. As this thesis adopts the Cilliers' thinking on complexity, it proposes complexity theory as being fully compatible with a living systems theory, but more than that – a worldview with which to know, understand and act within living socio-ecological systems, one of those systems being Gaia itself (Cilliers, 1998, 2000a,b, 2008; Osberg, Biesta & Cilliers, 2008; Audouin et al., 2013; Preiser, Cilliers & Human, 2013). With that said, Cilliers also makes it clear that there is no single coherent theory of complexity that ultimately is supposed to unlock all the secrets of the world (Osberg & Biesta, 2010), and so we can only make tentative and modest claims whenever we deal with complex systems and theory.

2.4.8 Complexity theory and its implications for education

"What is education for? If one seriously considers the range of theories and philosophies invoked ... it is obvious that there is little agreement on what formal education is doing, much less on what it is intended to do."

(Davis & Sumara, 2008: 34)

It is now well known and understood that socio-ecological systems are complex embedded systems (Gallopín, 2003; Liu et al., 2007; Armitage et al., 2009; Swilling & Annecke, 2012; Audouin et al., 2013; Capra & Luisi, 2014) and so need to be treated and engaged with using a complexity systems lens. This thesis then asked the questions: Are education systems not complex socio-ecological systems? What would curricula and pedagogy look like if they were informed through complexity?

Literature and research on complexity theory and education is a fairly recent development (Davis & Sumara, 2008; Mason, 2008b; Siu, 2008) and could be said to have started through the work of Edgar Morin who provided an important foundation when considering the contemporary, industrial age viewpoint on education and also insights into what education should strive towards through the lens of complexity (Morin, 1999a). Literature tends to look at complexity theory and its implications to education in four broad categories: educational research (Kuhn, 2008; Lemke & Sabelli, 2008; Radford, 2008), curriculum (Morrison, 2003; Doll, 2008; Jess, Atencio & Thorburn, 2011; Gough, 2013), pedagogy (Morrison, 2008; Osberg, Biesta & Cilliers, 2008; Osberg & Biesta, 2010; Gough, 2013; Sund, 2015) and school reform (Siu, 2008). This thesis will focus on the latter three as being most applicable to the research aim.

Work done by Osberg, Biesta and Cilliers (2008: 214) focuses on an "emergentist epistemology" in education, with knowledge through education being viewed upon as an emergent property or response of a (classroom) system, where knowledge and reality are a part of the same complex evolving system, placing importance on a temporal and not only a spatial relationship between knowledge and reality. This is a movement away from the modern westernised way of thinking, particularly in contemporary education and its institutions, about knowledge being something that

is purely a representation of reality, something that can be controlled and dispensed upon learners by teachers (Osberg, Biesta & Cilliers, 2008).

Other literature has focused on complexity theory being used to generate organisational and institutional change (Siu, 2008), a new momentum and direction within education systems by incorporating massive and sustained interventions at as many levels in the system as possible (Mason, 2008b) until the “critical mass” is reached (Mason, 2008a: 5). It has also been proposed that complexity theory can essentially be interpreted as educational theory due to the ontology of education, it being a knowledge-producing system in itself that involves complex living beings, and also due to the fact that education as a single entity has been influenced by a diverse set of separate disciplines (Davis & Sumara, 2008), making it a complex system. Davis and Sumara (2008) also suggest certain conditions required in promoting complexity and learning as an emergent property of education, namely: internal diversity, internal redundancy, neighbour interactions and the decentralisation of control. Importantly, when it comes to complexity, it cannot be assumed and therefore managed into existence (Davis & Sumara, 2008), instead it is something that emerges and then can be demonstrated retrospectively.

Gough (2013) has more recently looked at curriculum alignment and pedagogy through a complexivist approach and argues that curricula should not be constructively aligned and prescriptive by nature, functioning “... as a tool for perpetuating established norms and rules, a plan or path that leads, pushes or coaxes learners in one particular direction” (Gough, 2013: 1223), and should rather be “deconstructively aligned”, having gaps and room that become sites of emergence for learners (Gough, 2013). From a pedagogical perspective, Gough (2013) suggests that teachers and learners using complexity should acknowledge complexity reduction in classrooms and question how the complexity is being reduced, who is reducing the complexity, for whom and in whose interests. Gough (2013) also argues that complexity reduction can be resisted by not insisting on evidence-based education, but if inevitable, then accepting a variety of different forms of evidences.

One way complexity theory and thinking has been implemented into schools and EE recently is through game-based approaches to pedagogy (Storey & Butler, 2013; Schulze, Martin, Finger, Henzen, Lindner, Pietzsch, Werntze, Zander & Seppelt, 2015). Complexity thinking has been applied to either Physical Education based games and activities (Storey & Butler, 2013) or electronic and online games that incorporate complexity and systems thinking in solving complex socio-ecological problems (Schulze et al., 2015).

Complexity theory has also successfully been implemented as an underlying framework for curricula and for informing pedagogy in Hong Kong (Morrison, 2003), Scotland (Jess, Atencio & Thorburn, 2011) and Sweden (Sund, 2015). The idea that learning is an emergent property of a complex system and not simply a “filling of an empty vessel” scenario is further emphasised by a complexivist approach and radically alters the way that teachers engage with the curriculum as well as with their learners (Morrison, 2008; Osberg, Biesta & Cilliers, 2008; Jess, Atencio & Thorburn, 2011). Keith Morrison sums this up in saying: “Learning is an ongoing, emergently choreographed dance between partners and agents (co-evolution through relationships and connections)” (Morrison, 2008: 26).

A benefit of adopting complexity theory as a way of thinking and acting in education, but in particular ESD, is the shift in attitude with which humans engage with the world; it is a shift towards realising that there is crucial importance in acting within the world in a sustainable way (Cilliers, 2008; Sund, 2015). It has been recently documented that one aspect that teachers really care about when dealing with ESD, within all subjects, is the notion of complexity and that it should not be understated nor oversimplified (Sund, 2015). Encouraging complexity when teaching ESD has shown to have facilitated themes of humility, awareness, personal connection and negotiable truth (Sund, 2015).

In one of Morrison’s (2010) later papers on complexity theory and school management and leadership, he critiqued complexity theory as being relativistic, confusing explanation with prediction and lacking in ethical and emotional dimensions of leadership, exonerating leaders from accountability and responsibility

for their actions (Morrison, 2010). He proposes complexity theory as having a social instead of an epistemic foundation (Morrison, 2010).

Despite the critique on complexity theory (Morrison, 2010), this paper takes the position that understanding complexity is about assuming responsibility for the choices that we as humans make, understanding that science has only informed humans up to a point, that there is limitation in scientific knowing and evidence and that we should draw upon a wider variety of knowing and keep emergence spaces open for creativity and learning to take place (Gough, 2013). Ultimately this thesis attempts to search for justification “as to why complexity, be it as a vocabulary, a metaphor, a theory, a methodology or an ontology is an educationally desirable ‘outlook’, ‘framework’, ‘point of view’, and the like” (Osberg & Biesta, 2010: 2).

2.5 Towards a “new moment” in Life Sciences Education: Facilitating critical complexity thinkers

In the final section of this chapter an attempt is made to weave together the literature that was reviewed and create a theoretical framework using a South African educational context, which is the first research objective of this study.

Complexity theory offers a promising framework in the field of SD, not only when it comes to understanding complex systems and wicked problems,²¹ but also in developing better strategies and solutions when engaging with them (Cilliers, 2008). It exposes the limitations to science and knowledge and so increases the responsibility that is needed to be taken when using and acting on this knowledge that was created in this manner (Cilliers, 2008; Cilliers & Preiser, 2010; Preiser, 2012; Woermann & Cilliers, 2012). Education through complexity therefore has the ability to initiate and then facilitate a paradigmatic shift in the way that humans approach, make sense and then deal with complex socio-ecological systems, and so helps human consciousness co-evolve towards a more sustainable future.

²¹ Wicked problems are problems that are impossible to solve due to their complex nature. As soon as a solution is applied, it causes new problems to emerge that were originally unintended (Preiser, 2012).

Ecoliteracy is fundamentally complex and so it seems possible that complexity could be emphasised further within specific curriculum content, particularly within Biology or the Natural Sciences (Emmeche, 2004), where theories that helped create complexity thinking, such as evolution and molecular biology, are typical complex systems themselves (Cilliers, 1998, 2000b, 2008; Heylighen, Cilliers & Gershenson, 2007). Curriculum content and ecoliteracy, such as evolution by natural selection, biodiversity and classification, ecology, human evolution, deoxyribose nucleic acid (DNA) and genetics, and human impact on the environment are all ideal theoretical “vehicles” to promote conditions that generate an understanding of complex systems and therefore can be approached, taught and learned using a complexity lens.

An important contextual consideration is that the complex concept, biological evolution, was only taught in South African Life Science classrooms for the first time in 2008, 149 years after Darwin’s seminal work *The Origin of Species* was first published. Considering that the theory of evolution by natural selection is arguably one of the most insightful, enlightening and stirring discoveries in modern science, commonly thought now to be the unifying theory of understanding all living organisms (Holtman, 1996; Lever, 2002; Nurse, 2003; Vidal, 2009), it could therefore be argued that South African education, in particular our scientific ontology and epistemology, has been severely deprived (James & Wilson, 2002; Lever, 2002). It is evolution, ecology, DNA and genetics, *inter alia*, that have allowed for the interrelatedness, non-linearity and unpredictability of complexity to extend into other areas of the Life Sciences curriculum such as biodiversity, classification of life and “Human Impact on the Environment” (Department of Education, 2011). It has also provided the possibility for this interrelatedness to transcend disciplinary boundaries into other subject domains, which opens up the space of transdisciplinarity (Max-Neef, 2005; Michelsen, 2013). It scratches away at the surface of answering hard questions that have been sitting deep in human consciousness for centuries, questions such as: What is life? What does it mean to be human? Where and when did life first begin? And what is our place in the universe?

Mary Evelyn Tucker speaks to this idea in the article *Our Place in the Universe*. Tucker, (2014: 52) suggests that through evolution, science is beginning to “weave together the story of a historical cosmos that emerged 13.7 billion years ago”, which

has created a “sense of common evolutionary heritage”. Tucker (2014: 54) proposes a “new moment for science” that involves three intersecting dimensions:

1. Understanding the evolution of the universe and the Earth using the scientific method.
2. “[I]ntegrating the evolutionary narrative as a whole” and finally,
3. “reflecting on the story with a sense of our responsibility for its continuity”.

From this she postulates that a “new integration of scientific facts, story and meaning” emerges (Tucker, 2014: 54).

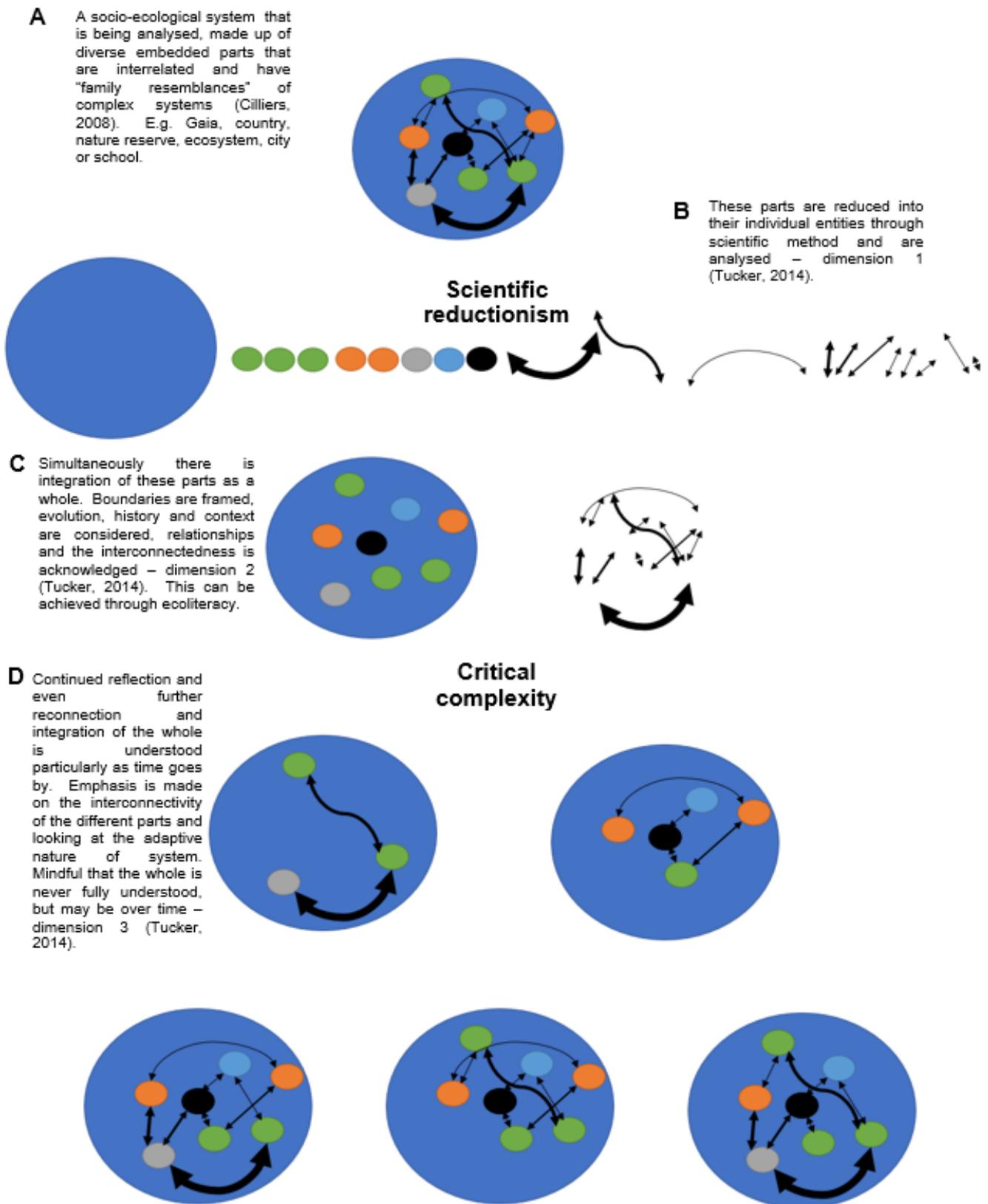
This “new moment for science” could be applied to a wide range of scientific concepts and theories, particularly within the South African Life Science curriculum. The first dimension involves the scientific method, which is reductionist, however is inevitable and necessary, whereas the second and the third dimensions would be best achieved through a complexity methodology. Acknowledging that there is a “performative tension” between reductionism and complexity means that this approach to science, of the three intersecting dimensions, is congruent with Cilliers’ critical complexity (Cilliers & Preiser, 2010; Preiser, Cilliers & Human, 2013). The third dimension of reflection supports this post-reductionism “epistemological rethink” as it offers the appraisal of complexity that includes systems thinking or holism, as well as reductionism (Mazzocchi in Audouin et al. 2013). This “new moment” for scientific thinking and knowledge creation is shown in figure 8 and is the outcome of the first research objective of this thesis.

Whether or not “the emergence of sciences of complexity is a reflection of the changing social situation for the scientific sub-system in a postmodern and hyper-differentiated world” (Emmeche, 2004: 27), it still offers a possible re-merging of philosophy and sciences. It also offers an opportunity to place ethics back into scientific knowledge, providing moments for reflection, making the limitations of models and theories explicit (Cilliers, 2000a, 2008; Osberg, Biesta & Cilliers, 2008), and therefore exposing the errors and illusions of knowledge. Finally, it helps our understanding when it comes to confronting uncertainty (Morin, 1999a; Montuori, 2014). The hope is that a movement towards complexity theory in knowledge creation means complexity thinkers will assume more responsibility (Cilliers, 2000a,b, 2008) and become more mindful about decisions and actions that are taken

within complex social-ecological systems. Just as a reductionist, mechanistic and compartmentalised approach underpinned the scientific knowledge that was created during the education systems that flourished since the Age of Industrialisation (Morin, 1999a; Harding, 2006, n.d.; Heylighen, Cilliers & Gershenson, 2007), so too perhaps a critical complexity approach should underpin a “new moment” in an interconnected education system which will flourish in a much-needed future Age of Sustainability.

Without educating this sensitivity, we churn out scientists without philosophy, who are merely interested in their subject, but not thoroughly awed by it. We churn out clever careerists, whose only concern is to make the grade, be the first to publish, be the first to be head of a department or split the atom. It is this kind of training which leads to the mentality responsible for the massive social and environmental mistakes of Western-style development. Trained to shut down our perception of the world so that we see it as a mere machine, we are perfectly free to improve the clockwork for our own ends. (Harding n.d.:4-5)

Figure 8: The “new moment” for science and a theoretical framework for knowledge creation



Source: Author's elaboration

2.6 Summary

This literature review has made an attempt to review academic and contemporary literature on the following broad topics: SD, ecoliteracy and complexity theory. These topics were reviewed so that a theoretical framework could be developed as a pedagogical approach to ESD (figure 8); one that is influenced by ecoliteracy frameworks and underpinned by complexity theory and a living systems view of life. Particular importance was placed on evolutionary perspectives of each of these topics and the context was narrowed down in the last section 2.5 to a South African Life Sciences classroom. Key findings from this review are the following:

- SD is a complex, embedded and contextual process.
- Ecoliteracy has the potential to provide tools, frameworks and methodologies for education towards SD.
- Complexity theory is essential for understanding how to engage, know and therefore act in socio-ecological systems.

The theoretical framework developed from this literature review not only achieves the first research objective of this thesis, but more importantly aims to provide education with an approach to create critical complexity thinkers in both teachers and learners, who have an understanding and attitude that enable them to co-evolve with the natural world towards a sustainable future.

In the next chapter, the research design and methodology of this study will be explored.

Chapter 3

Research Design and Methodology

3.1 Introduction

In this chapter the qualitative research approach, ethnographic design and action research methodology are reviewed and in each case questioned. The research methods are then elaborated on extensively, accounting in detail how the research was carried out and the rationale behind these methods. Finally data generation, analysis, interpretation of the research, as well as the research limitations and assumptions are all discussed.

3.2 Research Approach, Design and Methodology

In this section the research approach, design and methodology will be discussed in more detail.

3.2.1 Qualitative research

The research approach adopted for this thesis was qualitative, which has now become acceptable, if not even mainstream (Yin, 2011). Qualitative research has a broad application and is dependent on the area in which it is being applied and so, instead of giving it a single definition, Yin (2011) rather gives five features of qualitative research that all apply to this research:

1. It is a study of meaning under real-world conditions.
2. It represents the views and perspectives of participants in the study.
3. It is contextual.
4. It contributes insights into emerging concepts that help explain social behaviour.
5. It uses multiple sources of evidence.

This research was empirical and predominantly inductive, however it became clearer as it progressed that there was no one single blueprint or term that could describe the approach, design and methodology (Yin, 2011). Therefore it can be said that in some ways it followed traditions of naturalism, critical realism, ethnography, constructionism, interpretivism and postmodernism (Bryman et al., 2011; Mouton,

2011; Yin, 2011; Stringer, 2014). However if it had to be boxed, this qualitative research design was ethnographical, as it was a “study and appreciation of human interaction and communities through immersion, direct participation and observation” (Bryman et al., 2011: 42), with case study features as it was also an “in depth study of one or more individuals or phenomena in its existing context” (Bryman et al., 2011: 42).

3.2.2 Participatory action research

One defining feature of this research since its inception was that the most suitable adopted methodology was to be PAR. PAR can be defined as a study which involves the research participants

“ ... as an integral part of the design [that] use mainly qualitative methods in order to gain understanding and insight into life-worlds of research participants ... [and] have an explicit (political) commitment to the empowerment of participants and to changing the social conditions of the participants.” (Mouton, 2011: 150)

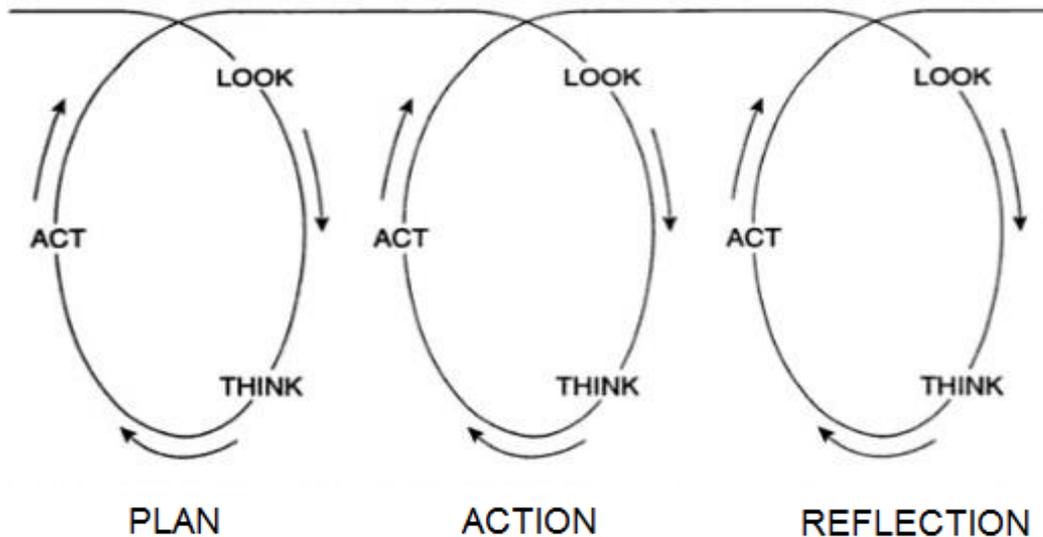
Pain, Whitman and Milledge (2010) say that PAR is “collaborative research, education and action used to gather information to use for change on social or environmental issues” (Pain, Whitman & Milledge, 2010: 2). It is a methodology and not a method (Walter, 2009) and so both of these definitions aptly describe the research methodology undertaken.

Why PAR?

The rationale behind choosing PAR was that there was an implicit need for action, participation and engagement in this research by both participants and researcher. As summarised by Stringer (2014), PAR is empowering, democratic in nature, as it involves collaboration by all participants; it is equitable in that it acknowledges the equality and worth of all participants; it is liberating, in this case, particularly to those learners who may have felt oppressed within current mechanistic, product-driven education models, and it is life enhancing, allowing the expression of diversity and potential by participants (Stringer, 2014).

This research also implicitly adhered to a plan, action and reflection cycle or, as Stringer (2014) had named, the look, think, act routine (see figure 9). Therefore PAR was the chosen methodology.

Figure 9: Stringer's action research interacting spiral as it relates to the plan, action and reflection cycle



Source: Stringer, (2014: 9)

The postmodern perspective of PAR allows for deconstruction of power and control, particularly when it comes to knowledge creation in research, which has as much to do with politics as it has to do with understanding (Stringer, 2014). This is where the role of the researcher and reflexivity within PAR becomes of utmost importance (Stringer, 2014). The researcher is a catalyst, who does not impose on but rather stimulates people to change, enabling participants to develop their own analyses of the issues and make a change. "Researchers increase their effectiveness when they immerse themselves in the richness of group life" (Stringer, 2014: 95). Reflexivity offers an honesty to the rich, messy and complex nature of experience and so, in the case of this research, it was less about what we "write to learn" (Bolton, 2010: 6) and more about how we "reflect to learn". Research has also shown that reflective practices of real-world sustainability problems help learners become more aware of and empowered by these issues and how to deal with them (Hofman, 2015; McGibbon & Van Belle, 2015).

3.2.3 “But it’s not scientific”: Questions of legitimacy in PAR

PAR is gaining popularity and support in the professional and academic community, although there is still contestation by many academic researchers around it not being a legitimate form of inquiry (Stringer, 2014). There is a low degree of control, a small number of cases, the potential for over-generalisability, the possibility of strong causal and structural changes, and it has the tendency for researchers, as they are so involved, to become overly emotional and subjective (Mouton, 2011).

This research paper acknowledges as much as possible these limitations and questions of legitimacy, and attempts to adapt reliability and validity where possible for qualitative research, and therefore it focuses on trustworthiness and authenticity as measures of validity and reliability (Bryman et al., 2011). There was continued “checking for rigour” through addressing credibility, transferability, dependability and confirmability (Stringer, 2014: 91) throughout the research process.

Ultimately, as complexity underpins this research, it seemed only fitting that a methodology that acknowledges the complexity, contextuality and the messiness of socio-ecological systems, as well as the subjective nature of reality, should be used.

3.3 Research Methods

In this section and the sections to follow, the overall research methods that achieved the overview shown in figure 1 of section 1.6.1, are described in further detail. The actual WWN project spanned six months, however it is safe to say that the thinking and planning of the research behind the project began over a year ago²². It must also be made explicit that although the subsequent sections order the methods in a tidy and linear manner, the reality is that the process was nothing like that, and that all three research objectives, including the writing of this thesis, were being addressed often simultaneously. Table 3 provides the overall research methods and summarised timeline that took place.

²² At the time of writing this thesis.

Table 3: Overall research methods and summarised timeline for *Working with Nature* project

Date	Action
15 January 2015	Handed in ethics clearance paperwork to department.
Feb – Mar 2015	Planned and finalised dates for WWN workshops.
5 February 2015	Submitted paperwork for ethics clearance.
7 February 2015	Held a voluntary introductory meeting for teachers who were interested in WWN project.
11 March 2015	REC approval was granted for doing research on WWN project.
13 March 2015	Introductory workshop was held for teachers and learners on Human Impact on the Environment. Research began on WWN project
14 March 2015	Introductory workshop was completed and complexity workshop was done.
15 March 2015	Participants went on an immersive outing to False Bay Nature Reserve.
22 May 2015	Biomimicry workshop was done with participants.
15 August 2015	Presentation workshop was done with participants.
28 August 2015	Tangible hand-ins were taken in from learners.
3 September 2015	Final presentations were given by each learner group and final reflections on project were done.

Source: Author's elaboration

3.4 Research Methods for Objective 1: Literature review

Develop a theoretical framework through a literature review for informing a complexity approach and pedagogy to the contemporary Life Sciences CAPS.

3.4.1 Literature review

The literature review for the purposes of this study can broadly be defined as a “scholarly review in a focused and goal-directed way of prior work in an area of interest” (Bryman et al., 2011: 379). There are various different types of literature reviews (Murray, 2015), but Mouton (2011) broadly gives two ways of looking at a literature review as either being a study on its own, or as it being the first phase of an empirical study (Mouton, 2011).

Literature reviews have been met with some resistance within the qualitative research domain because if the purpose of qualitative research is to explore the most real “meaning” of a particular event, this cannot be done in its purest

expression after being influenced by other researchers' perspectives on similar events through a literature review (Yin, 2011).

However having said this, the literature review of this thesis functioned more towards the latter of Mouton's (2011) two categories of reviews. It acknowledges that the place of theory is different in action research and reviewing prior academic literature may not "make sense" of all the complexities of the social world (Stringer, 2014: 38), but simultaneously any research process cannot proceed "atheoretically" and so should be applied to inform the methodology and the process of inquiry, in this case action research (Stringer, 2014: 39). Ultimately, a "selective literature review" (Yin, 2011: 62) was done specifically to achieve the first research objective of the thesis, which was to "formulate a theoretical framework from literature that [was] used to inform the research approach, design, methodology and methods" (see research objectives section 1.4).

Method of reviewing the literature

I began the review by searching the following online global databases: EBSCOhost, Gale, JSTOR, ProQuest, SAGE, Scopus and WorldCat, using primarily the University of Stellenbosch's search engine SUNSearch, however Google Scholar was also used, particularly as a starting point. The search key words that were used were: SD, education, ESD, complexity theory, critical complexity, systems theory, ecoliteracy, environmental literacy, ecological literacy, EE, biomimicry, and Boolean operators and general searching was done. Once a useful recent article was found, I would use the reference list to begin searching other related articles and so I began the method of what I subsequently discovered after a meeting with Faculty librarians at Stellenbosch University to be called the "pearl growing" method (Stellenbosch University Library and Information Service, 2011). Seminal works were discovered by sorting lists of search results by citations, and relevant journals, such as *Educational Philosophy and Theory*, were internally searched.

This strategy had many flaws, most notably that I was restricting my search to particular authors and journals, as the same authors tended to be published in the same journals. Furthermore it was critical that the most recent literature was systematically searched for a Master's dissertation. Therefore the "building blocks"

search strategy was employed (Stellenbosch University Library and Information Service, 2011). I set out my search keywords as shown in table 4, and systematically searched both global and local databases, specifically SA ePublications, for up-to-date relevant literature. Databases and dates of searches were also noted. I was selective in the articles and books that I chose and visited the Stellenbosch library for help in this regard.

Table 4: “Building blocks” search strategy used for literature review

AND

Primary Keyword	Secondary Keyword	Tertiary Keyword
complexity	education	sustainable development
complexity theory	pedagogy	sustainability
critical complexity	curriculum	biomimicry
systems theory		ecoliteracy
		environmental

OR

Source: Author’s elaboration

3.5 Research Methods for Objective 2: *Working with Nature* project

Help create, facilitate and experience a critical complexity learning process for Grade 11 learners and teachers through a PAR methodology entitled WWN, by using the “Human Impact on the Environment” content of the CAPS and other forms of ecoliteracy as a guiding framework.

3.5.1 Participant recruitment

In December 2013, while marking the final Life Sciences matric paper with other teachers in the Western Cape, a colleague of mine, Ms C, briefly introduced the idea of the project to some 200 teachers. At the beginning of the following academic year, an email was sent to those teachers, as well as to another 948 individuals on the Life Sciences Educators’ Network, inviting Life Sciences teachers to an initial meeting on 17 February 2015. At this meeting Ms C and I briefly introduced the project as we understood it then to be.

If they were interested, teachers were encouraged to engage with their learners about the project in their classes and extra-mural activities, and bring those who were keen to an introductory workshop that was set to take place on 13 March 2015. Therefore the research started with 35 learners and nine teachers from six different schools, who were purposefully sampled and voluntarily signed up at the introductory workshop.

3.5.2 Ethical considerations

It was very important to consider the ethical implications that our research had, particularly as we were working with 16 to 17-year-old adolescents. Furthermore, the transparent, open and democratic nature of action research (Stringer, 2014) meant that our project information would be shared with each participant, and thus parts of the project ran the risk of being opened up to the broader public, which they ultimately were. However, processes and guidelines for ethics in research were drawn up using information from Bryman et al. (2011), Mouton (2011) and for ethics in action research in particular, Stringer (2014). Therefore participants had the right to refuse to partake or withdraw at any time. All data related to their participation was made accessible to participants before being shared and so they were given opportunity to revoke any data that they were uncomfortable with. All information was stored safely and consent was obtained for any information that was made public or revealed to others (Bryman et al., 2011; Stringer, 2014).

As already introduced in section 1.8 of this paper, REC approved consent forms for the teachers and parents, and assent forms for the learners were given to them. The assent forms carried the same principles of the consent forms, however the language was simplified for learners to understand. An hour-long session was spent with all the participants explaining the research purpose, aims, use of results, and likely consequences of the study, and so informed consent was given by all the teachers and learners. Parents were not a part of this session, however learners were asked to take consent forms back home to their parents and explain their understanding of the research to them. Parents were encouraged to contact me if they had any further questions or queries. Signed consent and assent forms were then returned the following day after the research was initially informed.

As with most action research (Stringer, 2014), the essence of the work was about process – the way things were done – rather than about the results that were achieved; furthermore the research was empowering and on a positive lived experience. Therefore there was nothing about the research that would be harmful to the participants nor the environment and so consent for this research included journals (in this case free writing), interviews, film and photograph documentation, which could be shared to a broader community for educational purposes. Names and identities of participants and institutions are fictitious in the write up of the research results to ensure anonymity.

3.5.3 Project funding

The project and the research was funded partly by the NGO TBP and partly by the City of Cape Town.

3.5.4 Introductory workshop

Nine teachers, including myself and Ms C, and 35 learners from six different schools from the Western Cape met in a classroom at an independent boys' school, School A, on the 13 March 2015. After I gave them some instruction, the participants took seats in a random manner and quietly began filling in a diagnostic questionnaire (see appendix 3.1). While they were doing this, the Arthus-Bertrand film *Home* was playing in the background, which is a powerful narrative with aerial footage of Earth that shows humans' impact on the planet.

The diagnostic questionnaire

The purpose of the diagnostic questionnaire was not only to find out general demographic information about the participants, but also to find out what types of technology and social media platforms the participants were familiar and comfortable with. The reason for the latter was two-fold:

- As action research is a democratic and equitable process (Stringer, 2014), we wanted to establish the easiest and least intimidating platform to communicate with all the participants as a group and as individuals, being cognisant of the reality that they came from diverse backgrounds and socio-economic levels.

- We also needed indirectly to establish their socio-economic levels without making participants feel embarrassed about their family's material wealth. The reality of South Africa is that there is such a large difference between the material wealthy and the material poor (Pretty, 2013) that if this research was to be transferrable and meaningful to the typical South African classroom, it was essential that a wide range of participants were included. Stringer (2014) makes inclusion a clear goal of action research by saying: "It creates contexts that enable diverse groups to negotiate their agendas in an atmosphere of mutual trust and acceptance and to work toward effective solutions to problems that concern them" (Stringer, 2014: 31).

The aim of the diagnostic questionnaire was to establish what the participants' expectations were. Then, by asking the last five questions of the questionnaire again at the end of the learning experience in a post-project questionnaire (see appendix 3.2), the effect of the entire project on each participant's thinking, values and knowledge was assessed.

The questions asked were:

1. Why are you here?
2. What do you expect from the WWN project going forward?
3. What do you understand about human impact on the environment?
4. What do you understand about SD?
5. Does what you know NOW about human impact on the environment play a role in what you really think or do? If yes, explain how it impacts?
6. What is your solution to making the world a better place? Human well-being and SD being important in that better place.
7. How do you want to be/participate in this world?

Consideration was taken as to how these questions were presented. They were asked in hard copy and all grouped together, leaving a large space only at the end of the list of questions, instead of leaving a space underneath each individual question. We wanted participants to be encouraged to write as much as they wanted on each question, and so if we had prescribed a limited space underneath each question, this

may have forced them to write only in the space allocated for each question. This technique was carried through all questionnaires given to the participants.

The “ice-breaker”: getting to know each other

Once all participants had answered the questionnaire, as an “ice-breaker activity”, I asked the participants to choose an animal that they identified themselves with and to go around the room and meet another “animal” and explain to that person what animal they had chosen and why they had chosen it. A few rounds of this were done so each person met about five other participants in a relaxed and playful manner.

Using videos for initiating discussion and interest

A short 5:38 minute introductory film was then shown to the participants, entitled *The Ultimate Roller Coaster Ride: An Abbreviated History of Fossil Fuels* (Post Carbon Institute, 2010). This video, which is freely available online, was produced by the Post Carbon Institute and provides a striking historical perspective of the history of fossil fuels and their future in just 300 seconds (Post Carbon Institute, 2010). The video served as a discussion point for the participants and also provided them with further insights into some of the themes of the project.

Explaining what the project was “about”

Ms C and I then spent time with the learners, explicitly explaining what the WWN project was about, making it clear that it was completely voluntary for all participants and emphasising that the learners shouldn’t feel that they needed to do this because their teachers asked them to. This was important in liberating all participants to equal levels (Stringer, 2014). Ms C also highlighted reasons why it would be beneficial for both learners and teachers to get involved in the project. She said that this was a project that engaged with real world issues and was not only a representation of the real world, which is the common paradigm in conventional classrooms and learning. She made it clear that in the project, participants would be learning 21st century skills and attitudes, but at the same time they would be covering a section of their Grade 11 curriculum content “Human Impact on the Environment”, which would be examined in their final Life Sciences Matric Paper 1 at the end of 2016. As suggested by CAPS, teachers are required to do a large assignment on the “Human Impact on the Environment” section (Department of Education, 2011).

Therefore, the WWN project would be beneficial to both teachers and learners as it would provide them with a potential framework for that assignment. Finally, Ms C also mentioned that the project would benefit teachers and learners beyond their formative educational lives, with the impact potentially extending outwards and into their broader communities. Ms C carefully went over the project instructions (see appendix 3.3) and the dates and deadlines that the participants were committed to if they chose to participate (see appendix 3.4).

Getting informed consent

The consent and assent forms were handed out in hard copy and electronically, and explained in detail to all participants, who acknowledged that they fully understood the voluntary nature of the project and the research (see section 3.5.2 for more detail). Assent forms are the same as the consent forms however they are slightly adapted so that minors could understand and sign along with their parents. The learners were able to take their consent and assent forms home to their parents to be signed and returned the next day at the complexity workshop. The second language English speaking participants made it clear that they understood the details discussed in English and that they did not need a translator.

Lunch was then served to all the participants by a caterer named Fahmieda Barends, who works as an entrepreneur and caterer for the Cooking Bag Revolution²³. She gave the participants a short but intriguing presentation on her business and the principles behind smart cookers, finally serving a delicious meal that was cooked in a Wonderbag™, which is made from recycled polystyrene foam as an insulator (Wonderbag Company, 2015).

The first dimension of the “new moment”: a reductionist lecture

After lunch, Ms C did an hour-and-a-half session with the participants, lecturing them from a PowerPoint presentation, in a very reductionist manner, on all the content of their “Human Impact on the Environment” (see table 1 for content detail). Emphasis was made on the science, terminology and meaning of the terms and concepts from CAPS. The five topics covered in CAPS were elaborated on in detail and included:

²³ Consent was electronically given for inclusion of details for this thesis.

1. Atmosphere and climate change
2. Water availability and quality
3. Food security
4. Loss of biodiversity
5. Solid waste disposal

The purpose of this reductionist lesson was to apply the theoretical critical complexity framework developed in the literature review of this paper (see figure 8) to our pedagogical, and methodological, approach towards the project. Therefore, scientific reductionism formed the first part of the three intersecting dimensions (Tucker, 2014) of a new moment in science education as summarised in section 2.5.

Being a tree, mosquito, ant, river, rhino or Table Mountain

After a quick stretch break, participants divided themselves into six groups and each group was given a living organism or living context which they had “to be”. These included a tree, a mosquito, an ant, a river, a rhino or Table Mountain. They then had to describe diagrammatically how at least three of the five topics covered in the Human Impact PowerPoint given earlier had impacted on them. The learners did this in their groups by writing with different coloured white board markers on the desks in the classroom that have a special paint that allows them to function like white boards. After half an hour, they then had to report back to the rest of the group their thoughts and reflections on being those particular animals or contexts.

Explaining what the research was “about” and grouping the schools

The last few hours of the introductory workshop were administrative and reflective. The schools that were going to be working together were grouped by all the teacher participants, ensuring that a well-resourced school partnered up with a poorly-resourced school. The idea from this was that we didn’t want any participants to feel that they were disadvantaged when it came to access to information, technology and skills. School A, an independent boys’ school, was split into two groups and partnered with two relatively poorly-resourced schools in Cape Town, School B and School C; whereas School D, an independent school for girls, was partnered up

similarly with School E which was from the Paarl²⁴ region and School F from Cape Town.

Free writing and video reflections: a form of contemplative and reflective pedagogy

The first of a series of free writing was then done with all the participants, myself included, on a sheet of paper for five minutes. The reflection was prompted with the question: “From what you have experienced today, how does the current state of the world make you feel?” Free writing is a widely practiced technique of reflection and contemplation that was popularised by Peter Elbow in 1973 (Elbow, cited in Kahane 2014). It involves writing for a fixed period of time without stopping, the only rule being that the pen or pencil must not stop moving (Kahane, 2014). It can be used with or without prompt questions and can help learners generate new thoughts as well as represent their already existing thoughts (Kahane, 2014). The aim of doing free writing was to provide a rich and genuine voice to the learners and their thinking to be used for thematic analyses at a later stage. As David Kahane (2014: 126) states: “I was astounded again and again by the wisdom and authenticity of voice that I encountered in most free writes – a much rarer phenomenon than when I read students’ analytical essays.”

Another form of reflective data, two-minute individual video reflections, were also taken towards the end of the day. In this case, three learners at a time were taken to sound-proof work rooms, in which they had a laptop and instructions to video themselves for two minutes. In these videos, participants were asked to consider the question: “From your current knowledge on the state of the world, how does this make you feel?” and then reflect for two minutes without rehearsal or practice. Information technology facilitators helped with the management of this process.

²⁴ Paarl is approximately a 40-minute drive from Cape Town

Reflexive box 5: The story behind free writing and two-minute video reflections

It is interesting looking over my own research notes to see how I came to use free writing and video reflections as my primary form of data collection. In February 2015, Ms C and I attended a conference on community engagement in health research in Botswana, which was organised by the Wellcome Trust. The focus was on food systems, health and the environment and we went because of a related food security project that we had also worked on with various schools. It was here that I met the report author for the conference. As I explained my research to her on a two-hour bus trip to see a small scale farmer just outside of Gaborone, she suggested and briefed me on the idea of free writing as a reflective and even reflexive practice (see Bolton 2010, for elaboration on difference between reflectivity and reflexivity). As my thesis was in many ways about analysing complexity thinking, it dawned on me on the bus ride that free writing, which can potentially allow for rich qualitative data to emerge, could be used as a way to analyse the thinking of the participants. At the time, I also thought that a reflective process may be a liberating and meaningful learning experience for the participants.

The two-minute video reflections came from a programme that was started by George Eadie, called “2minFriday” in 2012. This was a reflective, personal development tool that used a video “selfie”²⁵ of no longer than two minutes. I say “was”, because due to a lack of a feasible business model, the programme has been postponed since then. During a Skype conversation with George in February 2015, I was able to gain a thorough understanding of the power and risks that came with using this tool. The empowerment and personal development aspects of the video “selfie”, however, outweighed any of the risks and it seemed to be fully complementary with free writing.

²⁵ “Selfie” is a buzzword that was included into the online Oxford Dictionary in 2013 and means taking a picture (or in this context a video) of oneself (Oxford Dictionary, 2013).

Reflection questionnaire and flash drives for resources

Finally, participants were asked to complete a short reflection questionnaire (see appendix 3.5), which was done as a part of the reflection cycle of PAR (Walter, 2009; Pain, Whitman & Milledge, 2010; Stringer, 2014). It was established from the diagnostic questionnaire that every participant had access to a computer and so each school was given two flash drives, one for the teacher and one for the group of learners. On each of these flash drives were electronic versions of all the resources that were covered in the introductory workshop and other resources that were going to be covered in future workshops. A list of the electronic resources that were saved onto these flash drives can be found in appendix 3.6. The thinking behind the flash drives was that the learners could use them not only as electronic resources, reducing our printing load, but also as a way of physically handing in electronic documentation, even if they didn't have reliable internet connectivity.

Participants were asked to read two articles, which were given in both hard and e-copy, in preparation for the next meeting. These were Johan Rockström's *Planetary Boundaries* article (Rockström, 2009), and a case study on the complexity in Lake Victoria which I had adapted and simplified from the article *Complexity: Common Denominators of Complex Systems* by Dominique Chu (Chu, Strand & Fjelland, 2003) (see appendix 3.7).

3.5.5 Complexity workshop

In an attempt to infuse complexity thinking into the participants before their immersive outing to False Bay Nature Reserve, participants attended a complexity workshop on 14 March 2015, the day before their outing.

Complexity of Lake Victoria

After a group discussion on the Lake Victoria case study, a short 11-minute video clip was shown from Hubert Sauper's Oscar-nominated documentary *Darwin's Nightmare* (Sauper, 2004), which was directly related to Chu's article and starkly emphasised the interconnectivity of the lake's ecology to a variety of social and economic factors within Tanzania and abroad.

Complexity and systems theory lecture: “a cautionary tale”

I then presented to the participants an adapted version of a PowerPoint lecture that was given to me by Rika Preiser²⁶ during a Complexity and Systems Theory module that I attended in 2014 (Preiser, 2014). To conclude this lecture, another short animated video clip was shown that concisely explains systems theory and the implications this has for decision making. It is essentially about how the World Health Organisation (WHO) used the well-known insecticide dichlorodiphenyltrichloroethane (DDT) in Borneo in an attempt to prevent the spread of malaria but instead, through bioaccumulation of the toxin within the ecosystem, all the cats on the island died and a plague broke out, and so the unintended consequence was an outbreak in rodents and a new disease (Sustainability Illustrated, 2014).

Thinking like a mountain and how wolves change rivers

We then all went outside the classroom as the weather was good and sat underneath a large Poplar tree and read out loud Aldo Leopold’s chapter *Thinking like a Mountain* (Leopold, 1949), which speaks about an ecological attitude of humans towards wolves and deer in the 1920s and 30s. It once again emphasises the interconnectivity between all living and non-living, suggesting that even mountains have memory. This linked up neatly with the next short video clip shown to the participants entitled *How Wolves Change Rivers*, which introduces an enlightened ecological concept called “trophic cascading” in which biodiversity and resilience within ecosystems is increased through the introduction of top level predators and consumers (Sustainable Human, 2014)²⁷; this was not fully understood during the time period in which Aldo Leopold alludes to in his poetic writing. Participants were asked to listen carefully to George Monbiot’s narration and in groups try to map out the complex Yellow Stone National Park ecosystem described in the film. They did this once again using the coloured white board markers and drawing on the desks with the film being repeated three times so that

²⁶ Permission was obtained by the author to use and adapt the PowerPoint to make it appropriate for a younger audience.

²⁷ In more recent research, this famous American ecological success story of the Yellow Stone National Park has been debunked on a number of points, but as even the author of this research pointed out: “Does it really matter if it’s not true?” (Middleton, 2014)

they had enough time to take in all the information presented in the video. The groups then had to report back to the rest of the participants on their maps and describe how society and the economy were related to the ecosystems that they had just drawn.

3.5.6 Place-based learning: Immersive outing to False Bay Nature Reserve

Participants met at School A in the morning of 15 March 2015 and departed by bus for the Rondevlei section of the False Bay Nature Reserve²⁸. Along the bus ride, participants were encouraged to observe and comment about the parts of the city they were driving through. At Rondevlei we met an Environmental Officer from the City of Cape Town, who gave a 45-minute presentation on the False Bay Nature Reserve conglomerate, a declared Ramsar site (Ramsar Convention Secretariat, 2014) situated within the Cape Town urban setting. It was an ideal and close location to explore the tension that exists within socio-ecological contexts and it also provided a relevant reference point to critically and reflexively discuss the content, complexity and application of the CAPS “Human Impact on the Environment” content (Department of Education, 2011) (see table 1).

Rondevlei: exploring biodiversity through Goethean observation, rapid sensing and sound mapping

After this, the participants were asked to find a quiet spot alone within the Rondevlei Bird Sanctuary, and for an half an hour they went through a Goethean observation on any plant that they were drawn towards (see appendix 3.8) and a biomimicry rapid sensing or sound map activity (see appendix 3.9, as well as section 2.3.7 of literature review). The curriculum discussion focus at Rondevlei was on biodiversity.

Lotus River: exploring water availability and quality

We then made our way to the Pelican Park housing development via the two Lotus Rivers which are tributaries to Rondevlei and Zeekoevlei. Learners got out to explore the river and walk alongside it. The curriculum discussion focus at the river was on water interconnectivity, quality and availability.

²⁸ False Bay Nature Reserve until recently was referred to as the False Bay Ecology Park (City of Cape Town, 2015).

Pelican Park housing development: exploring energy, atmosphere and climate change

Pelican Park housing development is the City of Cape Town's largest integrated, mixed-race, mixed-income housing development, situated on the banks of Zeekoevlei Nature Reserve, extending east up to the busy Strandfontein Road, which runs its way from the city centre into the informal settlements known as the Cape Flats. The multi-level governance and participatory approach to the development has been laudable (City of Cape Town, 2014). Due to the integration of more diverse housing typologies, space opened up for cross subsidisation, allowing for the development to procure better quality homes, which focused on some novel socio-technical infrastructures that promote sustainable living (Oscroft, 2014). This provided a good discussion point around the content of energy, atmosphere and climate change, along with many other topics of the curriculum.

At Zeekoevlei, participants had their packed lunches and enjoyed the recreational area. A discussion was had around human well-being and happiness and how this is interrelated with the ecosystem services.

CFWWTW and the Coastal Park Landfill: exploring solid waste disposal

Participants were then taken to the Cape Flats Waste Water Treatment Works (CFWWTW), which is one of the City's largest sewage treatment works and where sludge waste is made into non-pathogenic pellets that can be used as fertiliser or for making local bricks (Matthews, 2003). From the CFWWTW there is a good view of the Coastal Park Landfill, which stands approximately 25m from ground level, making it the highest landmark on the Cape Flats, and which will be in operation only until 2022 (Jackson, 2015). The City of Cape Town is attempting to establish a material recovery facility on site, as well as a cleaner development mechanism (CDM), which will capture solid waste gases and convert them to energy on site (Coetzee, 2014). The curriculum discussion here was on solid waste disposal, but aspects around nature's closed cycles and using this principle to close socio-ecological cycles were also discussed.

Philippi Horticultural Area: exploring food security

The last stop on the immersive outing was the Philippi Horticultural Area, which is a rurally zoned farming region of over 2000 hectares located within the Cape Flats, and which has been shown to be critical to ensuring local food security. It has also played a role in addressing the City's gender inequality, and in promoting environment and climate change resilience (Battersby-Lennard & Haysom, 2012). Food security was the main curriculum focus discussed at this site.

Examining complexity of contexts and reflection

The outing ended back at Rondevlei where participants got into their collaborative school partnerships and each was given one of the sites they had visited during the day as a context to examine. They then had to report back to the larger group what the "bigger picture" was, paying attention to the complexity of the system they were looking into and drawing in aspects of the content covered in CAPS. Final reflections were made through a ten-minute free writing session.

3.5.7 Teacher meeting on assessment of project

On 21 May 2015, teacher participants from the six schools represented met for two hours to design collaboratively an adapted assessment tool that could be used on the project. This ultimately became the project rubric (see appendix 3.10), which is discussed in the results section, chapter 4, of this paper. The purpose of this was to provide an opportunity for evaluation by teacher participants for future, similar-type projects, as per the plan, action, reflect cycle of PAR (Walter, 2009; Pain, Whitman & Milledge, 2010) (see figure 1). Assessment in education globally as well as in South Africa is dominated by standardisation, quantitative and summative assessments that lack purpose or value (Bayaga, 2013; Long, Dunne & Mokoena, 2014), paying attention largely to learning product over learning process. Therefore, this meeting was also an opportunity to develop a process-, not product-, grounded assessment tool that would be used to evaluate the final projects. This could potentially be used by teachers in future if they chose a similar type of project as their curriculum-based assignment in Grade 11.

3.5.8 Biomimicry workshop

Participants met for a three-hour session on biomimicry on 22 May 2015 which was facilitated by a biomimicry professional. The purpose of this was to give the participant groups an opportunity to use biomimicry and its principles to design potential sustainable solutions to the challenges that they identified in their own project contexts. At the end of this workshop, another ten-minute free writing was done as an individual reflection on the process of the project.

3.5.9 Presentation workshop

Participants were then involved in a workshop on 15 August 2015 where they discussed and planned their group projects in preparation for their final presentations on 3 September. At this point, the project assessments had been finalised and so we used this time also to go through the assessment rubric (see appendix 3.10), which had been collaboratively created over the previous few months. The purpose was to give the participants a sound understanding of what was expected at the end of this project and what ultimately was going to be evaluated. Emphasis was made on cooperation, collaboration and partnership, as well as the idea that there would be no marks attached to this project, as this was in line with a shift away from the quantitative and towards the qualitative (Capra & Luisi, 2014).

We were very aware that the rubric itself would be challenging for some learners to grasp and comprehend, and so an adapted rubric was formulated which allowed for the participants to write in a blank space, next to the target descriptors, what their interpretation was of what was being suggested. Therefore each phase of the rubric was systematically discussed within the groups, allowing them to form their own understandings of what was required from the project.

A large part of this day involved activities based on the communication and presentation of participating group projects. The groups began by first exploring an appreciative inquiry process (see appendix 3.11), in which participants were given the opportunity to define, discover, dream and design their group projects further. The purpose of this was to find the commonality amongst all the groups, the individuals within the groups, and to acknowledge further all the process work they had already done, but had not yet reflected on.

They then went on to evaluate the various ways in which their projects could be presented, from linear Word documents and PowerPoint presentations, through to incorporating videos, drama, song and dance. Time and practice were given to all participants to familiarise themselves with the setting of their final presentations, and to reflect on their personal feelings and comfort levels around speaking and communicating in public. The day ended once again with a ten-minute individual free writing exercise on the process of the project.

What was stressed throughout this workshop was that there was a diversity of ways the learners could go about communicating their projects and that it was important to know not only who their audience was, which is the traditional motto for doing presentations, but also to know who they as individuals were, and who their groups were. Perhaps herein lies the difference between group work and collaboration (Quinn, 2012). Group work is known traditionally to be when more than one individual works together towards a common goal, however the tasks are usually evenly and “fairly” distributed amongst the members of the group. Collaboration is the same, however there is “positive interdependence” (Hung, Young & Lin, 2015: 36) or a deeper awareness and appreciation of the group members, and so each individual brings into the group his or her own skill set, knowledge, attitudes, values and passion. It seems logical therefore to make the inference that this may be thought of as a form of mutualistic symbiosis, with the key driver being diversity, as in natural systems, enabling the group or system to move forwards towards the common goal.

3.5.10 Final presentation day

The participant learners then presented their group projects to the broader public in School A’s theatre on 3 September 2015. This was done for evaluation, assessment, educational and awareness reasons. Teachers, parents, heads and learners from other schools came to listen to the dissemination of the group projects, which involved each group’s understanding of a chosen socio-ecological system, its complexity, and the application of possible sustainable solutions through biomimicry. Once their presentations were completed, participants then did their final reflections on the entire project, which consisted of a post-WWN questionnaire (see appendix 3.2), already been elaborated on previously in section 3.5.4.

A final two-minute video reflection (see appendix 3.12) was also done by every participant. This was done in the exact same way as the initial “video-selfies” but this time participants were asked to consider how the past five-and-a-half months had impacted them as a person, their understanding of local and global issues and their understanding of complex systems/problems. The reasoning for this was to analyse the project narratives that may have emerged through and the potential changes that may have occurred in the participants’ knowledge, thinking and their values from the start to finish.

3.5.11 Final project assessment

Although the original intention was to have the final communication phase of projects evaluated by all participants – both the teachers and the learners – the learners felt that it would be unnerving to evaluate each other, especially if it was before they had to present their own projects. Therefore only the teacher participants evaluated the projects after the final presentation day according to the collaborative rubric (see appendix 3.10) that was developed. This rubric was sent out to the learners two weeks after each group did their final presentations.

3.5.12 Post-project teacher interviews

During the weeks after the project, I made appointments to conduct semi-structured interviews with the teacher participants. The idea was to gain their insight, feedback and understanding of the entire project, as well as to ascertain what difference the project had made to their own thinking, values, knowledge and teaching (see appendix 3.13).

3.5.13 Various other meetings and interventions: March – September 2015

As is expected with PAR, which has a low degree of control (Mouton, 2011), there were a number of other recorded and unrecorded meetings, unstructured interviews and activities that were done throughout the WWN project. These would have also helped shape and influence the project and research as a whole. For instance, Ms C and I met on a weekly basis and communicated with the other participants continuously through the various digital platforms that were set in place, such as WhatsApp Messenger, email and Facebook. Participants were also encouraged to meet regularly in their smaller groups to discuss and work on their projects. They

were given one compulsory appreciative inquiry exercise (see appendix 3.14) to do in their first smaller group meeting together, and I also continuously encouraged them to carry on with their free writing throughout the project. These “other” and often unplanned meetings and activities have not been individually mentioned and elaborated on in this chapter, as it would become overwhelming, and so what has been described here are essentially the meetings and workshops that were planned from the beginning of the research and in which all participants²⁹, including myself, the researcher, were present.

3.6 Research Methods for Objective 2: Gathering data

Data for this research was organised into four separate yet interrelated categories: individual data, group data, workshop data and researcher observation data. A diverse set of communication platforms were set up to accommodate the different types of data obtained throughout the project. A WWN WhatsApp group and Facebook page³⁰ were established that allowed a two-way sharing of information and simultaneously a place to collate photographic data. The website³¹ allowed us to collate and upload the group projects, which included the tangible hand-ins and the final presentations, as well as workshop videos taken during the project. Table 5 summarises these categories of data and gives the method by which this data was collected.

²⁹ As can be expected when working in PAR over a prolonged period, there were meetings and workshops that some participants were unable to attend.

³⁰ See <https://www.facebook.com/TBPworkingwithnature>

³¹ See <http://workingwithnatureproject.weebly.com/>

Table 5: Categories of data and collection methods from the *Working with Nature* project

Data	Source	Method of Collection
Individual	Questionnaires	A diagnostic questionnaire was done at the start of the research and a post questionnaire at the end of the research. These were done on paper and collated by the researcher, by hand.
	Free writing	Participants were trained and then asked to do a free writing individual reflection at the end of each workshop/meeting. They were encouraged to continue doing this throughout the project. The compulsory writing was done on paper and collated by the researcher whereas the voluntary writing was done and handed in whatever way suited the participant.
	Video reflections	Two-minute video reflections were done at the start and end of the research. These were saved onto loaned laptops and collated by the researcher.
	Photographs	Photographs were taken throughout the project and collated by the researcher. Select photos were shared on the Facebook page.
	Semi-structured teacher interviews	Semi-structure interviews were done with teachers after the project. These were recorded using a smart phone by the researcher.
Group	Appreciative inquiry	Groups underwent two appreciative inquiry processes during the project. This was done on paper and collated by the researcher.
	Final group projects	All groups worked together to create a tangible hand-in on their own project, as well as a presentation on their project that was uploaded onto the WWN website.
Workshop	Questionnaires	Questionnaires were done at the end of some workshops. These were done on paper and collated by the researcher.
	Group activities	Artefacts (posters, drawings, mind maps) emerged from various types of activities that were completed throughout the project. These were done mostly on paper, if not, photos of the group activities were taken by the researcher.
	Photographs	Group photographs were taken throughout the project and collated by the researcher. Select photos were shared on the Facebook page.
	Video footage	All workshops were filmed by professional film makers. This material was collated and produced by the film makers in discussion with the researcher.
	Unstructured feedback	General feedback and comments were taken by the researcher after workshops. These were collated through researcher notes using OneNote software.
Researcher observation	Researcher notes and recordings	All meetings and observations were recorded by the researcher using a smart phone and a laptop. Notes were taken and stored on OneNote software.
	Project communication	Communication via email, Facebook and WhatsApp was saved and stored by the researcher on a smart phone and a laptop.

Source: Author's elaboration

3.6.1 Individual data

The individual data consists of the primary data that I collected through a variety of methods. Pre- (diagnostic) and post-project questionnaires were done on paper, which I collected and stored. Two-minute “video-selfies” were collated by an information technology facilitator who took them off the loan laptops and shared them with me by putting them onto my external hard drive. The free writing reflections were done on paper, which I collected and stored. If participants chose to do extra free writings above the ones done during the workshops, they could hand them in to me in any way that best suited them. Ms C, myself and other participants took photos using smart phone cameras throughout the project and some were shared across the various communication platforms – the WWN WhatsApp group, the Facebook page and the website. I recorded the teacher semi-structured interviews using a recording device on my smart phone, as well as my laptop and made e-notes using Microsoft OneNote software. All data was safely stored onto my personal secure laptop and was backed up onto my external hard drive.

3.6.2 Group data

This was data collected from collaborative work done by one or more of the participants. This included two appreciative inquiry processes that were done by participants, both teachers and learners, within the partnered school groups and that were done on paper, which I collated and stored (see appendices 3.11 and 3.14). The final tangible hand-ins and the final group presentations done as per the WWN instructions were also collected in electronic form and uploaded onto the WWN website.

3.6.3 Workshop data: The filming of *Working with Nature*

The workshop data included all the data that was gathered on the workshops as a whole, for instance the workshop feedback questionnaires, as well as any comments and unstructured feedback that I got during or after the workshops from the participants. It also included all data that was gathered from the workshop activities done in groups (see section 3.4 for further elaboration on the specific activities), which I collated either by hand, through photographs and videos using my smart phone, or by writing researcher field notes using Microsoft OneNote. The type of data would determine the type of tool I used when collating it. The only form of

secondary data in the project, which was the filming of WWN, was also categorised as workshop data. This was done by a professional film company called Masala Filmworks, which not only filmed the workshops and provided me with any individual, group and workshop footage that I required, but also produced a 20-minute film capturing the project journey as best as possible. This film was produced and completed only after much review by both Ms C and myself, as we needed it to represent the project narrative as accurately and as interestingly as possible. The purpose of filming the WWN journey was to try and capture both the system and the system “ambiance” (Chu, Strand & Fjelland, 2003: 20).

3.6.4 Researcher observations

I recorded all other meetings, observations and communication that pertained to the project. This was done using either my smart phone as a recording device or by using Microsoft OneNote software that is on my laptop. It was therefore stored securely on my laptop and backed up on my external hard drive.

3.7 Research Methods for Objective 3: Making sense of data

Investigate through thematic coding of qualitative data, the effect that this collaborative critical complexity learning experience had on thinking, values and knowledge of learners and teachers from six diversely different secondary schools in the Western Cape.

The rich, textual, audio and visual data that was generated from this research was then analysed, which involved “breaking up” the data into manageable themes, patterns, trends and relationships” (Mouton, 2011: 108), and “lightly” interpreted, which involved “the synthesis of one’s data into larger coherent wholes” (Mouton, 2011: 109). I say “lightly” because I remained mindful of the limitations to qualitative data, to the discourse outlined in section 3.2.3 of this paper and to the complexivist approach of acknowledging the limitations of reductionism. Table 6 outlines the key data types that were ultimately used in this thesis and their respective methods of analysis that were taken.

Table 6: Data sources used and their respective method of analysis.

Data	Source	Code	Method of analysis
Individual	Questionnaires	IQ	Thematic coding of text
	Free writing	FW	Thematic coding of text
	Video reflections	VR	Thematic coding using ALTAS.ti
	Semi-structured teacher interviews	I	Transcribed and then thematic coding of text
Group	Appreciative inquiry	AI	Thematic coding of text
	Final group projects	GP	Audio was transcribed and thematic coding was done on text
Workshop	Questionnaires	IQ	Thematic coding of text
	Workshop activities	A	Content analysis of activity artefacts
	Photographs	P	Content analysis
	Video footage	V	Thematic coding using ATLAS.ti
Researcher observation	Researcher notes and recordings	R	Content analysis
	Project communication	R	Content analysis

Source: Author's elaboration

3.7.1 Coding frame: Towards integrative thinking and values

The data generated in this research was subjected to thematic analysis (Mouton, 2011). However, instead of only searching for themes within the data retrospectively, the themes were preselected from literature that explored a shift in perception from one that is reductionist or self-assertive, towards one that is more complexivist, integrative or systems orientated. Capra and Luisi (2014) have highlighted what they felt were the tendencies that would emerge from this shift in thinking and values. These tendencies are shown in the table 7 and so the integrative tendencies, specifically, were used as a “light” coding frame for the data. The term “light” is used here in keeping with the complexivist traditions of not being too trapped into reducing or boxing the narratives, as either or, as the tendencies are so interwoven themselves, that one narrative may fall into multiple themes and vice versa – “[t]he knack lies not in describing opposites when making knowledge claims, but in thinking both at the same time” (Preiser, Cilliers & Human, 2013: 269). When dealing with complexity, “we never escape the realm of choice” and so using this as justification for this paper’s analysis, perhaps it requires us to “enter into the ambiguity of the both” (Preiser, Cilliers & Human, 2013: 271).

Furthermore, other key emergent themes and experiences from the data collated were “unpacked” (Stringer, 2014: 139), allowing for important narratives and stories from the research to surface.

Table 7: Coding frame that will be used to analyse the research data thematically

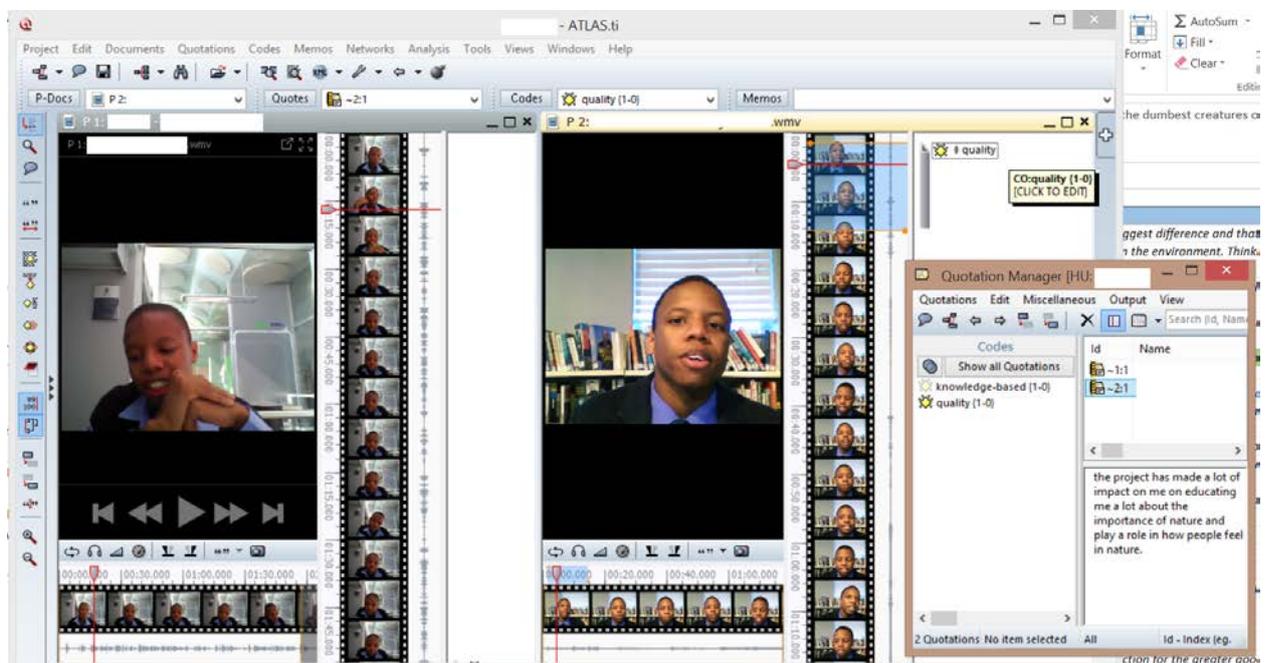
thinking		values	
self-assertive	integrative	self-assertive	integrative
rational	intuitive	expansion	conservation
analysis	synthesis	competition	cooperation
reductionist	holistic	quantity	quality
linear	non-linear	domination	partnership

Source: Capra and Luisi (2014)

3.7.2 Coding, interpretation and analysis of text and video

Audio and textual data was transcribed and then coded using Microsoft Excel whereas video data was transcribed and coded using ATLAS.ti 7 qualitative software (see photo 1). The video codes were then integrated into Microsoft Excel and analysed using the pivot table functionality.

Photo 1: Screenshot of ATLAS.ti software used to analyse video footage



As will become apparent, whole quotes analysed against themes were used often in the analysis and when writing up chapter 4. They were also transcribed and then

written in their “raw” form, unless spelling and grammatically errors made it incomprehensible. This was purposefully done to expose to the reader the potential bias or generalisability that may have been made during the interpretation (Stringer, 2014).

3.7.3 Review and writing up of narratives

All quotes and narratives, as well as their interpretations used in this paper, were sent to the respective participants for their review as well as their final consent for publication (see appendix 3.15), as stipulated in their consent forms. This also gave participants an opportunity to point out and rectify any misquotes or misinterpretations.

Quotes from participants were referenced using pseudonyms. This was to protect the identity of the participants and their respective narratives. If deemed relevant, the source from which the quotes were taken, i.e. free writing, questionnaire, video reflection, were stated. This enabled the narratives and Chapter 4 to read more flowingly, giving impetus to the “lived experiences” (Stringer, 2014: 60) of the participants.

3.7.4 Triangulation of data

The credibility of the research was then enhanced through triangulation of the data (Stringer, 2014). Triangulation involves “using more than one method of investigation and source of data in the study ... so findings can be cross-checked, and as a reliable and valid way to understand complex social realities” (Bryman et al., 2011: 45). Therefore the variety of data obtained in this research through questionnaires, reflections, video footage and semi-structured interviews was used to cross-check against the themes to validate the findings. This was achieved again using Microsoft Excel.

3.8 Limitations and Assumptions of the Research

In this section the limitations and assumptions of the research are reviewed.

- This research was heavily qualitative, which means there were implications to the validity and reliability of the study, particularly if compared to a quantitative research criterion (Bryman et al., 2011; Yin, 2011). However, if adapted

accordingly to qualitative research by using “certain methodological and disciplinary conventions and principles”, as set out by LeCompte and Goetz (cited in Bryman et al., 2011: 44), the research maintained qualitative validity and research findings could be transferrable but perhaps not replicable.

- The research might come across as being too subjective, which could generate bias, however it also allowed me, the researcher, who was submerged in the social setting, genuinely to reveal the world as it was being experienced. The subjectivity-objectivity dichotomy is one of the polarisations of science that complexity theory itself challenges and offers an enlightened perspective on this discourse that can be applied to qualitative research (Cilliers, 2000a; Morin, 2005).
- It will be difficult to replicate this research as it was experiential, highly contextual and followed a very naturalistic tradition of qualitative research in its chosen context (Bryman et al., 2011). However, having said this, the process could be adapted and variations could be replicated in other contexts.
- Related to the point above, the research will therefore encounter problems of generalisation as it was contextual and so findings should be treated sensitively and empathetically.
- The exploratory, democratic and participatory manner in which the research was conducted meant that there was a low degree of control. Teaching and learning moments that were carried out needed this flexibility as they dealt with a diverse set of actors, and so needed to be sensitive to the non-linearity and feedback loops that emerged from the complex socio-ecological setting.
- It would have been difficult to determine strict causal explanations to the findings that emerged from the research and instead it aimed to offer anecdotal findings or tentative interconnections that may or may not support the research theories explored in the literature review.
- Structural limitations to the research included establishing continued funding to carry out all meetings and workshops with the various stakeholders.
- The project was done with a cross-sectional range of schools within the Greater Cape Town region but would always have been limited in sample size and sample diversity as the ideal would have been to have done this with all the schools in the region.

- Communication and language barriers were especially limiting when dealing with a diverse sample group whose first language was not necessarily English.
- The use of fictitious names, and constrictive nature of academic reports can diminish from the “lived experiences” (Stringer, 2014: 60) of the individual participants. As justified through (Stringer, 2014) who in his chapter *Giving voice: alternative report structures* explains that “[b]y the time readers arrive at the heart of the report... The voices of principal stakeholders have become muted and sometime lost in the bureaucratic issues that tend to predominate in reports” (Stringer, 2014: 226–227).
- Although some attempt was made to find contextual and particularly African specific research, a large portion of the literature used in developing the framework and in conducting the research methods and methodologies was Eurocentric, originating predominantly from the global North.

The main assumptions of this research before conducting it were as follows:

- The exposure of teachers and learners to complexity and systems theory as an approach to thinking about, seeing and dealing with socio-ecological systems as guided by the curriculum framework would create “complexity thinkers”. This was not necessarily the case as complexity thinking as a learned construct was an emergent property itself and so, as Gough (2013) states, these processes were not deterministic in the ordinary sense and could only be demonstrated retrospectively. Complexity cannot be managed into existence (Davis & Sumara, 2008) but instead certain conditions can be facilitated within a system which gives space for complexity to emerge.
- The participants who understood complexity would engage with socio-ecological systems in a more responsible, effective and mindful way as this was supported by literature originating out of the Cilliers school of complexity thinking (Cilliers, 2000b, 2008; Preiser, 2012; Woermann & Cilliers, 2012; Preiser, Cilliers & Human, 2013).
- Schools, teachers and learners would be willing to participate and engage in the project and continue to do so over the year.

3.9 Summary

This chapter to some degree ordered the complexity that is embedded in the research methodology and methods when studying a lived experience, by explaining how the paper's three research objectives were supported through the overall research design and methodology. It was demonstrated in this chapter, *inter alia*, that there is no one single approach and design that this research can be categorised into, as it possesses aspects of both ethnography and case study designs and fulfils a variety of qualitative traditions. The research methodology also posed some questions of legitimacy, which were acknowledged, however the methods were described and supported and the importance of reflexivity throughout the PAR process was further discussed. A rich variety of data was generated and this was analysed through thematic coding by computer software, using Capra and Luisi's (2014) integrative thinking and values as a "light" framework. Finally the chapter concluded with a review of the identified limitations and assumptions of the study.

In the next chapter, the results and the analysis that emerged from implementing this research methodology and methods will be discussed.

Chapter 4

Results and Analysis

4.1 Introduction

“Working with Nature project has broadened my mind-set in the sense that I don't look at things as just what they are, I think about what they could be, how they could help us. I think, why is this plant here? It has purpose, if it didn't have a purpose it wouldn't be on Earth. How can I use it to my advantage, why is it there? Why in this environment rather than the next one? So... Working with Nature made me look for the deeper meaning in everything, and questioning, becoming a critical thinker.”

– Kadiria

This chapter aims to engage with the third and final research objective of this paper, which is to analyse, through thematic coding, the effect that the WWN project had on the thinking, values and knowledge of the participants. Before this is attempted, the workshops are briefly analysed as they provide an outline and context for deeper analysis. The thinking themes used “lightly” in the analysis were holism, synthesis, non-linear and intuition, and the value themes used were cooperation, partnership, conservation and quality. After analysing the effect of the learning process on the explicit-formal and informal knowledge typologies, other key emergent themes – diversity values, grit and resilience, and contextual thinking – are briefly discussed. Teacher participant narratives gave rise to pedagogy-specific themes, such as process learning and learner-centeredness, and so these are examined briefly before the chapter ends with a triangulation of the six most dominant themes.

4.2 Participant Information

From 35 learners and nine teachers, only 29 learners and eight teachers completed the entire six-month project, 65% of the participants who completed were female. The final participant group (see photo 2) was made up of six learners and two teachers from School A, four learners and one teacher from School B, four learners and one teacher from School E, five learners and one teacher from School F, seven learners and two teachers from School D and three learners and one teacher from School C.

Photo 2: Working with Nature participants



4.2.1 Disbelief in contemporary education

Of the seven participants who did not complete the project, five were males. The reasons for not completing the project differed in each case, however one story from a boy named Tim, who not only left the project but also decided to leave formal education altogether, was of particular significance. He had lost faith in conventional education and felt that it stifled creativity and innovative thinking. In Tim's first free writing he said:

I began to think how pointless the current education system was, if you are an entrepreneur. This is because an entrepreneur works for him[self], therefore, not really needing a matric or CV, and secondly because nothing you learn in school is relevant to what you want to do. – Tim

This became a theme amongst quite a few other learners who were involved in the project, both boys and girls, who felt that educational systems and models needed changing. Caleb, who in one of his free writings, said: *“judgement, a false/unnecessary education in schools, much needed mentality shift, holistic viewpoints needed.”* He came to realise that he enjoyed the WWN's learning approach because he later reflects: *“I learnt that I prefer this style of learning*

(holistic), compared to the style experienced in school (tunnel vision like).” Another participant, Mark, alluded to this theme fluently in one of his free writings when he wrote: *“This initiative [referring to the project] allows for “out the box” thinking which is something education in South Africa has been missing.*” And when asked, after completing the project, what the solution to making the world a better place was, Robin responded: *“Education ... that spurs on ideas that can change our views and the way we approach problems.”*

These voices arose despite very little prompting or encouragement from our workshop processes regarding changing educational paradigms, and so it's interesting that the need for educational reform is not only being expressed retrospectively within education systems, as seen in the literature (Jansen & Taylor, 2003; Irwin & Lotz-Sisitka, 2014), but also introspectively.

4.3 Workshop Results and Analysis

In order to fully understand the thematic analysis of sections 4.4 – 4.8, it seems only fair that that the context from which these themes emerged is analysed, as this exposes the causal structures that may have played a role in the theme development.

4.3.1 Introductory workshop analysis

It was evident from the introductory workshop reflections that the learners enjoyed themselves. Most commonly expressed was the appreciation for meeting other learners and teachers from other schools. As was the intention, the ice-breaker activity was uncomfortable for some but after that most of the learners found the “Human Impact on the Environment” reductionist lecture by Ms C very informative, but perhaps too long a time period to be sitting and listening, even though there was a stretch break in between. The lecture covered the entire CAPS “Human Impact on the Environment” section, paying particular attention to the following topics: atmosphere and climate change, water availability and quality, food security, solid waste disposal and loss of biodiversity. In each case, pure content and terminology were emphasised, but this was interspersed with global and local information on the status quo of each topic, and focused on knowledge that has been deduced through

scientific inquiry. There was some questioning from the learners, however it was evident that all participants were still trying to establish themselves within the group and so the atmosphere was still quite “formally institutional”.

Photo 3: Learners at the introductory workshop



The activity of becoming a tree, mosquito, ant, river, rhino or Table Mountain got the participants interacting much more freely and there was excitement and laughter as they imagined being something “other than human”. From their report back to the rest of the group, and from further analysis of their drawings, it was evident that they were beginning to gain some understanding of the interrelatedness that exists between the five topics covered earlier, as well as the interconnectivity between ecosystems services and social systems such as health, education and economies. A sense of empathy and frustration was evident, particularly when the “rhino group” presented, as the obvious emotional issues of being a rhino lead onto a learner-generated discussion on the ethical dilemmas between big and small species, in this particular case, between rhinos and ants.

Photo 4: Becoming a rhino, tree, river or Table Mountain activity



The session ended with free writing and two-minute video reflections, which the participants thoroughly enjoyed. The predominant feeling that came from the introductory workshop was one of anger and frustration as to the current state of affairs on our planet. Kadira's video reflection begun with:

I'm basically disgusted in a way, in how we treat the planet because it's the only home that we basically have. We take it so for granted and this is a very sensitive issue to me, because I see myself as a very compassionate person, and I just think that we as humans, think too much about ourselves. – Kadira

And Jessica concluded in her reflection:

It can't just be a few people, everybody has to help because else we're not only going to kill ourselves; we're going to kill everything else on the Earth. As humans we're so selfish, we sort of inhibit other people or other species from growing - different forms of plants, different forms of life, which we really need to change, in order to ... I don't know... to carry on living. – Jessica

These reflections were in some way purposefully influenced by the sterile, analytical and reductionist frame that we focused on during this introductory workshop, the

“doom and gloom”, so to speak. This was partly because of my own personal learning experiences at the Sustainability Institute (see reflexive box 6) and partly because it is a reality that science is pointing towards an even bleaker future if current global trajectories don’t change (Fischer-Kowalski & Swilling, 2011; Swilling & Annecke, 2012; Pretty, 2013; Steffen et al., 2015).

Reflexive box 6: My learning experiences at the Sustainability Institute

After doing eight intensive modules for my Postgraduate Diploma at the Sustainability Institute, I picked up a trend within the modules. I don’t know whether this was intended by the programme creators or not, but it was there for me, and I sensed it every time. The week-long module started off with a review of dense literature, covering deep theoretical aspects on the topic. It made me end each day feeling heavy and in some ways even depressed about humanity, the Earth and its current state of affairs. This was compounded by the afternoon and sometimes evening group work, which demanded patience and a mindful appreciation towards the diversity of people you were working with. By midweek, halfway through the module, I felt as if I had hit rock bottom, as all the frustrations from the module began to surface. And then transformation arrived usually on the last day, just before I would present my final group project. The theory and group discussions became lighter and more positive, as case studies of human innovation and reconnection to nature were reviewed. Hope and clarity on personal action were brought forth, as my frustrations and depression lifted. This may solely have been intuitive thinking and held no bearing to the truth, however it played a significant role on how I influenced the learning process of the WWN project.

4.3.2 Complexity workshop analysis

It was always going to be interesting to see how 16 or 17-year-old learners were going to deal with complexity theory and the characteristics of complex systems. As complexity theory can be deeply philosophical, it was quite surprising that the majority of the learner participants got a sense of what complex systems were and there was lively debate around the case study of Lake Victoria (see appendix 3.7). It was evident, and will be analysed further in section 4.4.2, that the “one man with his

bucket” dictum had a major impact on all the participants, because non-linearity emerges as one of the most predominant themes from the overall experience.

The activity of working in groups and trying to map out ecosystems, while listening to George Monbiot narrate *How Wolves Change Rivers*, really seemed to emphasise the interdependence and relationships within an ecosystem, and each time the film was replayed, groups would notice something else that they had missed previously. Some found themselves at the end of the activity in awe of the complexity of an ecosystem, as Bielle proclaimed after the experience: *“The complexity of everything really surprised me, in actually seeing how intertwined everything is.”* Making these interconnections, linkages and forming relationships, like the non-linearity, were the main manifestations of introducing complexity theory to the participants and so they too will be analysed in the subsequent thematic sections.

4.3.3 Immersive outing to False Bay Nature Reserve analysis

It is difficult to describe the impact that this outing had on all the participants, as it was something that was perceived in the moment, and so tends to lose some value when described from research recordings, artefacts and reflections. All the participants responded positively to the experience as being something beneficial to helping them understand the complexities surrounding socio-ecological systems. Josh described that he was *“shocked by how little [he] knew about where [he] lived”*, and Tara felt that *“physically learning through going out and exploring was a more effective learning experience than sitting and listening in a classroom environment.”*

This was further supported by many others in their free writing and feedback, including Kate who began making the first tentative steps away from a “re-/presentational epistemology” to an “emergentist epistemology” (Osberg, Biesta & Cilliers, 2008) when she reflected saying: *“I learnt best when we were taken to the places and given information where I could put it in context.”*

Photo 5: Immersive outing to False Bay Nature Reserve



This realisation by Kate, when coupled with re-negotiations and re-thinking the status and purpose of her new-found contextual representation, may facilitate her to see her knowledge from learning in context being about “participating in the creation of an unfinished universe” and so therefore knowledge that is temporally, and not only spatially linked (Osberg, Biesta & Cilliers, 2008: 215).

The Goethean observation, rapid sensing and sound mapping activities were incredibly beneficial, not only in integrating aspects of place-based learning, but really in opening up sensibilities to other forms of knowing, and therefore knowledge creation. This will therefore be analysed further in section 4.6.

Photo 6: Participants doing their free writings at the end of the day



It must, however, be disclosed that the biggest impact, as per the participant reflections of the outing, were the Philippi Horticultural Area, the Coastal Park Landfill and the CFWWTW. The Philippi Horticultural Area, which is uniquely embedded within the Cape Town urban settlement fabric, provoked a large response from participants. One participant remarked that, despite living in the area, she had never fully noticed and understood its value. Nombeko remarked that: *“it was a really interesting thing to actually have a cultivated land instead of people building houses on that land.”* From this it is evident that the outing pushed the normative values of some learners who are a part of a society in a housing crisis, to realise that it may be valuable to preserve urban land for food security and climate change resilience.

Photo 7: Philippi Horticultural Area made the biggest impact on the participants



4.3.4 Teacher meeting on assessment of project

From a pedagogical perspective, the two-hour teacher session on the assessment of the project was immensely beneficial and significant. We collaboratively generated a rubric (see appendix 3.10) for assessing the project that was not for marks (see reflexive box 7), and emphasised in the rubric that the process of the learning experience was more important than the end product. The rubric was adapted and modified from two existing rubrics that were designed for project-based learning, and was divided into five phases – the understanding, application, reflexive, communication and overall phases. Recent literature supports this as it calls for the development of effective project-based learning assessments (Du, Su & Liu, 2013).

The understanding phase covered aspects such as background information, composition and structure of context, recognition of complexity of chosen system, and referencing. A significant aspect of this was the adoption of understanding the complexity of the chosen system, which had the target descriptor as being: “[v]ery deep understanding of the complexities of their chosen system is demonstrated. The interconnectedness of their ‘Human Impact of the Environment’ topics is emphasised and the boundaries, uncertainty, richness and emergence of their system is acknowledged.” What this emphasised was the interconnections between

the topics that each group covered in their projects, which put them into a position where they may have needed to use synthesis and holistic thinking. Furthermore the rubric recognised that they needed to acknowledge the limitations of their chosen contexts. This may have affected the way in which the groups understood the contexts they were researching, how they approached them and what contextually sensitive applications they suggested in addressing the challenges in making their contexts more sustainable.

In the application phase, the groups were encouraged to use biomimicry principles when addressing the sustainability of their chosen contexts. Once again this meant that synthesis and holistic thinking was required. The emphasis here was that “conclusions are not jumped to but rather deliberated” and this was further supported by “deep understanding of biology is explored and recommendations/solutions attempt to create conditions conducive to all of life’s systems flourishing” (see appendix 3.10); this was in line with process rather than product as will be further analysed in section 4.8.1.

Other aspects of the rubric which more than likely affected the project approach taken by the learners were the emphasis on reflection, introducing creativity, resilience and originality, as well as group cohesion, collaboration and participation. These may have played a guiding role in the themes that emerged from the participants, particularly when it came to their final group presentations. It must be pointed out, however, that this meeting and finalisation of the rubric by the teachers only happened halfway through the project, and so it wasn’t made explicit to the learners before the project commenced, which is common practice for most conventional rubrics and assessments. This may have played a role in nurturing creativity and adaptability within the project, but more so, it demonstrated how process was emphasised within the project learning experience. Having prospective assessment tools can bring structure and order to teaching and learning, but potentially at the risk of simultaneously losing spontaneity, uncertainty, adaptability, creativity and innovation. Are these not the skills and attitudes, the transgressive pedagogies (Lotz-Sisitka, Wals, Kronlid & McGarry, 2015), that are needed in our current human condition to help navigate through the global polycrisis in sustainable direction?

Reflexive box 7: It's all about "the mark" at the end of the day

Ask a primary or high school teacher what the most common question asked by learners is, and you'll more than likely get the response "Sir/Ma'am, is this for marks?" We are mark obsessed, almost to the point that it has become insatiable. At the school where I teach, we have an online, real-time reporting platform called "Marks Live" and I am often queried by both parents and learners for explanations on their weightings and percentages. As democratic as this may sound, we (the general teacher community) still tend to mark for the sake of generating marks. Learners use marks as a benchmarking tool and teachers use assessment as a tool predominantly for reporting, accountability and control. After five years of teaching, I now know that I can set any assessment I want to achieve the average that I require, regardless of the learners' knowledge, let alone competency. Furthermore, a fair share of our assessment strategies and methods stifle innovation, creativity and critical thinking. This made me question how complexity theory would address assessment and evaluation in schooling.

4.3.5 Biomimicry workshop analysis

It was clear from the diagnostic questionnaire that the majority of participants had decided to enrol into the WWN project because they wanted exposure to biomimicry. Not only does this say something about the popularity of the approach, but on a metaphilosophical level, it perhaps is a manifestation of the co-evolutionary consciousness movement towards reconnecting with Gaia. It is clear from analysing the free writing that this idea of learning from, and not necessarily about, nature made an impact on the participants. As Anne put it:

The concept of "biomimicry" has served as a huge inspiration to me because it uses nature as a mentor in educating us. As ultimately nature is the perfect system, so we do need to learn from it, and we do need to be educated by it. – Anne

Additionally, what became apparent throughout the project was the vocational calling for many participants to biomimicry. Ms L, a participant and teacher in the project, explained that two of her learners were interested in taking aspects of their projects further, beyond high school. For one of her students, Kate, this was significant, as she explained:

Her mum was there to watch [the final group presentations], for once Kate has actually showed an interest in studying something after school. Which is huge. She takes Design as a subject as well, so for the first time she could see where her subject Design and her subject of Biology has a massive link, in the concept of biomimicry. – Ms L

For Rory this was something of importance for him too:

*I have been interested in biomimicry for a while - I love the idea of being able to create and innovate new technologies that are inspired by nature, as well as being sustainable. I envision myself having a career where biomimicry principles are used.
– Rory*

This discourse highlights not only the need for biomimicry, or if I dare say so, any ecoliterate approaches, to be more openly acknowledged and radically integrated into conventional education models in South Africa, not only within schools, but also beyond compulsory education and into higher education. It tends to expose, once again, the blind spots of Cartesian education models, which end up isolating subjects and disciplines into silos, making it unnecessarily problematic for interdisciplinary, let alone deeper and empowering transdisciplinary, education.

Moving away slightly from rational towards intuitive analysis after the biomimicry workshop, it seemed that the participants had transitioned through their earlier frustrations and anger stage experienced in the introductory workshop (see section 4.3.1), and were now onto the more creative, innovative and hopeful stages as alluded to in reflexive box 6. This intuitive feeling can be somewhat justified through the following excerpts taken from the learners' free writings after the biomimicry workshop:

Working with different personalities and everyone with their own view and opinions about biomimicry gets us excited and creative. – Ghalibah

*I am looking forward to physically creating the garden so we can adapt and modify it.
– Robin*

I'm looking forward for the day we tackle our contexts from different angles.

– Nomsa

This is only the beginning of my journey, because my group and I are going to continue with this project to better the lives of humankind. – Jason

Nature is a beautiful thing and I wish that all people felt the same way about it as I do. Then maybe, humans could live alongside nature in harmony. – Josh

Photo 8: Biomimicry workshop



4.3.6 Presentation workshop analysis

The presentation workshop was vaguely thought through at the start of the project, with the purpose and relevance of the actual workshop evolving as the WWN project progressed over time. It became an important element in that it gave the learners a sense of comfort as they established that other groups were at similar stages of the project, and that it was okay if they had not found “the answer” to their challenges and problems. It allowed participants to begin tying in their contexts tangibly, formulating some sort of coherent narrative about the process of their projects, and therefore answering the who, what, why, where, when and how; this being one of the main guidelines suggested on the project instructions and rubric.

Photo 9: Presentation workshop

One of the themes that emerged from the WVN project was an attitude of confidence. It is safe to say that this workshop played a large role in giving the learner participants the confidence to communicate their projects to a larger audience.

Furthermore, the two appreciative inquiry processes that were created and used played a significant role in forming collaboration and cooperation between the participants. An overall pattern appeared to materialise in this process, in that during the defining stage, most of the themes were about cooperative, collaboration and partnership values. In the dream stage almost all the participants visualised some type of quality value such as happiness, enjoyment, equality and human well-being as being their ideal outcome. And finally in the design stage, there seemed to be predominantly holistic themes around education and reform. It is of course dangerous to draw up such patterns and to over-generalise, as the structural causation of this was most likely the way the questions were worded. Therefore these are more clarifications, than anything else.

Photo 10: Participants exploring the diversity of communication methods

4.3.7 Final presentation day

The final presentation day was an accumulation of the work that each group had done over the previous five-and-a-half months since the introductory workshop. Each group had accomplished a variety of different things, in a variety of different contexts, all addressing at least three of the five topics as outlined by the “Human Impact on the Environment” section of CAPS. Therefore the presentations³² were rich and diverse in nature.

The School A and School B group decided to look inwards within each school to promote sustainability by addressing the same topics, but using different approaches. The topics they addressed were waste management, loss of biodiversity and food security. School A actively implemented a bee-keeping society and a bee hive onto the school campus, demonstrating principles of bio-utilisation. School B, however, focused on addressing awareness within their school, which further dealt with a multiplicity of topics as well as certain values and attitudes, such as apathy and ignorance. They communicated their process of the project through a PowerPoint presentation, creating a website, storytelling and drama.

The School A and School C group decided to explore a local rugby stadium as their context, focusing on atmosphere and climate change, predominantly through energy usage, reducing water consumption and solid waste disposal. After conducting various interviews with stakeholders and doing research, they presented their

³² All final group presentations were uploaded onto the WWN website and can be downloaded from the following address: <http://workingwithnatureproject.weebly.com/teams.html>

findings by using a Prezi³³ entitled *Greening the Stadiums of South Africa*. Here they acknowledged internal and external complexities, proposed both behavioural and technical potential solutions to the stadium, and suggested a few creative, radical biomimicry applications to improving the stadium's sustainability. They also created three short videos to help communicate their understanding of the topics to the audience.

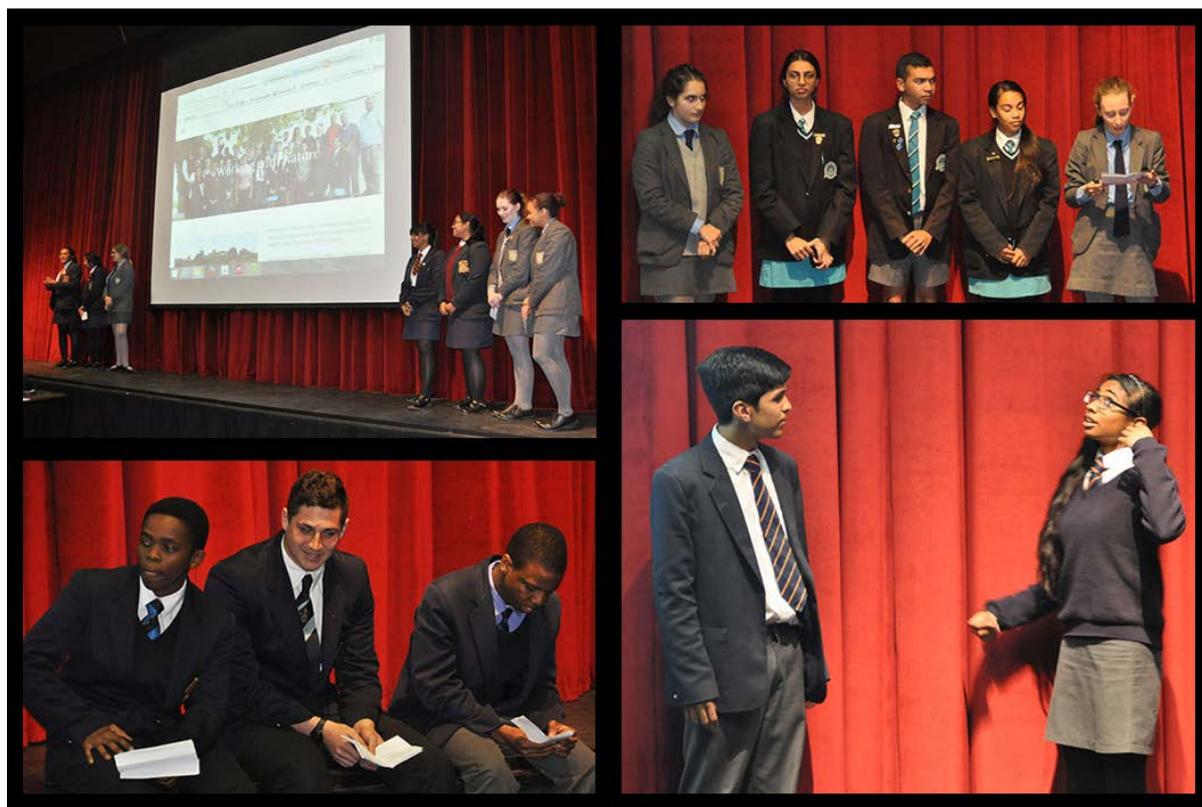
The School D and School E group presented their *Cycle of Sustainability* which looked at the tuckshop³⁴ within each school. They used contextually sensitive approaches in both the understanding and the overcoming of the sustainability challenges within each setting. The three topics that they addressed were food security, water availability and solid waste disposal. This was a fascinating presentation as the narratives that emerged were deeply profound and provocative, and will be analysed in more detail in section 4.7.3. They presented using a PowerPoint presentation, but they also created a blog which documented their journey throughout the WWN project.

Lastly, the School D and School F group presented an empowering action-orientated narrative by means of a short film. This group sourced, created and then planted a circular vegetable and indigenous fynbos garden at a relatively resource-poor primary school nearby School F. To ensure their own project's sustainability, they informed the learners and staff from the primary school about aspects surrounding food security, as well as how to maintain and nurture the garden so that it would continue to grow well into the future. Their project addressed the topics of water availability and quality, food security, solid waste disposal, and atmosphere and climate change.

³³ Prezi is online presentation software, ideal for presenting interrelated and connected themes.

³⁴ The term "tuckshop" is slang for "canteen", which is used in former British colonies.

Photo 11: The four participating groups on final presentation day



In an attempt to validate the thematic framework used in the analysis of the WWN project in the upcoming sections 4.4 and 4.5, data from multiple sources, including that from the final presentations, will be used to triangulate the results where possible (see section 4.9) and so improve the credibility of the analysis (Bryman et al., 2011; Stringer, 2014).

With this, I move on to the next section, having only sketched an outline of the results from the final group presentations.

4.4 Integrative Thinking Themes

Capra and Luisi suggest that intuition, synthesis, holism and non-linearity are all tendencies towards thinking in a more integrative way, which in turn may suggest more ecological thinking (Capra & Luisi, 2014). In the following sections, these thinking tendencies are used as themes of which the narratives from the WWN project will be further analysed.

4.4.1 Holistic and synthesis thinking

Capra describes the tension between holism and mechanism as a swinging pendulum, which can be thought as similar, to some extent, to the tension between complexity and reductionism (Capra & Luisi, 2014): “The emphasis on the parts has been called mechanistic, reductionist, or atomistic; the emphasis on the whole, holistic, organismic, or ecological ... it [holism] has become known as ‘systemic’ and the way of thinking it implies as ‘systems thinking’” (Capra & Luisi, 2014: 4).

The Oxford Dictionary defines “synthesis” as “the act of combining components or elements to form a connected whole”, as opposed to analysis (Oxford Dictionary, 2015a). Synthesis thinking has its roots in constructivism, and in this study refers to the “connections that students make” (Callaghan & Bower, 2012: 10), and so has to do with the creating or building up of elements in thoughts.

As these two ways of thinking are intimately linked – synthesis thinking gives rise to holism – they have been combined in this section, although I do acknowledge that they are not entirely the same thing and will attempt where possible to make this clear.

Holistic and synthesis thinking were undoubtedly the predominant themes that emerged from the WWN project. Sometimes they emerged explicitly; for instance, one of the teacher participants Ms R, commented: *“I also learned ... the times that I have been with Working with Nature, as seeing things not only as linear, cut and dry, but looking at everything as an entity, as a whole.”* Or in the case with Bielle when she reflected in her free writing: *“My eyes were opened to how everything is interconnected and forms part of a whole system; its living, relying, feeding and supporting.”* Tara in her final video reflection attempted to explain what she knows about complex systems by stating: *“Complex systems and problems are interlinked issues that we face in our lives and if we look at it as a whole, we'll have a much greater impact on all of it.”*

Often the holistic thinking theme was more subtle, and thereby needed deeper analysis. Andile reflected on the potential solutions that his group was coming up with in making the rugby stadium more sustainable. He wrote: *“It [the stadium] is a*

very controversial issue to work around, because we also have to consider long term issues that might arise from our very own implementations.” In order for him to consider the effects that their potential solutions or “implementations” had on the stadium as a whole, he had to think more holistically in understanding that implementing something, such as recycling, was not as simple as he would have originally thought.

As for synthesis thinking, the theme emerged when it was clear that the participants had constructed, created or built up thoughts or ideas from individual parts. For instance, Sabaahat reflected in one of her free writings that through her interaction with one of her group members, they created an idea of a sustainable RDP (reconstruction and development programme) house:

Eve and I had an idea for a great sustainable house, on which RDP houses can be based on, and we use geysers, heated by compost and a garden on the roof which cools it down, and also becomes the food source. – Sabaahat

Mr Z, who teaches at a poorly-resourced school, School C, summarised just how important synthesis thinking is when it comes to teaching and learning about “Human Impact on the Environment”. When asked how his understanding of complexity theory has impacted on his approach to teaching he replied:

... deforestation, it does contribute to climate change, and it does affect biodiversity, and it does cause thermal pollution. Therefore if you take into cognisance all these complex issues, they are interrelated, you can never just single it out and treat it as a single entity. They are connected, and this is how I have actually been challenging the learners now [since the WWN project], saying don't just look at one issue and isolate it, treating it as a separate entity, they are interrelated. And for me that has been amazing, that really has been amazing. – Mr Z

Holistic and synthesis thinking did not only emerge from questionnaires, interviews and reflections, but also became evident in the Goethean observation activity. Cassy wrote a poem to the plant that she observed at Rondevlei Nature Reserve,

which, by analysing her drawing that accompanied her poem, was most likely a *Restionaceae*³⁵. She wrote:

*We move and sway to the beat,
the ancient beat of the wind.
But we're still, we can't move our feet;
So we wait for the wind to begin. – Cassy*

There is a clear connection to the structure and adaptations of the plant from this opening paragraph. Restios are long, thin and sturdy and so possess adaptations making them suited to windy regions, furthermore they are only pollinated by the wind, hence the reason the plants wait for the wind to begin moving to different places. The plant also makes a distinctive rustling sound in the wind, which explains the “beat” that Cassy heard. She then goes on to describe the photosynthetic abilities of the plant through the words: “*my food is my body*” and finally ends the poem by referring to the function of the plant’s roots providing water and anchorage.

Holistic and synthesis thinking were evident in each of the four final group presentations. However, the one group that embodied this thinking the most in their approach to their project was the School D and School F group who created a vegetable garden at a local, poorly-resourced primary school. Their garden was circular in shape and they implemented companion planting, where certain plants were specifically put next to one another so that the adjacent plants symbiotically provide nutrients, and sometimes even protection for each other, therefore reducing the need for fertilizers and pesticides. They also addressed biodiversity, atmosphere and climate change by planting indigenous fynbos and carbon sink plants within the centre of the garden. The watering system they set up used water that was obtained from a rainwater harvest tank, which the school already had but was not using efficiently. Their prospective aim was to get the school to begin composting their organic waste, which would be used as a fertiliser for the garden. This, in turn, would produce fresh vegetables for the school children. Furthermore, to ensure the

³⁵ *Restionaceae* or restios are indigenous rush-like, monocotyledonous plants that are abundant in the Fynbos biome of Western Cape of South Africa.

continuation and sustainability of the garden, the group also engaged with the school children and teachers, getting them to help out in creating the garden, and teaching gardening skills and issues around food security.

4.4.2 Non-linear thinking

The second largest theme that emerged from the WWN project after analysis was non-linear thinking. Non-linearity is most closely associated with complexity theory (Cilliers, 2008), and until only recently, non-linear equations have essentially not been about linear approximations, in other words linearised non-linearity (Capra & Luisi, 2014). There is recent literature to suggest that non-linear thinking is a multidimensional, alternative form of thinking which may involve: “non-rational processes as intuition, holistic and total systems appraisal, imagination and visualization, perceptual flexibility, and creativity” (Groves & Vance, 2015: 111) and can therefore be defined as a “preference for attending to internal feelings, impressions, images, and sensations; and processing this information (both consciously and non-consciously) to form understanding, or a solution for directing subsequent action” (Groves & Vance, 2015: 113).

In this study, non-linear thinking emerged most greatly in the sense that the participants felt that small changes could generate large effects, having no rational, statistical or empirical evidence to suggest that this would occur. It often came up in questionnaires and reflections. It was randomly referred to as the “domino”, “snowball” and “whirlpool” effect and seemed to give the participants a sense of responsibility and deep mindfulness, that their actions not only carried consequences, but that what they did could have a larger impact or even make a big difference to the greater system. Table 8 summarises six selected narratives from different individuals and from various sources of data that demonstrate aspects predominantly of non-linear thinking.

Table 8: List of narratives that demonstrates the theme of non-linear thinking

Participant	Source of data	Narrative
Vagish	Post video reflection	<i>Complex problems don't always need complex solutions. Sometimes it's the simplest solutions that have the biggest impact and they make the biggest difference.</i>
Taibah	Post video reflection	<i>A small thing can change, can make a big difference. Even if it's a good thing or if it's a bad thing, it can impact.</i>
Adhira	Post video reflection	<i>I never really thought that we could make small changes that would actually amount to a lot, in my brain we always had to make these huge contributions that would have kind of like a snowball effect. But I suppose now I understand that when you make small differences and empower individuals, it's easier to actually create a whole network of people who are working together to solve a problem, instead of one individual with a large idea that may not actually work, or be put into practice.</i>
Caleb	Post video reflection	<i>I've also gained a greater understanding with regards to the "domino effect", and how something so small can trigger a "domino effect" and end up being something pretty big. The small little idea, or the small comment that we implement can end up growing and developing and can actually be put in place and be something actually quite amazing.</i>
Robin	Post questionnaire	<i>I have realised how incredibly cumulative our actions are, which can determine destruction or development. I now wish to reduce my negative impact in small, yet effective ways.</i>
Eve	Free writing	<i>We need to start what I call the "whirlpool" affect. Once one person creates the change then hopefully someone else will too and so it will carry on. Everyone together will create momentum that won't be able to stop. A whirlpool of passion, innovation and ideas for a greener tomorrow.</i>

Non-linear thinking was further supported in the final group projects. The School A and School B group in particular had based their project on a non-linear assumption that small changes would amount to large effects, and so their project focused on small, yet simple solutions. Adhira demonstrated this aptly in the conclusion to their group presentation:

All in all our small changes will make a huge long term difference, by reducing the carbon footprint of the school as well as changing the mind-sets of the students who attend it. When systems are put in place that become a part of the ethos of the school, it becomes nearly impossible to stop sustainable innovation. – Adhira

For the teacher participants, non-linear thinking was interpreted and analysed slightly differently, suggesting that during a lesson, what was most often referred to as

“going off on a tangent”, might be the consequence of increased non-linear thinking within teaching moments. Each teacher who was interviewed at the end of the project mentioned openly that they were now more prone not only to allow the class to be redirected elsewhere, but were comfortable enough to let that happen, knowing that valuable learning moments and experiences may perhaps emerge within these teaching “tangents”. Ms L described this happened when teaching her Grade 9s Chemistry of Life.

Even in the junior Grades, I am busy doing chemistry with my Grade 9's, and we went off yesterday on a completely different tangent about the chemistry of food. Even though this had nothing to do with acids and bases, which is what I was actually supposed to be teaching them, in my understanding it has completely enriched the lesson, because they saw that chemistry is life, and chemistry is everything all around them. – Ms L

4.4.3 Intuitive thinking

Although a single element of multi-dimensional non-linear thinking (Groves & Vance, 2015), intuitive thinking was mapped within the participant narratives. In an effort to stay “lightly” within the Capra framework, I have tried to find narratives that are more intuitive than anything else, within the participant data. This was the smallest theme to have materialised from the WWN project and it could be argued that many, if not all of the narratives that displayed non-linear thinking in section 4.4.2, demonstrated some degree of intuitive thinking, and this would not be incorrect.

There has been much research done on intuitive thinking (Groves & Vance, 2015). The Oxford Uehiro Centre for Practical Ethics has an interdisciplinary project on intuition and emotion on moral decision making (Oxford University, 2015). Intuition is characterised by

... holistic judgment derived from a subconscious scan and processing of information and is the automatic, unconscious “big picture” assessment of the often interrelated parts of a complex situation to point to appropriate decisions and new directions, rather than getting bogged down in the detailed analysis of huge datasets. (Groves & Vance, 2015: 113–114)

Some of the most intuitive thinking in the project came from one participant in particular. Eve engaged with the WWN on a deeper level than most, and over six months she had done, 26 free writings in total. In one of her first free writings just after the immersive outing she wrote: *“Where is our logic? I am not sure. But then, whoever needed logic to change the world. You need passion, inspiration, motivation and connection.”* Intuition, as being without logic or reason, is very much a part of Eve’s thinking about making a difference and taking action. In her next intuitive-centred free writing she asked the question: *“I am sure there is a secret to it, that humanity can use to create a better world ... is this secret too powerful to discover?”* In this second quote, intuition as a “gut feeling” (Groves & Vance, 2015: 114), is making her question whether the solutions to finding a sustainable future are out of human’s cognitive capacity, that perhaps they exist, but we are blind to them.

Other participants also expressed intuitive thinking in their reflections. Jessica, for example, said in her initial video reflection, *“I think because as a species, we’ve sort of evolved to become so advanced, it’s sort of impeding our own advancement really, if you think about.”* Here, Jessica was also tending to use her “inner sense” (Groves & Vance, 2015: 114), to suggest that human progress is in effect causing human regress.

However, it wasn’t a common theme and very little intuitive thinking was brought into the final group presentations. This is somewhat expected as the research they had done was analytical, and so all the decisions and solutions they presented were based on rational, empirically generated evidence and data.

The next section deals with the integrative value tendencies as outlined by Fritjof Capra (Capra & Luisi, 2014).

4.5 Integrative Value Themes

It is understood that values are an intricate and subjective phenomenon and that our thinking, which informs our knowledge, informs what is believed to be important, and will become a standard of our behaviour, except it is a lot more complex than just that. Capra and Luisi (2014) suggest that a broader paradigm shift from being self-

assertive to integrative requires a shift in corresponding changes of values, towards conservation, cooperation, quality and partnership.

4.5.1 Cooperation and partnership values

At first glance, one may assume that cooperation and partnership are perhaps all one of the same thing. However they are remarkably distinctive, yet, as was already discussed with holism and synthesis in section 4.4.1, they are also inextricably linked. In order to understand them, it often helps to look at the comparative that was outlined by Capra and Luisi (2014). Cooperation is seen as the integrative tendency of competition, and exists on every level from cooperative genes and molecules to cooperative global institutions and societies (Capra & Luisi, 2014). For partnership the self-assertive value was domination, and so is associated with important questions around power and control (Capra & Luisi, 2014).

Cooperative learning has been argued as being an integral part of promoting “social sustainable development” within education as well as “fostering positive intergroup attitudes in classrooms, multicultural and otherwise ... being instrumental in improving learners’ academic performance ... and being valuable in promoting positive social relations amongst group members” (Teise, 2013: 536).

As previously discussed, cooperation can be thought of as a sense of symbiosis, where there is a close mutually beneficial relationship between two elements within a system. Although there are differences between cooperation and collaboration, particularly in learning practices, (Hung, Young & Lin, 2015) for the sake of brevity this paper will consider them similar enough to combine. Cooperation and collaboration emerged throughout the WWN project and from all groups and participants involved. There were two main branches of cooperation that were evident: cooperation between participants within their groups, and cooperation between participants and nature.

When asked what worked well in the introductory workshop, Josh answered: *“The joining together of people who didn’t know each other previously, their collaboration and thoughts worked well.”* Jason echoed a similar narrative in one of his free writings: *“[f]or me, working in a group and collaborating with them is fun, because*

most things I did not know I learnt from them.” This idea of working together towards a similar goal also surfaced as Andile said in his free writing: “I feel like that we understand each other and we are all wanting to achieve the same goal.”

Mandisa saw an opportunity of using cooperation in her broader community:

I can ask the youth to now get involved and help society. Because on holidays there is nothing to do, there is no job for us, so we can do those things like recycle, plant trees and do everything that we can do to help society. – Mandisa

Whereas Megan saw even broader global applications of cooperation and teamwork:

I don't believe in problems but rather challenges, things that we can overcome and no challenge is ever too complex to solve. However, I also believe that teamwork is the best solution to a complex problem. So we need to connect and work together with other parts of the world, like global teamwork to solve global issues. – Megan

The second branch of cooperation that was evident from the narratives was the idea of cooperating with nature itself. Eve pointed this out when she wrote: *“We are nature, and the fact that we're working against it, is the real issue. Work with it.”* There is this understanding and frustration in Eve's tone, making it clear that we are no different to our natural environment, and that for us to make a transition towards our greater common goal, we're going to have to work with nature. Another slightly more bio-utilisation aspect of cooperation with nature is evident in Mandisa's thinking, who reflected saying:

I learned more things today about how we can help the world to change by not wasting, or do[ing] any harmful things that will destroy Mother Earth. I learned that we can use different things to save nature, by looking for answers in nature.
– Mandisa

In this reflection, Mandisa suggested that we can use nature itself to find answers in helping it.

As for partnership values, the slight difference here was that there were aspects of power and control emerging from the value-laden narratives. An honest reflection from Mzukisi made this point clear in his free writing: *“So we have some shy individuals in our group who have contributed in many other ways in the group, and there have been very opinionated individuals in our group, who have contributed to the group.”* The tension in this group is evident when Andile, who was in the same group as Mzukisi, further emphasised in his free writing: *“Everyone has their opinion on everything.”*

Staying with this group, which was the School A and School C group, it was evident in their final group presentations that there was a clear and strong partnership that existed between them. From a small observation, picked up by a number of teachers who commented in the assessment of the presentations, this particular group sat very close together when they presented, and seemed to be very in tune with each other, and each group member had a defined role to fulfil. Rory, another participant of this group, added value to this when he wrote:

I found this experience, going through the process of our project and going through the difficulties we had within the group and then working together. I found that really, really, an incredible experience. Something very different to what I had ever done before at school. – Rory

However, as Capra and Luisi (2014) point out, it is not a question of power or no power, it's a question of the right type of power appropriate for the new paradigm, which is empowerment of others in facilitating connections.

4.5.2 Conservation values

Conservation and preservation values were abundant throughout the project and came from many of the participants. They ranged from conserving the environment through to reducing or conserving resources. Raani said: *“[w]e as humans should always try to conserve what we have and not to waste or destroy everything because we cannot start all over. There is only one planet and we have to protect it.”* It seems that the majority of the participants knew what conservation was and that it was important to conserve or reduce our consumption of resources.

What was interesting in the analysis was that as the project progressed, there seemed to be less value being placed on conservation and more value on taking action in creating sustainable solutions. The point was made concisely by Anne in her final questionnaire: “... *it's not just this intangible mantra that people speak about, conserving the environment. It is now a passion and rather than just a statement.*” There is a clear shift from simply having an awareness about conserving the environment to actually wanting to take initiative and do something with the environment. This shift in perception is one that has occurred within the broader ESD and SD discourse, which critiques conservation ethics as being too inward looking or relying too heavily on intrinsic value, instead of being action-orientated, involving participation and stewardship (Carter & Simmons, 2010; Chapin, Carpenter, Kofinas, Folke, Abel, Clark, Olsson, Smith, Walker, Young, Berkes, Biggs, Grove, Naylor, Pinkerton, Steffen & Swanson, 2010; Reyers, Polasky, Tallis, Mooney & Larigauderie, 2012; Barnes & College, 2013; Locke & Russo, 2013).

4.5.3 Quality values

Capra and Luisi (2014) emphasise in their book that “the new science of life is essentially a science of qualities” (Capra & Luisi, 2014: 368), and that there needs to be a shift away from quantitative to qualitative growth within all aspects of society, as this is embodied within ecological systems. They distinguish qualities as properties that “arise from processes and patterns of relationships among the parts” (Capra & Luisi, 2014: 369) and that cannot be measured but can be mapped. Within the human realm this implies that qualities are results of subjective experiences and so, with that in mind, the subjective human experiences that emerged from the WWN project were mapped.

As perhaps expected, the quality values that emerged within the data ranged, but most seemed to be themed around the concept of the awe and wonder of nature. As Kate revealed: “[t]he world is beautiful ... *I've really learned how to appreciate how complex and divine it really is*”, and Anne described her plans in her free writing “[t]o *enjoy and preserve the artistry within the environment ... begin to respect it and observe and relish in its beauty.*”

However there were also many qualities of frustration, disappointment and stress that emerged. These tensions were mostly derived from working in groups and particularly with different schools, as Caleb said: *"I'm finding communication between the two schools frustrating."* Perhaps this was to be expected as the logistics of trying to coordinate two groups of learners and even teachers between two different schools can be difficult. An overwhelming majority of the participants felt upsets around group interactions such as: setting meetings times that would work for all group members, participants not arriving at their scheduled meeting times or participants pulling out of the project altogether. In two known scenarios, the socio-economic disparities played a particular factor in the tension between participants and their projects. These will be discussed later on in this chapter.

Various other miscellaneous qualities emerged from the projects which included feeling nervous about presenting in front of a large audience, finishing the projects on time, as well as enjoyment of working in groups and feeling happy and proud that they were a part of the overall experience. In the final questionnaire participants were asked to describe how they felt after the WWN experience and the words that came up more than once were: changed, enlightened, inspired and proud.

To conclude this section on quality values, the paragraph below is the closing statement from the School D and School E group, which in some ways, appropriately summarises this section on integrative values:

So I would like to kind of think of our progress as a flowering tree. Okay, I know that there is an environmental reference there but excluding that, with each branch representing the members of the group and the leaves and the flowers, representing our limitless supply of creative ideas. Our tree did wither and it did blossom and through the withering we were able to see the skeleton of our tree, and we could sort of grow from that. We could critically analyse the sustainability of the potential solutions and concepts we were thinking of putting in place. And so slowly but surely, this tree began to blossom and flower, and grow in height and complexity.

– Anne

4.6 Effect on Knowledge

Needless to say, to measure the effect that the WWN learning experience had on knowledge is difficult, because through a complexivist approach, all knowledge is approximate, a temporally and spatially emergent property of a complex system (Preiser, Cilliers & Human, 2013). Therefore whether it be through Habermas' critical theory of hermeneutics, Capra's living system's network approach, or Maturana and Varela's views on autopoiesis and cognition (Maturana & Varela, 1987; Capra & Luisi, 2014), the effect that this critical complexity learning experience had on the knowledge of the participants will be different for every participant. In an effort to provide some meaning to the narratives of the participants and the impact it had on their knowledge, the multiple knowledge typologies as portrayed by Fabricius, Scholes and Cundill (2006) become a useful framework. Although the original intention was to map indigenous knowledge systems with that of scientific knowledge systems, the explicit-formal and explicit-informal can be applied to the context of this study. Explicit, because the knowledge being revealed was codified into writing, recordings or drawings, but it was either formal, as in empirical knowledge, or informal, as in value-based knowledge, that seemed to be the most affected.

As for the explicit-formal knowledge, the impact of the learning experience was significant. This can be clearly demonstrated by reviewing the participants' understanding of the term "sustainable development" before and after the WWN project (see table 9). In both instances participants were asked what was meant by the term without any prior warning.

In each of the participants in table 9, their knowledge after the programme deepened on some level. For participants A, B and H, their knowledge on SD seemed to have become more holistic. For the other participants outlined in table 9, their answers afterwards show a better understanding of SD if measuring their answers against widely accepted, contemporary definitions.

Table 9: Knowledge on the concept of sustainable development before and after WWN project

Participant	BEFORE	AFTER
A	<i>Sustainable development refers to the growth of human occupation and effect with minimal environmental damage in the long-run.</i>	<i>Sustainable development refers is the innovation of structures in society, which do not add to global crises, and function for the greater good.</i>
B	<i>Sustainable development is the use of resources in a way that ensures that there will be enough for future generation.</i>	<i>Sustainable development takes into account relationships between social, economic and environmental issues and views nothing in isolation.</i>
C	<i>Sustainable development is how we protect the earth and sustain the earth's natural resources.</i>	<i>Sustainable development refers to the using or developments in a sustainable way, having enough resources for future generations.</i>
D	<i>Sustainable development is a "constant process of change" whether it be reducing your carbon footprint etc.</i>	<i>Sustainable development is the constant development in which appropriate resources have been used without compromising the needs of people in the future nor the environment.</i>
E	<i>Sustainable development is the protection of our resources.</i>	<i>Sustainable development is to use our resources in a way which we can save resources for the future generation.</i>
F	<i>Sustainable development involves how the human race develops or grows, introducing technology and other things that will make our lives better or easier.</i>	<i>Sustainable development is basically how an economy or country as a whole develops in ways that benefit the planet and it won't cause a downfall in future.</i>
G	<i>Sustainable development is when we should keep the environment eco-friendly.</i>	<i>Sustainable development is whereby you bring about change now which can still be effective in the long run.</i>
H	<i>Sustainable development has to do with creating solutions that are renewable, can be maintained, do not cost too much, and do not have a negative impact on the environment.</i>	<i>Sustainable development is all about creating systems that are resilient; systems that have perpetual momentum and can carry their purpose and their messages forward without continuous input. SD is creating solutions that are cyclic; and continue to solve whatever problem they are meant to, as well as others; long after they are put into place.</i>
I	<i>I don't know.</i>	<i>Sustainable development is a development which can be carried through overtime and is continually beneficial to all aspects.</i>

The final group presentations provided further evidence of the growth of the participants' explicit-formal knowledge. From using examples of technology, indigenous knowledge systems, and also basing their projects on policy and SD frameworks, it was clear that the participants had gained a deeper understanding and formal knowledge from their research. An example would be the explanation and interpretation that School A and School C gave on the two types of SD models

they had researched, the Venn diagram model and the nested model. In this quote, Rory explained the embedded or nested SD model:

This is called the embedded sustainability model which is just saying that everything is interconnected, so this diagram does it really nicely, that everything, the economy, the political systems of the economy, the way people interact within these sorts of contexts and the environment, they're interconnected together. The one thing they do rely on is governance, you know people wanting to make this change, people enforcing these sorts of changes. – Rory

In terms of the effect on informal and perhaps even more implicit forms of knowledge, the Goethean observation, rapid sensing and sound mapping provided some insights. Andile expressed how “being the plant” he was observing helped him learn about plant adaptations that assist the plant to survive in its environment: *“I got to be the plant and that taught me how a plant actually adapts to different temperatures and aspects.”*

Kate, who was searching for that connection between science and the arts, making schooling more relevant to her, expressed her appreciation for the Goethean observation: *“My favourite part of today was when we did the Goethean Observation. I really found that I appreciated the plant more by observing it both scientifically and artistically.”*

These activities also stimulated “multiple ways of knowing” (Widhalm, 2011: 6), engaging with the knowledge of the “heart” and “spirit” (McBride et al., 2013). Ghalibah reflected on her sense mapping saying:

We also did a sort of task at Rondevlei where we had to use our senses for five minutes, and I am amazed at myself. I've learned that I often use my hearing senses more than the others, and I have never even noticed this. So while doing this project, I know that I can get to know myself better as well. – Ghalibah

Adhira in some ways learned aspects of resilience from her Goethean observation, when she described her plant withstanding its harsh environment: *“I love its stem, it*

resembles a cheetah, with its spots. How fierce this plant is, to withstand this day, ugly area, and to become such a beautiful plant no matter where or what the circumstances are.”

It seems as though empirical knowledge emerged not only through formal methods but also through informal, and furthermore that participants learned not only about socially constructed theories but also about themselves in the process.

4.7 Key Emergent Themes

As far as research objective three goes, this thesis has explored the effect of the critical complexity learning experience on the thinking, values and knowledge of the participants. However, through analysing the data, various other themes emerged that could not be firmly mapped using the framework from Capra and Luisi (2014). I would like to pay brief recognition to these other key emergent themes.

4.7.1 Diversity values

Cooperation and partnership have already been discussed, however diversity values of the project are not quite the same, yet they still played a significant role within the WWN project. As Adam put it:

I am way more in tuned with my community. It's great finding out new things about the community that you didn't know about. Things that you wouldn't have known about if you hadn't done a project like this, and also interacting with other people from the community. – Adam

Themes of diversity came up continually throughout the project, and they weren't always positive and utopic. At one stage during the project, a participant learner was informed by her mother that she couldn't meet past 6pm in the evening due to the dangerous circumstances of her home area. She made this clear to the group, however, the other members who were not familiar with this participants living circumstances ignored her request of changing the meeting time, out of complete naivety. This tends to highlight the all too real aspects of South African culture, and the inequality that can sometimes mask our mindful empathy towards others within diverse set of circumstances.

4.7.2 Grit and resilience

Another major key theme that emerged from the project was that of “grit and resilience”, which is one of the skills and attributes outlined by Gerstein (2014) (see figure 6). The term “resilience” is increasingly being used in all levels of society in the wake of climate change. Originally adopted from ecology, resilience is the “capacity of a system to absorb recurrent disturbances ... such as to retain essential structures, processes and feedbacks” (Berkes, 2007: 283) and, as pointed out, can be both adapted or maladapted to certain situations: “There are many unhealthy systems that are resilient for instance” (Lotz-Sisitka et al., 2015: 74). However in the context of this paper, the terms “grit and resilience” are used to describe the perseverance, adaptability and resolve of the participants, despite disturbances and set-backs, such as the frustrations discussed in section 4.5.3, or the societal pressure points as discussed in the paragraph on diversity values.

This attitude is embodied most explicitly by Mandisa in her free writing.

I can share everything I want and our project is going well, we do have some challenges in our project. Some of us do not show up to our meetings, but what I told myself is that I am not going to give up, because I have put my time and energy to learn more about this project and where it will take me. – Mandisa

Or by Marie, an Afrikaans first language speaker, whose group probably experienced some of the most severe challenges in terms of distance, as her school, School E, is in Paarl, a 40 minute drive from her collaborating school, School D, which is in Cape Town.

It's been quite difficult, we faced quite a few challenges, thanks to distances, also because as an Afrikaans speaking learner, it's difficult to always effectively express myself in English. But it positively impacted me and I am thankful for the experience. – Marie

In both cases, the participants experienced their frustrations or disturbances and were able not only to persevere, but also thrive and produce something of significance.

4.7.3 Contextual thinking

As already quoted in this paper, contextual thinking is environmental thinking. This was one of the largest focus areas when developing the project and seemed to have been adopted by both the learner and teacher participants.

From the learners' perspectives, it was important in the project for them to gain the idea that each context is uniquely rich, diversely different, and temporally specific. It was an intentional "breakaway from the one size fits all" dictum. This was aptly explained and incorporated by the School D and School E group who worked on their chosen context, the school tuckshop, in uniquely different and effective ways. The narrative below from Sabaahat, during her final group presentation, eloquently explained the differences between the two school tuckshops:

My job was to compare my school, to School D. At my school, we did the "Cycle of Sustainability", but the "Cycle of Sustainability" needs three factors, that is basically: your tuckshop, your compost heap and a veggie garden. At School E, we lack two of those. We don't have a compost heap and we don't have a vegetable garden. Another problem, we were facing was that our tuckshop doesn't produce any organic waste, as Carina showed. It's just basically junk food. We do have a running feeding scheme that feeds 500 learners daily, since we are a school that consists of 1584 learners, yes, in our entire school. – Sabaahat

Their solution, in an effort to try and implement the *Cycle of Sustainability* into their context, was to use the organic food waste from the feeding scheme for their new vegetable garden that would go into producing healthy food options at the tuckshop, as it would have been difficult to grow enough food daily for a feeding scheme of that size.

For the teacher participants, contextual thinking was important, as in a country that has many poorly-resourced schools, the textbook becomes the only teaching and learning aid there is in classrooms. This not only creates learning moments that are without context, but it also creates a dependency on one particular view and understanding of knowledge.

Ms S, who teaches at School E, found it comforting to use the textbook a lot in her lessons before the WWN project, but has now realised the importance of context, more specifically something that is closely related to her school's immediate environment and community.

I used to focus or rely a lot on a lot on the textbook [laughs]. It's made me open my eyes up a bit more and be confident in the knowledge that I have, and so when we are actually looking at our society and our community and then focusing on a problem within our community, they [the learners] focus on it much more than just reading things out of a textbook and thinking that the problems are out there and not actually in our lives at the moment. – Ms S

Complex systems have a rich history, and “they cannot be conceived of without taking context into account” (Cilliers, 2000a: 9). This was demonstrated as being important in this research.

4.8 Teacher Narratives

Before this chapter concludes with a triangulation of the dominant themes, certain narratives emerged from the teacher participants that were specifically pedagogy related, these will also be briefly analysed.

4.8.1 Process not product

As pointed out earlier, the rubric was designed for process and not product, which was a considerable paradigm shift for both learners and teachers. The free writings and reflective nature of this project played a powerful role in this regard, as one learner, Naseh, pointed out that he felt the reflections difficult because he kept thinking that his writing was going to be marked and so he said: “*I kept on checking to see if what I was writing was right.*” (see reflexive box 7).

Having certain statements in the rubric such as “conclusions are not jumped to but rather deliberated” and “argument logically structured from beginning to middle to end” emphasised the process nature of the entire project, which was an aim when developing the project from the outset. Ms L, who teaches at School D, summarised this in her interview:

Another thing that was quite brilliant for me, was the concept of a rubric designed, having the ability to not have a mark. Which was such a good mental shift and I think something that needs to happen in education quite a bit. We get so fixated on something needing a mark, when instead of focusing on the product, we should be focusing on the process. That was very nice, a nice realisation for me personally.

– Ms L

4.8.2 Learner-centeredness

There is a global shift towards learner-centeredness in education (Morrison, 2008; Long, Dunne & Mokoena, 2014; Raselimo & Mahao, 2015), and throughout the experience, the WWN learning process was profoundly learner-centred, therefore the implications of this were interesting. Both Ms S, first-year teacher, and Mr Z, an experienced teacher, explained in their interviews that the WWN project had changed their approach to teaching, in that they are more empowered and open to allowing the learners to direct their lessons. The School C learners, who were a part of the project, had asked Mr Z if they could teach the other learners in the class parts of “Human Impact on the Environment” course work. And Ms S, who has over 50 learners in a class that caters for no more than 35, said that allowing learners to gain more control in shifting the lessons has counter-intuitively improved disciplinary issues within the classroom. These were both powerful messages from two very different teachers.

Ms R, who teaches at School B, acknowledged outright that WWN project had made her classes become more learner-centred.

I now try and make it more learner-centred, getting the learners, and also allowing them to use the content, the background that they have, to then communicate to the class or communicate with one another in a discussion. – Ms R

4.9 Triangulated Themes

In summarising this chapter and in an attempt to validate the narratives that emerged from the participants, the strongest themes are triangulated in the table below. This table was generated by taking selected quotes that explicitly represented the theme and plotting them against the various sources of data from which they emerged.

Table 10: Triangulated themes of the WWN project based on the integrative thinking and values outlined by Capra and Luisi (2014)

*	HOLISM	SYNTHESIS	NON-LINEAR	COOPERATION	PARTNERSHIP	QUALITY
IQ	<i>I think that we need to think before we do something. Think about all the effects that our actions will have. We will have a better understanding about the world and its various systems and this will lead to us being more conscious of our actions.</i> -Naseh	<i>I have learned about how everything is linked and that we use water in so many ways that I previously would not have thought about.</i> -Cassy	<i>I have realised how incredibly cumulative our actions are, which can determine destruction or development. I now wish to reduce my negative impact in small, yet effective ways.</i> -Robin	<i>The joining together of people who didn't know each other previously, their collaboration and thoughts worked well.</i> -Josh		<i>The drive for quality not quantity.</i> -Ms L
FW	<i>My eyes were opened to how everything is interconnected and forms part of a whole system; it is living, relying and feeding and supporting.</i> -Bielle	<i>Eve and I had an idea for a great sustainable house, in which RDP houses can be based on and we use geysers, heated by compost and a garden on the roof which cools it down and also becomes the food source.</i> -Sabaahat	<i>Everyone together will create momentum that won't be able to stop. A whirlpool of passion, innovation and ideas for a greener tomorrow.</i> -Eve	<i>I feel like that we understand each other and we are all wanting to achieve the same goal.</i> -Andile	<i>This togetherness that came from a simple idea can be the turning point in today's society.</i> -Tara	<i>Nature is a beautiful thing and I wish that all people felt the same way about it as I do.</i> -Josh
VR	<i>Complex systems and problems are interlinked issues that we face in our lives and if we look at it as a whole, we'll have a much greater impact on all of it.</i> -Tara	<i>Everything is basically interconnected. We shouldn't just look things as like one thing, we shouldn't just look at this pencil as just a pencil, you use this pencil to write, and writing helps you obtain knowledge.</i> -Taaibah	<i>A small thing can change can make a big difference. Even if it's a good thing or if it's a bad thing, it can impact.</i> -Taaibah	<i>So we need to connect and work together with other parts of the world, like teamwork to solve global issues.</i> -Megan	<i>We struggled a lot because we had to interact with each other.</i> -Nombeko	<i>...the importance of nature and plays a role in how people feel in nature.</i> -Andile
V	<i>It has broadened my mind-set in the sense that I don't just look at things at what they are, I think about what they could be, how they could help us.</i> -Kadira		<i>It's the changes that each individual can do and those change are of necessity going to be tiny, but every tiny impact has a larger impact.</i> -Ms C	<i>I can ask the youth to now get involved and help society.</i> -Mandisa		
I	<i>I also learned... the times that I have been with Working with Nature, as seeing things not only as linear, cut and dry, but looking at everything as an entity, as a whole.</i> -Ms R	<i>Coming out of last year's question paper as well, I remember with the marking, that was one of the things. The kids couldn't combine the two, once you had a case study where all the topics were related, they struggled.</i> - Mr M	<i>They realised how much influence they could actually have on something. And that their ideas don't need to be confined to a classroom discussion. That they can take it further.</i> -Ms L	<i>I found them very considerate of others and in turn very interested. And that was from both sides. And it was wonderful to get to know the kids from the other schools, in a wonderfully positive way.</i> -Ms C	<i>Because we teach at an all-boys independent school, they're inclined to mix with people who look like them and sound like them.</i> -Ms C	<i>So I think, the greatest thing they learned is what impact they have themselves.</i> -Ms S
A	<i>We move and sway to the beat, the ancient beat of the wind But we're still, we can't move our feet; So we wait for the wind to begin.³⁶</i> -Cassy					

*This column represents the source of data that each quote emerged from (see table 6). IQ (individual questionnaire), FW (free writing), VR (video reflection), V (video footage), I (semi-structured teacher interview) and A (workshop activities).

³⁶ The opening stanza of a poem written in a Goethean observation which demonstrates holistic thinking

4.10 Summary

This chapter has attempted to summarise a vast and rich body of qualitative data that emerged from the WWN project, as it set out to address the final research objective of this paper. It was difficult not to get trapped into the framing process, particularly when the themes used for analysis were so intricately interconnected. However, this was the reason that during this analysis, I used the framework “lightly”, to simply highlight the attributes that were learned during the WWN project. Therefore, a “lightly” applied framework was used in making sense of the effect that the project had on the thinking, values and knowledge of the participants. Numerous narratives and themes emerged from the project and these were briefly analysed. Key findings from this chapter will be discussed in more detail in the next concluding chapter, along with the limitations of the study and the recommendations for further study.

Chapter 5

Towards a “New Moment” in Life Sciences Education

5.1 Introduction

“We intend for it to be influential and to influence the lives of others, while in the process, influencing the lives of ourselves. We are the Universe as a whole made conscious, and life, the means by which the Universe begins to understand itself.”

– Megan

The final and concluding chapter of this paper aims to summarise this research from beginning to end, in an attempt to tie up the original research questions with the research findings. Section 5.2 discusses the results of the research by examining the first two research objectives and entering a discourse around the findings that emerged during the process of fulfilling the stated objectives. Section 5.3 takes a closer look at the final research objective, making connections between the original research questions and the findings from Chapter 4, specifically discussing the implications of critical complexity thinking. Final conclusions are summarised in section 5.4 before briefly analysing the limitations of the research in section 5.5, as well as the recommendations for further study in section 5.6. This paper then concludes, with the beginning in mind, through the final reflexive thoughts by the researcher in section 5.7.

5.2 Discussion of Results

The aim of this research was made clear in the *Introduction* chapter of this thesis, which was essentially to answer the following three questions:

1. What would a critical complexity approach to a learning process look like?
2. How might a critical complexity approach to a learning process develop the thinking, values and knowledge of Grade 11 learners and teachers?
3. Will this thinking, these values and this knowledge, developed from this learning approach, be more integrative, making these participants mindful of the complexities of socio-ecological systems?

The problem statement of this paper explored what being “mindful of the complexities of socio-ecological systems” meant by elaborating that participants would have a “better understanding of the interconnections within these systems; the importance and implications of context.”

In order to answer these questions, this paper set out three clear research objectives, the first being that of developing a theoretical framework, to inform what a critical complexity learning experience might entail, and the second being the actual methods of carrying out such a learning experience. The third objective was to address the problem statement directly in developing “integrative thinking skills and values that may enable [the learners] to address and navigate their choices ethically towards finding sustainable solutions to unsustainable problems.”

5.2.1 Discussion of research objectives 1 and 2

The WWN project was the result of those first two research objectives, which was a six-month learning journey experienced by 29 learners and eight teachers from six diversely different schools within the Western Cape of South Africa.

The theoretical framework was created through the review of literature from SD (section 2.2), ESD, ecoliteracy (section 2.3), and complexity theory and education (section 2.4), which were all integrated into what was called the “new moment” in Life Sciences education (section 2.5) (see figure 8). This approach to knowledge creation in the most general sense closely resembled the work around critical complexity (Cilliers & Preiser, 2010; Preiser, 2012; Preiser, Cilliers & Human, 2013) and therefore a further research question was formulated – if a critical complexity approach could be incorporated into a learning experience, what would the effect of this experience be on the thinking, values and knowledge of those who experienced it?

A critical complexity approach to knowledge creation was incorporated into a learning experience called the WWN project. What was significant about this was not so much the actual teaching and learning moments that were implemented to carry out this project, but rather that it was possible to integrate conventional education curricula, with transformative paradigms on knowledge creation, for ESD.

This is often referred to as “mainstreaming sustainability” within academic literature (Togo & Lotz-Sisitka, 2013) and has been incorporated successfully into various curricula in South African higher education institutions, bringing about educational reform (McGibbon & Van Belle, 2015; von Blottnitz, Case & Fraser, 2015). Too often, curricula are criticised for being too prescriptive, constrictive and therefore too resistant to rapid change and reform in meeting the demands of societies in transition. Yet the WWN project has shown that reform and transformation within mechanistic conventional education models is a real possibility (Montuori, 2014). In the case of this research, the WWN project engaged both teachers and learners, under the auspices of the CAPS Life Sciences curriculum, which may have set them thinking, knowing and then acting in a manner that promotes sustainability when addressing the challenges of the global polycrisis.

For clarification purposes, whether or not the participants of this experience eventually go onto being more mindful of the complexities of socio-ecological systems, which will make them enablers of the transitioning towards sustainable futures, this research has shown what is possible within conventional schooling. Research and funding, therefore, does not necessarily have to go into creating novel and often radical EE programmes and infrastructure.

Having said this, the research has also highlighted the drastic need for a refreshing new outlook and worldview within education, one that gives rise to complexity thinking, contextual thinking and ecological thinking. This may enable transdisciplinary teaching and learning to take form more organically and ethically, taking subjects out of their boxes, out of their classrooms and into context, bringing life to education, its meaning and importance to those who are still learning and not only to those who have learned.

Kate’s narrative from section 4.3.5 addressed this, in that within the conventional, Cartesian education system she has experienced, she struggled to marry her love for art and design with the sciences. Goethean observation and biomimicry were enlightening moments for her, in that she saw the space where more than one discipline merges. “Faced with the complexities of life, we all have to be artists in

some sense of the word. It is hoped that this will ... also make us better human beings” (Cilliers, 2000a: 32).

5.3 Discussion of Results from Research Objective 3

The crux of the research paper culminated into research objective 3, which asked the question whether having a better understanding of the interconnections within socio-ecological systems, and the importance and implications of context, would enable participants to address and navigate their choices ethically towards finding sustainable solutions to unsustainable problems.

There was little doubt that a six-month learning experience, such as the WWN project, would not have an effect on the thinking, values and knowledge of its participants. Therefore, the fundamental question of this research was about raising discussion around whether this integrative way of thinking might inform the type of knowledge and values needed to navigate ethically towards an epoch of sustainability?

Before this is discussed in more detail, it must be explicitly mentioned here that both self-assertive thinking and values, and integrative thinking and values, are essential aspects to all living systems, and that neither is intrinsically good nor bad (Capra & Luisi, 2014). What is unhealthy is an over-emphasis on either one of the tendencies while neglecting the other. This seemed to be what happened within science, society and specifically education systems over the past four centuries; integrative thinking and values were neglected to that of the self-assertive, and at the cost of our environment. Therefore, this research was an attempt to re-establish the healthy dynamic balance between the two.

5.3.1 Becoming critical complexity thinkers

The father of the Deep Ecology movement, Arne Naess, suggested that the “essence of deep ecology ... is to ask deeper questions” (Naess, cited in Capra & Luisi, 2014: 13). Becoming critical complexity thinkers meant a deeper level of questioning was engaged with by the participants, deeper questioning than most conventional Life Sciences classrooms would perhaps dare venture into.

Furthermore it is important to point out that complexity cannot be scripted or managed into existence (Davis & Sumara, 2008), therefore all that can be done is to create conditions that are conducive for critical thinking to emerge.

On reviewing the participants' feedback, it seemed that complexity as a way of thinking and viewing the world was infused at various levels within each participant, some deeper than others. Raani felt that the WWN project made her start thinking about complexity a lot more, and that *“one thing has an effect on another. Things are linked in life and we have to understand that our impacts, or one thing impacts on many other things.”* This statement clearly demonstrates that she understood to some extent the non-linear relationships and networks that exist within complex systems. Her next comment is connective in that it makes the cognitive leap, so to speak, in seeing that complexity thinking can be a potential framework for sustainability (Cilliers, 2008). She remarked that the solution to making the world a better place would be *“to get everyone to use complexity thinking, everything would be taken into consideration and this world would be more sustainable.”* Paradoxically, just as much complexity thinking is evident as is reductionist thinking in her final answer.

There was strong evidence from the results to suggest that the WWN project allowed for a deeper level of questioning and critical thinking to emerge. Ms L, in one of her earlier free writings reflected on what she had witnessed happening with the learners after the biomimicry workshop, saying: *“This project seems to be generating a level of questioning that I didn't think was possible.”* She was supported in saying this by one of her own learners, Eve, who remarked in her free writing: *“We not only need to answer the questions, but we need to question the answers.”* And so it was evident there was a profound level of thinking that emerged from the WWN project.

When learners are not only asking questions, but are also challenging the already known answers, the status quo, it means that they are beginning not only to think holistically, but they're also getting to a level that enables them to see and describe opposites when making knowledge claims, but thinking both at the same time (Preiser, Cilliers & Human, 2013).

5.3.2 Participating in the world: Sustainable ethics for sustainable futures

“I think people have the ideas that are there to change the world, to make our society better for everyone, but I think that people aren't willing to take those first unglamorous steps and take part in grassroots steps.”

– Cassy

So what are the implications for becoming a critical complexity thinker? Why does it matter having a better understanding of the interconnections within socio-ecological systems and the importance and implications of context? And did it make the participants navigate their choices ethically towards sustainable solutions?

It is acknowledged that this thesis has been somewhat biased towards the school of thought from the late Paul Cilliers when it comes to complexity literature. However, he did eloquently link complexity thinking to ethics, to the re-merging of ethics back into Science and a regaining of responsibility by humans for their actions. To acknowledge complexity is to acknowledge that any interpretation is a reduction in complexity, and so responsibility cannot be shifted away onto models and machines, it needs to be assumed by those who make their choices (Cilliers, 2000a,b, 2008; Heylighen, Cilliers & Gershenson, 2007; Cilliers & Preiser, 2010; Woermann & Cilliers, 2012).

It was mentioned earlier in section 4.5.2 that there seemed to be a movement away from conservation values towards a more action-orientated, participatory view of the world. It was clear from the analysis of the results that the movement towards integrative thinking, values and knowledge translated into an ethics of sustainability. Two aspects of this are worth further elaboration.

Firstly, there was a sense of sustainability and continuation of the participants' own projects; in other words, it didn't all end after the final presentations as three of the four project groups ensured that there was not only a legacy left, but that their groups actions would be continued after they were removed from the system.

Secondly, the participants' final group projects all involved some level of participation and action. This was not a requirement from the project instructions, nor from the

project assessment. They could have easily presented a theoretically-based project, having done background research on their contexts and presented potential solutions to the challenges of that context. However, whether it was starting a bee-keeping society, planting a garden, or initiating discussion and linking tuckshops up to vegetable gardens, there was an intrinsic need for action. Overwhelming data emerged to support this. Below is a brief list of some of the participants' answers to the final question of the WWN project, which was how do you want to be/participate in this world?

Becoming an active member in making the world a better place. – Adam

I want to see a change in perceptions on feminism and environmentalism in terms of activism and updated legislature to ensure that a just society is able to function in a sustainable way. – Cassy

Actively, with purpose and with greater meaning and sustainable impact. – Caleb

I would like to contribute to the well-being of our planet and the protection of its life forces. I want to make a change for the better; that is something the project taught me - how crucial change is and is something I want to be a part of. – Marie

It is through complexity in education that there is a rethinking of knowledge creation, a movement away from a representation of the world out there, towards engagement and participation in the world (Osberg, Biesta & Cilliers, 2008), which will equip learners to assume responsibility, become ethical decision makers, grounded “in place”, context and understanding; that problems may not ever be fully resolved, but sound judgment, or “phronesis³⁷”, is possible when navigating towards a sustainable future.

³⁷ From Greek origin, “phronesis”, is commonly used in philosophy as practical wisdom or sound judgement with practical elements (Oxford Dictionary, 2015b).

5.4 Conclusion: Towards a “New Moment” in Life Sciences Education

The key findings to this research can be summarised as follows:

- A critical complexity learning experience is possible within the CAPS Life Sciences framework, and was demonstrated through the creating and then the lived experience of the WWN project. It is important to note here that complexity cannot necessarily be managed into existence, but instead, conditions can be created to allow for it to emerge. Regardless, further “educational justification” (Osberg & Biesta, 2010: 2) was promoted within complexity theory in general.
- This research has provided an alternative complexivist approach to “mainstreaming sustainability” into secondary school level education (Togo & Lotz-Sisitka, 2013).
- There seems to be a need for creating opportunities where biomimicry practices and other forms of ecoliteracy, or ecoliterate approaches rather, are integrated into conventional education both at a secondary level and a higher education level.
- The WWN project had an effect on the thinking of its participants who moved towards more integrative ways of thinking. This included more holistic, synthesis, non-linear and intuitive ways of thinking.
- The WWN project had an effect on the values of its participants who demonstrated themes of conservation, both between participants as well as between participants and nature, cooperation, partnership and quality.
- The project also had an effect on the explicit-formal and informal knowledge typologies surrounding concepts of “Human Impact on the Environment” (Department of Education, 2011), SD and no doubt other content that was not specifically mapped in this research. It further highlighted the importance of engaging with “multiple ways of knowing” (Widhalm, 2011: 6).
- Other key themes emerged from the research analysis that included, diversity values, grit and resilience attitudes and contextual thinking.
- Furthermore, from the teacher narratives, pedagogy-specific themes emerged around the importance and implications of process learning over product learning and learner-centeredness.

In concluding the research done for this paper, it was shown that creating a critical complexity learning experience within a curriculum framework is possible, and that perhaps this may be the start of a transitioning towards a “new moment” in Life Sciences education. This translates not only into ESD, but also a complexity ethic – creating mindful youth who engage and participate in the world sustainably.

5.5 Limitations of Research

To initiate this section on the limitations to my research, I would like to acknowledge the assumption surrounding the “world of text” and the “reality of documents” (Bryman et al., 2011: 279). In a research paper that is about the complexity of a lived experience, it is somewhat ironic, in reduction of complexity, to attempt to convey this experience wholly through text. I therefore urge readers to combine their interpretation of this text with the short documentary film that was made on the WWN project, which can be watched on the WWN website³⁸. This may shed some “ambiance” (Chu, Strand & Fjelland, 2003: 20) onto the researched system and enrich the text.

This is related to the temptation to assume that this document reveals something “true about the underlying social reality” (Bryman et al., 2011: 279). The limitation of this research is that it does not and never will. However if taken in context, it may provide something transferable to other social realities.

Another identified limitation of this research was that it may be argued that using an existing framework on thinking, values (Capra & Luisi, 2014) and knowledge typologies (Fabricius, Scholes & Cundill, 2006) forms a bias in the interpretation of the narratives that emerged from the WWN project. However, as was pointed out in chapter 3, I used direct quotes and narratives in this paper where possible. This was intentionally done so readers would be able to form their own interpretation of the data and potentially identify blind spots and biases of the analysis.

Keeping with the PAR methodology, particularly the reflection part of the cycle, some of the limitations of the research methods were exposed by the learners in their

³⁸ WWN website: <http://workingwithnatureproject.weebly.com/>

reflections on the WWN project, and so I would like to give voice to these potential limitations. There was feedback that the biomimicry session was too short and that it could have been explored in more depth. Some participants thought that more reflections were needed throughout and the practical components of the project needed to be expanded on. And most appropriately, participants asked that provision for other languages, besides English, be made in the project.

My role, participation and often Northern perspective in this research, which is located in the global South, is duly recognised. This was hopefully tempered by the introduction of my own self-reflexive boxes throughout the writing of this thesis.

Finally, I do understand the multiplicity of variables that were being evaluated and that were at work in this research. However, as already explained in detail in section 3.2.3, this lack of control, potential over-generalisability and subjectivity was acknowledged both explicitly and implicitly throughout the paper, and should therefore not detract from the value of the research and its findings.

5.6 Recommendations for Further Research

Although action research tends not to incorporate any comparative studies (Stringer, 2014), it was intriguing to hear from the School D teachers who ran the WWN project with seven of their learners, while simultaneously running a “watered down” condensed version for the rest of their learners. According to Ms L, who commented on behalf of the learners from her own class, those who attended the WWN project had *“a far broader, more complex understanding of the system”*, whereas the girls who didn’t do the project *“got fixated on one system.”*

This reveals three main areas for further research. The one would be to move a similar type of critical complexity learning experience out of the PAR methodology and see the comparative effect on learners’ thinking, values and knowledge by introducing a control group that don’t explicitly get exposed to complexity theory, therefore situating it more firmly within a case study methodology. The second area would be to see how this kind of learning experience could be adapted to the seven weeks or 28 hours, as prescribed by the CAPS for the “Human Impact on the

Environment” section (Department of Education, 2011), and then analyse whether similar outcomes emerge. Finally, a mixed-methods approach could be applied to this research, combining qualitative and quantitative approaches, to see what impact projects, that are similar to WWN, have on the contemporary formative and summative assessments of learners in their schools.

However, perhaps what is most needed for further studies is to integrate ecoliteracy, complexivist and ESD approaches, both radical and transformative, within all structures and disciplines of current conventional education systems. This may be the most effective way of inducing structural changes that go onto create broader, whole system changes for a transition towards a future of sustainable, just and transformative education.

5.7 Final Reflexive Thoughts

Instead of placing my reflexivity within a box, I thought it fitting to finally conclude by bringing myself into the body of the research paper and to mention that the WWN project, the research and the thesis writing itself was not only transformative to those who were given explicit voice within the project, but also to me, the researcher and co-experiencer. I may not have provided sufficient light, within a written document, to the quality of learning that took place over the past six months, but I feel I gave life to interdependence and interrelationships, which are the very fabric of what learning is about.

Learning from cycles in nature and applying this to my own thoughts on this experience, I feel this is not the end, but rather the beginning of something new. The journey I have taken through this research has not taken me from the start and put me at the finish. Instead it has kept me in the original place, however I now see this place somewhat differently.

*“We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.”*

(Eliot, 1942)

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Appendix 1.1: WCED research approval letter



Directorate: Research

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REFERENCE: 20150130-42701

ENQUIRIES: Dr A.T Wyngaard

Mr Gerard Noel
Bishops Diocesan College
65 Campsground Road
Rondebosch
7700

Dear Mr Gerard Noel

RESEARCH PROPOSAL: TOWARDS A "NEW MOMENT" IN SCIENCE EDUCATION: FACILITATING CRITICAL COMPLEXITY THINKERS IN SOUTH AFRICAN SCHOOLS

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **01 February 2015 till 30 September 2015**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:
**The Director: Research Services
Western Cape Education Department
Private Bag X9114
CAPE TOWN
8000**

We wish you success in your research.

Kind regards.

Signed: Dr Audrey T Wyngaard

Directorate: Research

DATE: 30 January 2015

Appendix 1.2: REC approval letter



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Approval Notice Response to Modifications- (New Application)

11-Mar-2015
Noel, Gerard GV

Proposal #: HS1165/2015

Title: Towards a “new moment” in Science Education: Facilitating critical complexity thinkers in South African schools.

Dear Mr Gerard Noel,

Your **Response to Modifications - (New Application)** received on **09-Mar-2015**, was reviewed by members of the **Research Ethics Committee: Human Research (Humanities)** via Expedited review procedures on **11-Mar-2015** and was approved. Please note the following information about your approved research proposal:

Proposal Approval Period: 11-Mar-2015 -10-Mar-2016

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your **proposal number (HS1165/2015)** on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 218089183.

Appendix 1.3: Example of consent form



UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvenoot • your knowledge partner

STELLENBOSCH UNIVERSITY CONSENT TO PARTICIPATE IN RESEARCH

Towards a “new moment” in Science Education: Facilitating critical complexity thinkers in South African schools – TEACHERS

You are asked to participate in a research study conducted by Gerard Noel, BSc MedSci Hons (Human Genetics), PGCE (Life Sciences and Life Orientation), PGD (Sustainable Development) from the Sustainability Institute at Stellenbosch University. The results and knowledge gained from this study will contribute towards an MPhil thesis. You were selected as a possible participant in this study because your involvement, interaction and thinking during the **“Working with Nature”** workshops is invaluable to this study.

1. PURPOSE OF THE STUDY

The purpose of the this study is to see whether complexity thinking, which basically means thinking holistically, making interconnections, practicing reflexivity, acknowledging limitations and context is possible using the current Human Impact on the Environment curriculum as stipulated by CAPS (Curriculum and Assessment Policy Statement) as a framework through a series of workshops run by Teaching Biology Project (TBP) entitled “Working with Nature”.

2. PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:

Date	Time and Location	Action
TBC (ethics clearance dependent)	1 full day (08:00 – 16:00) @ <i>Bishops Diocesan College</i>	Participate in an introductory full day workshop for teachers and their participating learners where... <ul style="list-style-type: none"> • The project, journals, research and workshop dates and deadlines to all participants will be introduced • CAPS content (reductionism) on Human Impact on the Environment as prescribed by NCS will be covered • Participants will provide information on their expectations of project and what they hope to learn/achieve You will also reflect on the current state of world, the global "polycrisis"
13 – 14 March 2015	1 and half days <i>Busses depart and return from and to Bishops Diocesan College</i>	Participate in site visits to Rondevlei, Zeekoievlei, Cape Flats Waste Water Treatment, Coastal Park Landfill and Philippi Horticultural Area to immerse themselves into socio-ecological systems. Spend one night out at Rondevlei where... <ul style="list-style-type: none"> • Complexity theory and thinking will be introduced • The complexity of the socio-ecological systems being observed will be acknowledged • The importance of history (deep time), context (being in place), non-linear interactions, emergence, interconnectivity, self-organisation will be explained • The role/nature of science (theories and models) and its relationship with reality will be explored • You will reflect on complexity of socio-ecological systems
22 May 2015	½ day (14:00 – 18:00) @ <i>Bishops Diocesan College</i>	Accompany Learners to finding solutions to complex problems. <ul style="list-style-type: none"> • Be a part of a Biomimicry workshop "Learning from Nature"
April – August 2015	1 hour interview <i>Location to be discussed</i>	Be able to find a time and a date for a semi-structured interview reflecting on the process and project.
27 August 2015	½ day (15:30 – 18:30) @ <i>Bishops Diocesan College</i>	Participate and possibly help assess "Working with Nature" projects, assessments and evaluation of content and group are done. Reflection of project is incorporated into evaluation.
7 September 2015		Hand in and complete final "Working with Nature" project journal.

3. POTENTIAL RISKS AND DISCOMFORTS

During the workshops you may encounter the following risks and discomforts/inconveniences:

- **Lack of funding** for transport, food and accommodation.
During this study we will attempt to help facilitate you and your Learners (if applicable) where we possibly can. Food/eats will be provided during workshops and accommodation will be covered for overnight outing.
- **Timing and location** of workshops may be of an inconvenience.
During the introductory workshop we will try to our best ability to cater for all participants in the workshop in terms of timing. If location is an inconvenience, we will attempt to provide some form of transport for you and your Learners (if applicable).
- Access and use of certain **resources** (such as computers or internet connection) may be problematic.
Trained and professional advice and guidance will be given to you in helping you formulate innovative solutions for you to overcome any lack of resources that you may encounter. Furthermore, provision for certain resources will be made available to you if necessary.
- You potentially may not have time to participate or complete certain aspects of the project by the required **deadlines**.
Support will be provided in this regard by trained professionals and guidance and suggestions will be given to you so that you may overcome any obstacles that you may encounter during the project.
- Discussions that may occur during the workshops may challenge or even conflict with your personal **belief systems and values**.
Key to this workshop and study is diversity of value/belief systems and contexts. The project will be sensitive to this, allowing for equal and open communication and engagement from all participants no matter their circumstance or background. Various channels will also be created so that continuous feedback to the researcher and facilitators will be made possible.
- You may feel uncomfortable sharing your thoughts, ideas and feelings through the **journal and or interviews** that you will experience.
If you at any time would like to keep aspects of your participation in the workshop and study confidential and you would not like it to be a part of the study you will be allowed to communicate this and your confidentiality will be adhered to.
- You may feel uncomfortable being **filmed or photographed** during the workshops.
You will be given the opportunity to review, remove or edit any visual footage that is taken of you during the workshops, therefore respecting your right to confidentiality of information.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The research and workshops have many benefits both to you and to society as follows:

- You will be exposed to a rich teaching and learning environment with access to a variety of resources that will benefit your teaching and serve as a form of **professional development**.
- You will engage with **recent up to date information** and knowledge about the current state of the world in terms of human's interaction and impact on the environment.
- You will be able to use the tools and materials generated from this workshop going forward in your **own professions** (teaching careers etc.) and in your day to day lives.
- You will be able to use the **assessment tool** of the project as a school assessment as it will adhere to the guidelines proposed by the CAPS (applicable to teachers).
- You will gain insight into an alternative way of viewing the world (complexity theory), one which may potentially be beneficial and **transformative** for you personally and for society in moving towards a sustainable future, through science and education.

5. PAYMENT FOR PARTICIPATION

There will be no payment to you as a participant in this research.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will **remain confidential** and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of all information and data being captured and stored only by the researcher/co-workers. By signing this consent form, you allow aspects of this information (names included where needed) and other data such as that gathered by interviews and your journals to be used for the researcher's MPhil thesis, as well as for the NGO TBP to use it for evaluation and funding purposes. You have the right to review, remove or edit any audio- or videotaped data that may be used in the research.

If there is any publication of the results from the study to the broader public, you will be informed and you will have the right to remain anonymous in the study. Names and personal information will be altered to protect your disclosure.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact:

Principal Investigator:

Gerry Noel gnoel@bishops.org.za
+27 (0)73 641 6103 (personal cell number)

Research Supervisors:

Eve Annecke eve@sustainabilityinstitute.net
Robin Murray robin@fuelonline.co.za

TBP Director:

Cheryl Douglas cdouglas@bishops.org.za

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT

The information above was described to me by the principal researcher, Gerry Noel in English and I am in command of this language. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent voluntarily to participate in this study and I may request copy of this form at any time.

Name of Subject/Participant

Signature of Subject/

Date

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to _____
he/she was encouraged and given ample time to ask me any questions. This conversation was conducted in English and no translator was used.

Signature of Investigator

Date

Appendix 3.1: Introductory diagnostic questionnaire



Working with Nature 2015

Welcome and thank you for being a part of the Teaching Biology Project (TBP) “Working with Nature” project. Be prepared for the unknown and enjoy the stimulating journey that lies ahead.

For us to understand what you expect and what resources you currently have access to, please can you start off by answering the questions below as thoroughly and thoughtfully as possible.

Please note that this information may be used for research purposes.

Name: _____

School: _____

Email: _____

Cell number: _____

I own (mark all that apply please):

Cell phone that can access the Internet and email	Cell phone that cannot get Internet and email	Desktop computer	Laptop	Tablet
---	---	------------------	--------	--------

As a teacher/learner, I have access to use the following:

Desktop computer	Laptop	Tablet	Data projector	Cell phone	Internet	None of these
------------------	--------	--------	----------------	------------	----------	---------------

I have access to the Internet

At school: YES	At Home: YES	On my cell phone: YES
At school: NO	At Home: NO	On my cell phone: NO

I have an account for or can utilise the following (make a X in the appropriate boxes):

Email	WhatsApp	Twitter
Google Plus	Dropbox	One Drive
Blogger/other blog site	Instagram	Facebook
Skype	Facetime	Hangouts
SMS	None	

Sit by yourself quietly and consider the questions below. Answer the questions in the blank spaces and pages provided. Thank you!

1. Why are you here?
2. What do you expect from the "Working with Nature" project going forward?
3. What do you understand about human impact on the environment?
4. What do you understand about sustainable development?
5. Does what you know NOW about human impact on the environment play a role in what you really think or do? If yes, explain how it impacts?
6. What is your solution to making the world a better place? Human well-being and sustainable development being important in that better place.
7. How do you want to be/participate in this world?

Appendix 3.2: Post-project questionnaire



Working with Nature 2015 – Post questionnaire

Name: _____

Over the past five and half months you have been involved in the Working with Nature Project

Please can you complete your involvement by answering the questions below as thoroughly and thoughtfully as possible.

Please note that this information may be used for research purposes.

Sit by yourself quietly and consider the questions below. Answer ALL the questions in the blank spaces and pages provided.

1. In one word, how do you feel about the project you just did?
2. Was this project what you expected? **If no, explain how it differed from your expectations.**
3. What suggestions do you have to improve the project going forward?
4. What do you understand about human impact on the environment?
5. What do you understand about sustainable development?
6. Does what you know NOW about human impact on the environment play a role in what you really think or do? If yes, explain how it impacts?
7. What is your solution to making the world a better place? Human well-being and sustainable development being important in that better place.
8. How do you want to be/participate in this world?

Appendix 3.3: *Working with Nature* project instructions

Working with Nature Project

There are five topics within this section of work:

- **The atmosphere and climate change**
- **Water**
- **Food Security**
- **Loss of Biodiversity**
- **Solid Waste Disposal**

As a team (collaborating with another school) you will investigate how to:

- reduce the carbon footprint(atmosphere and climate change),
- reduce water usage (water quality and availability),
- reduce food wastage and increase use of local and seasonal food (food security).
- use indigenous plants (biodiversity loss)
- reduce waste (solid waste management)

CHOOSE a MINIMUM of THREE of the five topics mentioned above and apply to a particular context you decide to explore with your group.

- For example a household, a school/boarding house, a local business/organisation to which one of you have access.
- You and your partners will be presenting to your peers, teachers, invited guests from the City of Cape Town and schools your project.
- A select few will have the opportunity to present to the Junior City Council and possibly have a meeting with Helen Zille.
- Your presentation may take any format (movie, webpage, a short drama play) and we'll figure this out together over the next few months
- In your presentation you will need to:
 - Give background information on the topics you are covering with your selected context (See Addendum A on "Resources" folder on flashdrive)
 - State the causes of the problem(s)and consequences of not dealing with it effectively
 - Acknowledge the complexity of the system that you're engaging.
 - Propose viable recommendations and solutions; keeping in mind the 3 pillars of sustainability - environment, society and the economy - the 3 P's: People, Planet, Profit (think biomimicry)

ALL MUST BE RELATED DIRECTLY TO THE CONTEXT YOU HAVE CHOSEN.

Appendix 3.4: Project dates and deadlines

Dates and Deadlines

Date	Action
13 March 12:00 – 18:00 @Bishops	Working with Nature Introductory workshop with teachers and learners. <ul style="list-style-type: none"> • Learners and teachers expectations of workshop • Covering the content: Human Impact on Environment • Case Study: Planetary boundaries • The how, what, why, where of the project and research • How to keep a record of the project (free writing) • Tying it all together and reflection (video sessions) • Schools to pair up. 3 -5 learners per school
14 March 15:00 – 17:00 @Bishops	Complexity of socio-ecological systems with teachers and learners <ul style="list-style-type: none"> • Using case studies, games and PPT to illustrate complexity of systems.
15 March 09:30 – 16:00 @ Bishops	Exploring Human Impact on the Environment in the context of False Bay Ecology Park and visiting: <ul style="list-style-type: none"> • Rondevlei Nature Reserve • Pelican Park Housing Development • Zeekoevlei • Philippi Horticultural Area • Coastal Park Landfill • Cape Flats Waste Water Treatment Works <p>Reflection on complexity of above contexts and begin exploring possible contexts for your own project.</p>
April – August Times and locations to be discussed	Show and tell what you have been doing – researching a problem associated with Human Impact on the Environment in your own context (home, school, community) <ul style="list-style-type: none"> • Your team will be visited for any queries or help with the project. • Help given with reflective writing.
22 May 14:30 – 17:30 @Bishops	Learning from Nature to think up solutions to complex problems: biomimicry
15 August 10:00 – 16:00 @Bishops	Help with presentation of project in the format that you choose (movie, website, dance, play)
3 September 15:30 – 18:30 @Bishops	Final Presentation date

Reflective writing

- 10 min every week. Think about the project and free write. (+- 25 reflections)
- Time yourself.
- Method of handing in to be discussed.

Appendix 3.5: *Working with Nature* reflection questionnaire



Working with Nature 2015 – Introductory Workshop **Reflections**

Name: _____

Give us your feedback and reflect on the day by answering the following questions in the blank spaces below:

1. What worked well during the session?
2. What didn't work well during the session?
3. What did you learn about human impact on the environment?
4. What did you learn about yourself?
5. What did you find to be easy?
6. What did you find to be difficult?
7. Anything else you want to reflect on?

Appendix 3.6: List of resources on flash drive

- Addendum A supporting project instructions
- Aldo Leopold's *Thinking like a Mountain* electronic chapter
- CAPS "Human Impact on the Environment" PowerPoint
- Cautionary Tale: systems thinking video clip
- Complexity in Lake Victoria case study
- Complexity theory PowerPoint
- Fossil Fuels in 300 seconds from Post Carbon Institute video clip
- George Monbiot's *How Wolves change Rivers* video clip
- Goethean Observation activity
- Hubert Sauper's *Darwin's Nightmare* video clip
- National Geographic 7 billion population video clip
- Observation note taking activity for False Bay Nature Reserve
- *Planetary Boundaries* article
- Rapid Sensing and Sound Mapping activity
- Research consent and assent form copies
- Richard Feynman's Curiosity and Beauty video clips
- Smart Cooking presentation by Fahmieda Barends
- Stephen Harding *From Gaia Theory to Deep Ecology* article
- Sustainable Development PowerPoint
- Useful information document
 - Including researcher contact details
 - Link to WWN Facebook page
 - List of useful and interesting websites
- WWN diagnostic questionnaire
- WWN project instructions
- WWN reflection questionnaire

Appendix 3.7: Complexity in Lake Victoria case study

CASE STUDY - Complexity in Lake Victoria

Below is a paragraph taken from an article written by Dominique Chu et al. (2003) *Theories of Complexity: Common Denominators of Complex Systems*. It provides a brief account into the ecological and economic devastation caused by the introduction of the alien fish species, the Nile Perch, into Lake Victoria in the 1950's. In a limited way it demonstrates the knock-on effect (non-linear result) from disturbing one aspect of a complex socio-ecological system. In this case study, the context is a lake bordered by three African countries: Uganda, Tanzania and Kenya which brings up questions of politics. The environment refers to the ecosystem (both abiotic and biotic factors), the society involved in this case study are those that live around the lake and beyond and the economy that is embedded (situated) within that society as well as the European economy and society as most of the Nile Perch was caught, filleted and sent to markets overseas.

Read the case study below and supplement this text with clips from Hubert Sauper's 2004 award winning documentary *Darwin's Nightmare*.

The example we have chosen is the, among ecologists, rather well known case of the introduction of an alien predator species—the Nile perch—into Lake Victoria, the second largest freshwater lake in the world. Prior to the introduction of the Nile perch there were more than 300 different species of cichlid fish in Victoria, mainly of the genus *Haplochromis*. These species were genetically very closely related to one another, but nevertheless they represented a broad spectrum of different survival strategies. It appears that they quite recently (possibly not more than 15,000 years ago) began to fan out into different ecological niches with different food sources such as insect-larvae, detritus, scales of other cichlid fish, and many more. Before the introduction of the Nile perch, they comprised about 80% of the biomass of the lake. Although the fauna of Lake Victoria was highly interesting and special from an ecological and evolutionary point of view as it represented evolution in action, it was not so from an economical point of view. The cichlid fish, though abundant, were rather small and bony, and thus not ideal for exploitation by commercial fishing and export trade. It was desirable to introduce a bigger fish such as the Nile perch. As one can easily imagine, the introduction of such a large predator will have an enormous impact on the ecosystem and is likely to transform its structure. Over the rather short period of their evolutionary development into the various species, the small cichlid fish did not have to adapt to large predators (since there were none in Lake Victoria) and were rather defenseless to the threat the new species represented. Therefore, the fears and expectations among ecologists were that after an initial explosive boom of the perch population, the cichlid fish would quickly be driven into extinction, which would leave the Nile perch without food and cause its own disappearance. The net result might be a radical impoverishment, even a collapse, of the eco-system, and a total disruption of the fishing activity.

The first consequence followed as predicted. The Nile perch population really boomed and drove the cichlid fishes to the edge of extinction. But then the unexpected happened: Nile perch in open waters continued eating fish until there were virtually none left. But where were the thousands of starving Nile perch floating moribundly on the water's surface? Why hadn't their number declined rapidly? Why had the predicted collapse of the Nile perch population not taken place? Rather surprisingly, the Nile perch did not follow the cichlid fish into the extinction but settled on a sustainable population number, because the disappearance of the cichlid fish produced unforeseen side-effects favorable to other species in the lake. The fresh water prawn, for example, used to be a rather marginal player in the eco-system, at least with

respect to population numbers. With the disappearance of the detritus eating species of the cichlid fish, a niche opened for the prawn to occupy; in consequence the prawn population increased dramatically. The Nile perch, in turn, facing a shortage of cichlid fish, incorporated the prawn into its diet¹. Other species, such as the indigenous sardine, the dagaa, adapted in similar ways to the new situation, and took over some of the ecological niches the cichlid fish had before. Note that the increase of the prawn and the dagaa was not only a result of the disappearance of a competitor for food, but a genuine adaptation to a previously neglected food source. We stop at this point of the succession of events to conclude that the result of the introduction of an alien species into the ecosystem of Lake Victoria was its complete and unexpected transformation.

This article summarises one small consequence of introducing the Nile Perch. The documentary film *Darwin's Nightmare* provides evidence of further massive social impacts of introducing the fish, namely: the importing of weapons to supply to neighbouring states who were in civil war, an increase in risky behaviour such as prostitution and self-harming actions (young homeless children have been documented burning Styrofoam and other packaging and inhaling the toxic fumes), a decrease in local food security and an increase in health issues such as HIV and AIDS.

Table summarising the consequences and their interconnectedness to the topics from the Human Impact on the Environment content.

Atmosphere and Climate Change	Food Security	Loss of Biodiversity	Solid Waste Disposal	Water
There was an increase in the number of commercial fishing factories, trawlers/motorised boats, aeroplanes for transport and mechanised fishing equipment which all have an impact on the demand for fossil fuels and energy. The burning of these fossil fuels in turn pollute the atmosphere and have an impact on climate change.	Although there was enough food, particularly protein, to feed the local population before the Nile Perch was introduced, this rapidly changed as the fish that was caught by commercial fisherman was mainly exported to European markets leaving the local populations without a nutritious protein source, increasing food insecurity.	The loss of biodiversity due to the Nile Perch was immense as it drove the much of the diverse cichlid population into extinction. Biologist E. O. Wilson called this event "the most catastrophic extinction episode of recent history.	The packaging and waste products from the fishing factories were dumped along the lake shores which polluted the soils and the water sources.	The water of Lake Victoria became polluted, turbid (murky) and oxygen starved due to algal blooms and an increase in other producers in the lake ecosystem. This impacted negatively on the water quality of the lake.

¹ There is also evidence to suggest that the Nile perch became cannibalistic and began feeding on smaller perch.

Appendix 3.8: Goethean observation activity

Working with Nature: Goethean observation of plants

Name: _____

Purpose:

To “**quieten your cleverness**”, improve your observation skills and to appreciate what you can learn FROM nature and not only ABOUT nature.

Action:

- Go and find a particular plant that draws your attention.
- Sit down next to this plant. Be still, quiet, and present in-place (meaning don't think about anything else and clear your head).
- Really look at your plant, observe it for 5 minutes.
- Jot down any **SCIENTIFIC** thoughts, ideas, words or comments that come to mind while you are observing your plant (Use the space below).
- Look at your plant again for another 5 minutes.
- Now try and describe your plant **CREATIVELY** or artistically for 5 minutes. You can do whatever you wish to. You can draw your plant (try draw your plant without looking at your page), you can write your plant a poem, you can sketch, you can sing to your plant.
- Finally, spend the last 5 minutes looking at your plant again, but now get close. Touch your plant, feel the leaves, the stem. Don't pull the plant out! Try and imagine what it would be like to **BE that plant**.

Some questions for discussion:

1. How did you find this experience?
2. What did you observe **scientifically**?
 - a. How does a plant function?
 - b. How do the different organs function?
 - c. Why does a plant function the way it does?
 - d. How is the plant structure suited to perform its functions?
3. How did you observe your plant **creatively**?
 - a. What senses did you mostly use?
 - b. What did you sense in particular?
4. What was it like **being** your plant?
 - a. Did you notice anything about your plant in terms of where it was situated?
 - b. What was your plant doing in the place it was situated?
5. What was it like moving from a scientific description of the plant to being the plant?
6. What can you tell the class **about your plant**?
7. What have you learnt **from your plant**?

Appendix 3.9: Rapid sensing and sound map activity

Working with Nature: Rapid Sensing and Sound Map

Name: _____

Purpose:

To “quieten your cleverness”, improve your observation skills and to appreciate what you can learn FROM nature and not only ABOUT nature.

Action for rapid sensing:

- For 5 minutes make a list of as many spontaneous observations that you can manage about the environment around you using all your senses.
- When the time ends, look back at your list.
 - How many observations did you list in total?
 - What senses did you use for each observation (sight, touch, feel, smell, hear) – write these down next to each observation.
 - Are the totally random or are they related/interconnected?
 - Do you have a tendency to notice certain things about the environment around you or rely on a particular sense?

Action for sound map:

- For 5 minutes close your eyes and listen.
- With your writing material in front of you and still keeping your eyes closed, create a symbol, or write a word to represent each sound that you hear.
- Using these symbols, make a map of the sounds you hear all around you, in all directions.
- Are these sounds related or responsive to each other?

Use the spaces below and on the back of this sheet to complete this activity.

Appendix 3.10: Working with Nature final rubric

Date: _____

Supervisor/Teacher: _____

Name(s): _____

PHASE A: Understanding Phase					
Background information; knowledge and understanding of subject and concepts	Very wide range of reading/information researched on context; used reliable sources; sophisticated appreciation of broader intellectual frameworks; critical engagement with various forms of literature/information.	Broad range of reading/information and source materials; use of reliable sources; engagement with broader intellectual frameworks; critical engagement with relevant literature/information.	Good range and use of suitable reading/information; some relevant areas may be lacking in coverage but there is critical engagement with what is presented.	Acceptable range of reading/information and source materials; shortcomings in terms of coverage but there is clear understanding of relevant literature/information.	Inadequate range of reading/information and source materials; little or no understanding of broader frameworks and relevant literature/information.
Composition and structure of context	Argument is logically structured from beginning to middle to end; narrative is entirely coherent throughout. The where? Who? What? How? And challenges are excellently addressed.	Argument is logically structured but at times links and steps not made explicit; narrative is coherent but may lack clear substantiation here and there. The where? Who? What? How? And challenges are well addressed.	Argument has some gaps and too many links left out; narrative does not progress entirely logically. The where? Who? What? How? And challenges are adequately addressed.	An attempt to structure an argument is evident but not entirely successful; narrative does not progress logically. The where? Who? What? How? And challenges are addressed but with many gaps.	No argument is evident; narrative is illogical and incoherent. Most of the where? Who? What? How? And challenges are not addressed.
Understanding of complexity of chosen system	Very deep understanding of the complexities of their chosen system is demonstrated. The interconnectedness of their Human Impact of the Environment topics is emphasized and the boundaries, uncertainty, richness and emergence of their system is acknowledged.	A good understanding of the complexities of their chosen system is demonstrated. The interconnectedness of their Human Impact of the Environment topics is well acknowledged and the boundaries, uncertainty, richness and emergence of their system is acknowledged.	An understanding of the complexities of their chosen system is demonstrated. The interconnectedness of their Human Impact of the Environment topics is somewhat acknowledged and an attempt to acknowledge the boundaries, uncertainty, richness and emergence of their system is made.	A limited understanding of the complexities of their chosen system is demonstrated. The interconnectedness of their Human Impact of the Environment topics is barely acknowledged and the boundaries, uncertainty, richness and emergence of their system is not acknowledged.	No understanding of the complexities of their chosen system is demonstrated. The interconnectedness of their Human Impact of the Environment topics is not acknowledged and the boundaries, uncertainty, richness and emergence of their system is not acknowledged.
Referencing	Consistent; conforms to an accepted academic style, with no mistakes.	Not entirely consistent; shows ability to conform to accepted academic style.			Absent, inconsistent, or is not in appropriate format to conform to accepted academic style.
Comments:					

PHASE B: Application Phase					
Application of background information to context	Choice of extremely relevant case study/application; Coherent and logical linkage to phase A; Connective comprehension of project is shown by informed analysis; Very good to outstanding application of theory to practice.	Choice of relevant case study/application; Coherent and logical linkage to phase A; Connective comprehension of project is shown by informed analysis; Good application of theory to practice	Choice of relevant case study/application; some evidence of coherent and logical linkage to phase A; Some connective comprehension of project is shown by informed analysis Competent application of theory to practice (but room for improvement)	Choice of inappropriate case study/application; some evidence of coherent and logical linkage to phase A; Very little connective comprehension of project is shown by informed analysis Weak application of theory to practice	Choice of inappropriate to irrelevant case study/application; no coherent and logical linkage to phase A; No connective comprehension of project is shown by informed analysis No real application of theory to practice
Critical thinking	A rich understanding is demonstrated by the ability to effectively communicate and demonstrate sound reasoning. Any challenges/problems are identified and approached in a thoughtful, reflective and innovative way.	A good understanding is demonstrated by the ability to effectively communicate and demonstrate sound reasoning. Challenges/problems are identified and approached with good understanding.	Demonstrates an understanding of the system being explored and is able to identify and ask significant questions. Challenges/problems are identified and approached with an adequate understanding.	Limited understanding of the system being explored results in poor communication of reasoning. A few Challenges/problems are identified but are not approached in a thoughtful, reflective and innovative way.	Follows directions without understanding the purpose. Does not process information to develop new ideas for the system being explored.
Biomimicry principles applied	Conclusions are not jumped to but rather deliberated, deep understanding of biology is explored and recommendations/solutions attempt to create conditions conducive to all of life's systems flourishing.	Not all conclusions are not jumped to and some thought and deliberation has gone into making them. Good thinking has gone into the biology behind the chosen systems and recommendations/solutions attempt to create conditions conducive to most of life's systems flourishing.		Broad sweeping conclusions and generalisations are made with very little thought or understanding given to the biology behind the chosen systems. Recommendations/solutions are short-sighted and are not conducive to most of life's systems flourishing.	
Comments:					
PHASE C: Reflexive Phase					
Have the writers brought him/herself into the story?	Exceptional effort made to bring him/herself into the story in a subtle but concrete way.	Good efforts made to bring him/herself into the story, but possibly either over- or under-done.	Some evidence that the author has attempted to connect his/her own experience to the story, but this has not been done in a way that reinforces the project.	Little evidence that the members made any effort to bring him/herself into the story	No evidence that the members made any effort to bring him/herself into the story
Journal – Personal Reflections/free writing.	Exceptional personal reflections & evidence of learning, critical insights, honesty and coverage of intellectual, emotional and physical experiences by use of images, poems, drawings	Very good personal reflections & evidence of learning, some critical insights, honesty and coverage of intellectual, emotional and physical experiences by use of images, poems, drawings	Some personal reflections and some evidence of learning and critical insights (more than 1 page)	Very little effort and evidence of learning and critical insights - mostly a list of happenings (1 page or less)	No effort and little evidence of learning and critical insights (less than 1 page)
Comments:					

PHASE D: Communication Phase					
Communication	Communication skills are superior and demonstrate effective, oral, language, listening and comprehension. There is clear and concise substance in their communication of their research project and context. Management and implementation of communication tools used (technology, props, visuals, speech, drama) was excellent	Communication skills are good and demonstrate effective, oral, language, listening and comprehension, however group spoke around their project and so presentation lacked some substance. Management and implementation of communication tools used (technology, props, visuals, speech, drama) was well done.	Communication skills are adequate. Management and implementation of communication tools used (technology, props, visuals, speech, drama) was good.	Communication skills are below average; improvement needed in oral, language, listening and comprehension skills. Management and implementation of communication tools used (technology, props, visuals, speech, drama) could have been better.	Communication skills are poor and there are major gaps in the oral, language, listening and comprehension skills. Management and implementation of communication tools used/not used (technology, props, visuals, speech, drama) was poorly executed.
Questions handled & Time Management.	Communication of project provokes interesting discussion/questions from audience. Questions are well answered and time management skills are exemplary.	Communication of project provokes good discussion/questions from audience. Questions are well answered and time management skills are good.			Communication of project provokes very little discussion/questions from audience. Questions are not handled well or time management was problematic.
Comments:					
Overall					
Creativity, resilience & originality	Outstanding and notable creative insights and original thoughts derived from an in-depth understanding of the material. Team was willing to take chances/risks or able to adapt to changes/issues that they experienced.	Some creative suggestions and thoughts based on an in-depth understanding of the material, but these thoughts lack clarity or depth. Team took some chances and were able to adapt to changes/issues that they experienced.	Demonstrates a potential for creative and original thought, but either through lack of effort or inadequate grasp of basic material, this potential has not been tapped.	Minimal evidence of any creative effort to generate original thoughts or ideas	No evidence of any creative effort to generate original thoughts or ideas. Team struggled to adapt to changes/issues that they experienced.
Language and clarity of expression.	Narrative throughout is very fluent and clear; shows high ability to express theoretical material, reliable evidence and analysis.	Narrative is very clear; an attempt is made to express theoretical material, empirical material and analysis but certain concepts not clear enough.	Narrative or storyline is evident but needs further development; theoretical and empirical material and analysis are not always successfully expressed.	The nature of the storyline/narrative is not clear; ideas may be uncritically reported rather than analysed.	Storyline is unclear, ill-informed or unfocused; material presented is irrelevant or has not been understood.
Team cohesion, collaboration and participation	Team cohesion is explicitly evident and honest; collaboration skills are solid and initiative is taken in improving the team with sensitive and informed choices. Genuine understanding of team members is apparent and conflict management was superior.	Team cohesion is evident and honest; collaboration skills are good and initiative is taken in improving the team with sensitive and informed choices. Genuine understanding of team members is apparent and conflict management was good.	Team cohesion is not explicitly evident; collaboration skills are good and some initiative is taken in improving the team with sensitive and informed choices. There is some understanding of team members.	Team cohesion is not explicitly evident; collaboration skills are below average there was a very little understanding of team members and their attributes;	Team cohesion is not explicitly evident; and very little to no collaboration was undertaken by members; each member did their own thing and disregarded others in the team. Conflict was evident and not dealt with sensitively or effectively.
Comments:					

- d. Referencing

- e. Application of background information to context

- f. Critical thinking

- g. Biomimicry principles applied

DISCOVER

3. Think of as many (minimum of three) great moments and experiences you have had over the past 5 months with regards to your project. Were there any exciting meetings? What were the moments that you felt like you made some progress in the project? What was fun or interesting about your project? What made those experiences so great?

Appendix 3.12: Final video reflection



Working with Nature 2015 – FINAL video reflection

Instructions:

- You have a max of 2 min ONLY.
- You may not stop and start recording again – don't worry you can't make any mistakes.
- Consider the following and when you are ready start recording your video "selfie" by answering them.
- Save the file as your FIRSTNAME onto the desktop of the computer.
- Please note these videos may be used for research purposes.

You have been a part of the Working with Nature project for the past five and a half months – how has this impacted...

1. you as a person,
2. your understanding of local and global issues and
3. your understanding of complex systems/problems

Be **HONEST** and **YOURSELF** – there are **NO RIGHT** answers.

Appendix 3.13: Post project teacher semi-structured interview



Working with Nature 2015 semi-structured teacher interview and questionnaire

Name: _____

Over the past five and half months you have been involved in the Working with Nature Project.

Please consider the following questions and answer them as honestly and thoroughly as possible. The interview will take no longer than 30 minutes.

Please note that this information will be recorded and may be used for research purposes as per the consent forms you have signed for the project.

Teacher related questions:

1. What has been your approach to teaching Human Impact on the Environment before you did the *Working with Nature* (WWN) project?
2. Did the WWN project change your approach of teaching this section? If so, how?
3. Has your understanding of complexity had an impact on question 2? If so, how?
4. How has the WWN project impacted on your teaching in general? (Consider all aspects of teaching, not necessarily this section of work).
5. What aspects of the WWN project do you think you will be able to adopt into your classroom going forward?

Learner related questions:

1. What do you think your learners have gained and learned from this project?
2. Do you think that they would be able, having experienced the WWN project, to answer CAPS content based questions from the exam guidelines and questions on case studies on this section of work?
3. Have you noticed anything different in your learners since the WWN project? (Think about any changes to their skills, attitudes, values and thought processes that you may have picked up).

General questions:

1. What other stories would you like to share regarding the WWN project?

Appendix 3.14: Appreciative inquiry process I



Working with Nature 2015 – Appreciative Inquiry Process

Name: _____

Name of person you interviewed: _____

Date: _____

Find a partner and ask them the questions below and listen intently – resist the urge to speak/answer their questions for them. Roughly jot down their answers in the spaces below, write enough information so that you can retell their “stories” and answers to the rest of the group. Spend 5 minutes interviewing each other and then get together in your group and spend 10 – 15 minutes telling the group about the amazing ideas, thoughts and stories you heard from your partner.

DEFINE

1. What do you want to achieve or do in this project? What is your idea of a great project and presentation?

2. What do you do well and what can you bring to this project and group (Don't be shy)?

DISCOVER

3. Think of as many (minimum one) great moments, experiences or even ideas that you have come across in your life where sustainable solutions were being implemented. Something that was perhaps innovative, that helped society and promoted/conserved the environment. What where they? Why were they sustainable? What made them so great/innovative? How did they benefit the environment? How did they make you feel?

4. If you thought of more than one great moment, experience or idea. What did they all have in common?

DREAM

5. Imagine a sustainable future? What would it look like? How would people live? What would they have that made them to live sustainably? What would the natural environment look like? Would people be happy?

DESIGN

6. What can you think of doing in your homes, schools, communities that would help you towards creating the sustainable future you dreamed of above? What can you do? How would you act? What can you design and create? Who can help you?

Appendix 3.15: Further consent and review of data



UNIVERSITEIT • STELLENBOSCH • UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY CONSENT TO PUBLISH/DISSEMINATE DATA FROM PARTICIPATED RESEARCH

Towards a “new moment” in Science Education: Facilitating critical complexity thinkers in South African schools

Dear [NAME]

Over the past year, you were involved and gave consent to be a participant in this research on a learning experience called the *Working with Nature*.

The data that emerged demonstrated that the project was a positive “lived experience” by all those involved. From this data that was collected, from free writings, questionnaires, video footage, workshop activities, you were quoted saying the following:

Quote 1:

“It [the stadium] is a very controversial issue to work around, because we also have to consider long term issues that might arise from our very own implementations.”

Quote 2:

“I feel like that we understand each other and we are all wanting to achieve the same goal.”

Quote 3:

“Everyone has their opinion on everything.”

Quote 4:

“I got to be the plant and that taught me how a plant actually adapts to different temperatures and aspects.”

Quote 5:

“...the importance of nature and plays a role in how people feel in nature.”

Do you allow, the principal researcher Gerard Noel (see details below) to use...

- quote(s) stated above,
- first names where relevant,
- pictures taken from workshops which have all been uploaded onto Working with Nature website and Facebook page,
- *Working with Nature* short film footage, which you have already seen at the final presentation day on the 03 September 2015.

In his MPhil thesis write-up, other academic publications and any further dissemination (communication) of research?

1. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact:

Principal Investigator:

Gerry Noel gnoel@bishops.org.za

+27 (0)73 641 6103 (personal cell number)

2. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT

I hereby consent after review, to allow for the above information to be used by the principal researcher Gerard Noel in his thesis write-up, academic publications and any further dissemination (communication) of research.

Name of Participant

Signature of Subject/

19 October 2015

Date

SIGNATURE OF INVESTIGATOR

Signature of Investigator

19 October 2015

Date