Developing an ecological approach to science teacher education

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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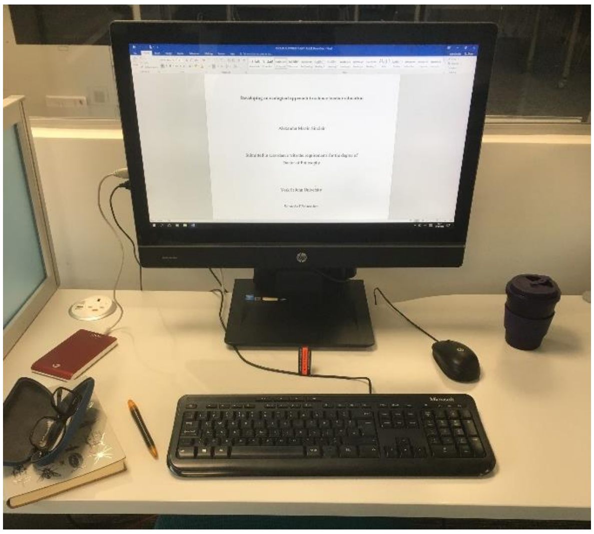

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Abstract

This thesis documents the research I have undertaken as a science specialist in a teacher training institution in higher education. It details the epistemological transformation I have undergone in coming to claim that I have developed an ecological approach to science teacher education.

The thesis contends that the improvement of planetary well-being needs to be premised upon developing a way of thinking which is antithetical to the dominant technical rational form of logic and epistemology adopted by much of the western world. I propose that a particular perception of science, and the forms of knowledge it can generate, has played a role in promoting these epistemologies. The thesis suggests an approach to science teacher education which demonstrates that science is an ecological act is necessary; one which can highlight the importance of understanding the relational, dynamic and provisional nature of knowledge.

I also recognise that the manner in which education is undertaken is as important as what is taught and suggest that the development of mutually respectful educational relationships are necessary for developing ecological epistemologies.

The action research methodology adopted for the study reflects the transformational nature of knowledge generation by charting the two action-reflection cycles undertaken throughout the research process.

Through this research, and consequently by defining an ecological approach to science teacher education, I have been able to articulate and theorise the manner in which I live out my practice. In doing so I suggest that I have provided an explanation of my pedagogy which demonstrates the interrelated nature of values, curriculum, and the way in which I taught.

The thesis provides suggestions for science teacher educators and science teachers that may help in reconceptualising science which may contribute to developing a way of thinking and working that is necessary for improving planetary well-being.

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Abbreviations

BA – Bachelor of Arts

BERA – British Educational Research Association

CARN – Collaborative Action Research Network

DCSF – Department for Children, Schools and Families

DfE – Department for Education

DfES – Department for Education and Skills

GCSE – General Certificate of Secondary Education

ITE – Initial Teacher Education

ITT - Initial Teacher Training

NFSS – National Framework for Sustainable Schools

NQT – Newly Qualified Teacher

QTS – Qualified Teacher Status

STEAM – Science, Technology, Engineering, Art and Mathematics

STEM – Science, Technology, Engineering and Mathematics

UK – United Kingdom

UNESCO – United Nations Educational, Scientific and Cultural Organisation

Introduction

This thesis documents the practitioner-based doctoral study I have undertaken as a science specialist in a teacher training institution in higher education. The research was conducted from October 2011 to May 2017 in collaboration with two cohorts of students and took the form of two action research cycles, which are set out below as Cycle 1 and Cycle 2, each with a different focus and content.

The key focus for this thesis is the epistemological transformation I underwent throughout the process of conducting the research. In charting my progress I will show how my views of science and of the purpose of science education have evolved and how my practice has changed because of this new understanding. This research and development of my thinking have led to my claim to knowledge that I have developed an ecological approach to science teacher education.

To commence this report I will outline how my concerns about planetary well-being led to the original focus for the enquiry. The belief that I could work with the students to influence both their professional and personal lives resulted in the formation of my initial research question which was; ‘How can a curriculum for ecoliteracy be developed with starting teachers?’ I will explain how the relative lack of success in this approach was premised upon a particular non-ecological way of thinking. I will suggest that non-ecological thinking is characterised by linear epistemologies and that this can be attributed to a western worldview which rarefies a particular perception of science as dealing with absolute truths. I will describe how my experiences, as a student and as a teacher of science in schools, were influenced by this prevalent worldview and how this subsequently resulted in my creating a curriculum for ecoliteracy which mimicked and replicated the orthodox way of schooling to which I was accustomed.

Critical analysis of the lack of success of the curriculum for ecoliteracy was a destabilising cognitive process and helped me to identify that the focus of Cycle 1 of my research had mainly been confined to raising awareness about the planetary crisis alongside providing teaching activities for the students to use in school. It also highlighted the tensions I felt while introducing the curriculum based on my own belief system and preoccupation which were not necessarily congruous with those of my students.

While developing a curriculum for ecoliteracy I had not fully understood Sterling’s (2001) assertion that any learning about planetary well-being within the current mechanistic educational paradigm is likely to achieve little. I appreciated that the work with these students during this cycle had, in part, helped to reproduce a particular non-ecological way of thinking which would further reinforce the dominant epistemologies based on western, technical-rational forms of thinking. Through this new appreciation a clearer emphasis emerged and I came to understand that any education for planetary well-being needed to be rooted in a new way of thinking and that this would require challenging the dominant western ways of thinking which can often be founded upon misconceptions about the types of knowledge that science can produce.

I maintain that this new way of thinking is ecological in nature. For the purposes of this thesis, the term ecological is not confined to common definitions, many of which are predicated on concerns about the environment. Both Bateson (2000) and Guattari (2008) argue that ecology is the deep-rooted ability to acknowledge the patterns of relationships among all aspects of experienced reality. I argue that an ecological way of thinking has its foundations in Capra's (2005) systems thinking and Orr's (1992) ecoliteracy which challenge and replace the dominant technical rational form of logic and epistemology and which highlight the importance of understanding the relational, dynamic and provisional nature of knowledge.

Cycle 2 of this action enquiry explored how this understanding for the need to help the students develop an ecological way of thinking gave rise to my reconceptualization of science and how this was then translated into my teaching practice. Much of western society places great belief in the process and knowledge which a certain form of science produces. I propose that reimagining science may be understood as synonymous with developing new epistemologies. I will demonstrate that I used strategies which showed that I was aware of the relational and transformative processes of science. However, I will also suggest that this afforded me the opportunity to avoid confronting the students about planetary issues which had caused such tensions during Cycle 1.

While promoting the idea that students should develop relational epistemologies I had not fully attended to my own learning and thinking. I identify the complex and difficult manner of coming to understand what an ecological approach to my practice might encompass and show that despite the rhetoric I was still thinking in a fragmented manner. I will show that during both Cycle 1 and Cycle 2 I viewed pedagogy as the act of teaching (Alexander 2008) which was distinct to the curriculum which I perceived simply as a content-based syllabus.

In addition to the promotion of a way of viewing science and curricula as processes, I suggest that an ecological approach to my practice should encompass the interrelated nature of my personal context, a transformational curriculum and the relational manner in which I teach. I also identify that this practice must explicitly take into account the expectations of the students and the educational system within which I am working and that this will reduce the tensions I feel about introducing issues which are of value to me.

The thesis provides a prospective model for new science teacher education if this unbounded, ecological way of practising were to be adopted.

The following will briefly outline the actions taken in Cycle 1 and Cycle 2 and justify the reasons for undertaking them.

Developing a curriculum for ecoliteracy – Cycle 1

The first cycle focused solely on developing a curriculum for ecoliteracy. The stimulus for conducting this research came from my growing concerns for planetary well-being. In brief, my anxieties developed from the fact that the global human population had recently reached 7 billion inhabitants and the negative effects this was having on our planet: resource depletion and the numerous and complex effects of anthropogenic pollution, which were all set against a backdrop where the difference between the world’s richest and poorest showed appalling injustices. Indeed, according to John Beddington (the then UK government’s chief scientific advisor) the world is;

> heading towards a series of major upheavals which could all come to a head around 2030. This could result, he warns, in a ‘perfect storm’ of food shortages, water scarcity and insufficient energy resources leading to public unrest, cross-border conflicts and mass migration, since all of these issues are operating on a similar timescale.
>
> (cited in Hicks 2010, p.1)

My position at St Mary’s University College (now known as St Mary’s University) is to help starting primary teachers to develop their science subject and pedagogical knowledge as part of their three-year undergraduate degree programme. In my position as senior lecturer and with an increased understanding of the problems facing the planet, I came to ask similar questions to Hicks who enquires;

> What then should the role of education be in turbulent times? Should it be to turn a blind eye to such alarmist talk and focus instead on league tables and school improvement or does it have a wider role - to alert society to possible changes that lie ahead and to prepare teachers and young people to face those changes with as much confidence as possible?
>
> (Hicks 2010, p. 1)

Similarly, Moore Lappé (2007, p. 74) describes how, as individuals, whether consciously or not, our actions send out ‘ripples’ to the environment. She maintains that; “the choice we have is not whether, but only how, we change the world.” Considering this, and that; “I want[ed] to be part of the solution rather than part of the problem,” (Whitefield 2004, p. no page) I felt that the science teaching education programme, on which I taught, could be utilised to help develop the students' understanding of these planetary issues and influence both their personal and professional lives as primary school teachers.

The following will briefly outline how I initially came to use the term ecoliteracy.

While identifying what a science teaching education programme might encompass I was aware of the problems associated with the terms sustainable and sustainable development and because of this I wanted to dissociate from a curriculum for sustainability. Perhaps the most influential and widely accepted definition for the term sustainable development comes from the Brundtland Report (World Commission on Environment and Development 1987). It provides what, at first sight, seems to be a practical guide to what sustainable development might necessitate. It states that sustainable development is development that; "ensure[s] that it meets the needs of the present without compromising the ability of future generations to meet their own needs," (World Commission on Environment and Development ibid, p. 15). While importantly there is an emphasis on human needs, such as food, clothing and shelter the interpretation of this report by many is that this is development which can be sustained without lifestyle changes being made. It has also been argued that this definition supports the importance of continued economic growth and therefore promotes the underlying issue of consumerism which, along with the ever-increasing global population, is the elephant in the room regarding the degradation of planetary well-being (Orr 1992). The term sustainable has also been appropriated by mass culture and is often now used as an adjective to define numerous, non-environmental related issues. I was aware that the Earth had either reached or will reach its carrying capacity imminently (United Nations Environment Programme 2012) - although exact figures are highly contested - and that planetary boundaries (Rockström et al. 2009) are also likely to be exceeded soon, so sustaining the existing planetary situation was not tenable.

With a belief that this global crisis is ontological in nature, I concurred with Schumacher's (1973) claim that modern man [sic] does not perceive himself as part of nature but as an external force capable of controlling it. I was starting to comprehend Braungart and McDonough's assertion (2002, p. 26) that little regard, if any, is given to the; "health of natural systems, [or] an awareness of the delicacy, complexity and interconnectedness," given that western society's current primary focus is the speed at which a product is produced and consequently received by the customer. Orr (1992) makes the connection that this is a consequence of modern western education systems which have been designed to assist the industrialisation of the planet by their conquest over all things natural. It was at this point of understanding that I began to make the link that it was humans' educational experiences which were developing the disconnected relationship many have with the planet

It is this disconnection from nature and an inability to comprehend the consequences of our actions, which has led Orr (1992) to label most students leaving educational institutions as ecological illiterates. By inference, contemporary learning institutions now have the potential to produce graduates who are not only ecologically illiterate, but also; "able to exploit others and the environment more efficiently and effectively than their predecessors," (Sterling 2001, p. 45). While not fully comprehending the epistemological ramifications of this standpoint I was drawn to Schumacher's (1997, p. 54) warning that; "if still more education is to save us, it would have to be education of a different kind." My quest became to discover what such an education should look like.

I appreciated that in my current role as a senior lecturer at an English initial teacher education institution and as a secondary school science teacher for twelve years prior to that, I had played a part in helping to propagate this form of illiteracy, although it was not until much later in the research process that I fully understood how. The thesis will chart the difficulties I had understanding and therefore defining the term 'ecoliteracy' and how this was misappropriated during cycle 1. Orr clearly outlines the relational nature of ecoliteracy when he describes the term as;

> that quality of mind that seeks out connections. It is the opposite of specialisation and narrowness characteristic of most education. The ecologically literate person has the knowledge necessary to comprehend interrelatedness and an attitude of care and stewardship.
>
> (1992, p. 39)

I will demonstrate that I had mistaken this as only applying to learning about planetary issues and it did not involve a radical epistemological shift regarding the way I thought about everything.

I will argue that at this stage of my development my scientific background had helped me to appreciate the anthropogenic nature of the planet's problems. During early writing which articulated my understanding of ecoliteracy I had stated that in its most fundamental form it denoted the ability for an individual to ask, 'what then?' questions with reference to a person's actions and the subsequent consequences on planetary and human well-being. This simplistic definition initially satisfied my understanding of the 'quality of mind that seeks out connections' (noted above; Orr 1992) and subsequently provided reasons for why the proposed curriculum for ecoliteracy was predominantly focussed on raising awareness about planetary issues and teaching strategies.

The account of the first cycle in this project will outline how the science sessions on the teacher education programme were used specifically to devise a curriculum for ecoliteracy. It will chart the work that was undertaken with a specific group of 18 students studying on the aforementioned degree in 2011. During their course these students had the option to study two National Curriculum subjects (as stipulated by the government; Department for Education and Skills 1999, the current National Curriculum at the time of this research) in greater detail to gain a deeper insight into subject-related pedagogy. It was a group of students that elected to undertake the science specialist course who were invited to participate in the early stages of this doctoral research. While there were broad outlines for the learning outcomes of the course, and specific assessments to be completed, the course provided an opportunity to focus on any science related area which could be useful for their future teaching careers. It was with this underlying premise that I endeavoured to produce a curriculum for ecoliteracy which I hoped would encourage the students to take ownership of their actions towards the planet in both their personal and professional lives as teachers.

This aspect of Cycle 1 also focussed on how the curriculum for ecoliteracy was developed through a particular teaching approach and was the initial introduction to an ecological approach to my practice. This approach drew upon published work from my Masters studies (Sinclair 2010). During these studies I had undertaken a critical appraisal of my practice and become aware that during my time as a secondary school teacher I was subconsciously driven by the need to develop trusting relationships in order to gain mutual respect from those I taught and worked with. I believed this concurred with Glenn's (2006, p. 183) stance when she states that; "I believe that I am developing a theory of practice that locates the possibility of learning in the relationships that are created between people". I termed the relational nature of this form of pedagogy a 'mutualistic practice'. I hoped therefore to develop the curriculum for ecoliteracy through a relational way of working with the students. The initial research question for Cycle 1 therefore became; "Can a curriculum for ecoliteracy be developed through a mutualistic practice?"

This thesis will also exemplify the deep-rooted tensions I felt because of the clear intention of the research which was to introduce the students to issues premised upon my beliefs and values. A prominent feature of this thesis are the questions I raised regarding the appropriateness of this approach and whether the methodological process of this research was ethical and served the students' best interests.

Developing an ecological approach to science teacher education – Cycle 2

Following work with the students from Cycle 1 my understanding of ecoliteracy had evolved and I appreciated that this was formulated through an ecological epistemology. Analysis of the data from this stage demonstrated that the students' awareness of planetary issues had been raised and they felt empowered to incorporate a variety of teaching strategies into their practice. In addition to this the data suggests that the students appreciated the mutualistic practice which I had developed with them.

Understandably there was limited evidence of an epistemological shift. I explain that, in part, this was due to my focus particularly on teaching rather than learning and which I define as a non-ecological approach to their education and my practice. In addition to this the students had not been challenged to think in a manner different from the dominant technical rational forms of education to which they were accustomed. They had not been given the opportunity to view knowledge as transformational and emergent. While fixating on the relational way of working with the students I had overlooked the relational nature of epistemology. This issue will be explored at a later stage but here it is sufficient to say that it resulted in the development of a curriculum which focussed on objective knowledge and not as a process which was experiential and transformational.

The experience gained from Cycle 1 led me to believe that a prerequisite of any form of environmental education, and therefore any step towards planetary well-being, must be through the development of ecological thinking. I will argue in Chapter 2 that western education, in particular science education, has played a major role in perpetuating a non-ecological way of thinking based on the neo-liberal value of egocentricism. Egocentrism is founded on the anthropocentric premise that perceives humans as masters [sic] of the planet who have the ability to control it (Clarke 2012).

In order to help the students to develop a relational and ecological way of thinking I proposed that it was necessary to challenge the orthodoxy of current science education; this being one which promoted linear epistemologies and the learning of propositional facts in order for knowers to be tested for exams. The dominant perception in science education is that any knowledge produced by science is fixed and immutable, and that this is what good science teaching should aspire to promote (Harlen 2010). While this paradigmatic shift in thinking cannot be the sole domain of a science education, I believed that it could be used as one of the tools in assisting students to adopt an ecological mindset.

The account of Cycle 2 details further research with a later set of students conducted in the academic year starting in September 2016. It highlights the resources and practices which were developed in light of the knowledge gained from the first cycle. These new resources and fresh practices were developed in order to demonstrate the related nature of scientific knowledge and to help children and students recognise that many scientific hypotheses are evolving; what we learn now may well be different in a generation’s time.

The account of Cycle 2 will also re-visit the tensions I experienced from Cycle 1 about introducing the students to issues which were of personal value only to me and which I felt may not have been of interest to them. It will suggest that because of this sensitivity about introducing the students to controversial issues regarding planetary well-being I over-emphasised the need to reconceptualise science and science education in order to develop an ecological way of thinking. This was at the expense of learning about issues concerning planetary well-being.

The text so far sets the scene for an outline of the research. The following now details how the rest of the thesis is arranged and describes the content of the chapters.

Chapter One provides the context for Cycle 1 of this research. It provides a description of the difficulties facing the planet and its inhabitants and thereby aims to justify my desire to create a curriculum for ecoliteracy with starting teachers. Through scrutiny of my previous experiences as a school student and secondary science teacher it offers possible suggestions why I viewed a curriculum only as a syllabus and ecoliteracy only as a process of awareness raising and the learning of facts.

Chapter Two argues how science and science education have played a role in creating a non-ecological mindset and provides reasons why the curriculum for ecoliteracy (outlined in Chapter 1) had limited success. It suggests an approach towards science and science education which is ecological in manner; this approach is underpinned by the promotion of transformational and relational epistemologies and ontologies.

Chapter Three offers an overview of the literature about action research and provides a theoretical framework for the methodological approach adopted. It defines the term cycle and explains the forms of reflection which have been used throughout this thesis.

Chapter Four outlines the methodology adopted for this research and justifies the choices made with reference to an ecological approach to research. It discusses the data collection methods used and the subsequent data analysis for Cycles 1 and 2. It attends to issues concerned with validity, reliability and generalisability.

Chapter Five is the first of three analyses chapters. This chapter analyses the data collected from Cycle 1 to provide evidence for the success of a particular aspect of my pedagogy. It will outline whether I developed mutually respectful relationships as part of my mutualistic practice (pedagogical facet A – developing a mutualistic practice).

Chapter Six also analyses the data from Cycle 1. It will generate evidence to address another aspect of my pedagogy (pedagogical facet B – developing ecological epistemologies). It will highlight whether the curriculum for ecoliteracy developed the ecological epistemologies which I have argued are a pre-requisite for planetary well-being.

Chapter Seven analyses the data from Cycle 2. It will provide evidence of my transformed thinking between Cycles 1 and 2 and particularly highlight how I was reconceptualising science. It will also demonstrate how this new way of thinking manifested in the activities that I produced for the students during this cycle.

Chapter Eight provides a summary of conclusions and recommendations. It draws upon all three analyses chapters and in doing so provides a tentative outline of my ecological approach to science teacher education. As a consequence of this it details the personal significance of undertaking the research and charts the development of my thinking through doing so. Additionally it identifies the potential implications to others of this work by suggesting how the ideas contained within this thesis might be utilised by those in educational roles in helping them, in turn, to redefine their practice and realise their educational values.

It is important to note that I have summarised and theorised my understanding of an ecological approach to science teacher education within Chapter 2. The reason for this is as follows. This thesis focusses upon the changes in my thinking throughout the research process to the point of writing this document. In order to explicate these changes I considered it necessary to provide theoretical justifications for the way I was thinking at the start of this research and contrast it with my current ecological epistemological views. Within Chapter 2 I have provided a broad outline of my understanding of an ecological approach to science teacher education to act as a signpost for the remaining part of the thesis. I hope that in doing this I am providing the reader with the necessary foresight so they can appreciate the transformative journey I have undertaken in getting to this point. Issues related to how I reached this perspective will then be detailed throughout Chapters 4-8.

Chapter 1. Preparing the Scene

1.1 Context for this research

The chapter provides the starting context for this research; it details my own schooling and then my work in mainstream secondary schools as a science teacher. It is necessary to offer this to establish the reasons for the type of curriculum for ecoliteracy that was developed with the students during Cycle 1. In particular it will justify how I had been inculcated into a non-ecological way of thinking which resulted in specific views about curricula and ecoliteracy which were non-relational in nature. The context will also provide evidence of the way in which I thought and worked and will subsequently be used to demonstrate the transformational nature of this research which led to the development of a second cycle of enquiry and to my claim that I have developed an ecological approach to science teacher education.

I work in higher education and am a science teacher educator at a teacher education institution helping to prepare students who are training to become primary practitioners. I will argue that I have had relative freedom in shaping my identity for this role. Unlike my time in school, I am only loosely confined by guidelines which are set out in policy documents and provide the overarching aims for the courses I teach. The main aim of my practice is to help equip student teachers with the confidence to teach science in the primary school classroom. I have the relative autonomy to decide what is taught and the manner in which this is done. However, I do suggest that while I have this independence I am somewhat constrained by my students' perceptions of how effective I am in preparing them for teaching in school. This is evidenced in course evaluations. I am comforted by Gregoire's (2003) argument that it is the role of teacher education programmes to help students redefine and challenge their initial beliefs about education but am also aware this may lead to issues if my students' experiences do not meet their expectations of what the focus of their science sessions should entail. This has become particularly pertinent following the introduction of student tuition fees. Research suggests that most students now view themselves as paying customers of services (Kandiko & Mawer 2013) who are demanding that their expectations are met.

Prior to this position in higher education, I spent ten years (1996 – 2006) as a secondary school science teacher in a variety of English schools. My primary role was to help young adults, aged between 11 and 16, to achieve the best grade possible in their final science exams (GCSEs) at the end of their compulsory schooling. The exam grades achieved were the standard by which both the pupils and I were judged. The ability to help pupils pass these exams was understandably valued by pupils, parents and schools; teachers who could achieve this goal were highly respected. Judgements on my teaching (by Ofsted) at the time, and the grades that my pupils were attaining, demonstrated that I was 'excellent' at my job. However, even at this stage, exercising minimal critical awareness, I was conscious that my ability was in helping my pupils to pass exams rather than gain a true scientific understanding. I likened my practice to a conveyor belt system (Sinclair 2010) where pupils would be fed facts travelling on the belt throughout the duration of their course until they took their exams, which is when they got off. This only confirmed the experiences I had received in my schooling that it was the teacher's role to impart knowledge to help children pass exams.

Elliott (2007) notes how the various content-based curricula, produced to teach for such exams, separate 'ends and means' in the educational process with the former driving the latter. In this case, the 'ends' are the learning of scientific facts which are founded on an ideology that primarily values the importance of propositional knowledge. The 'means', therefore, are a curriculum and a style of teaching and learning which reinforce the significance of such knowledge. At this point in my practice, my commitment to propositional knowledge was being reinforced by the praise I was receiving for being accomplished in the exam process and the fact that my experiences as a student and as a teacher had only been within such a system. There had therefore been no need for me to critique whether there were other epistemological stances and therefore differing ways of viewing a curriculum, pedagogical practices or forms of knowledge.

On starting my current job in 2006, it was my belief that I could achieve the module aims through a continuation of my practice from secondary schools and in turn help reproduce the practices and epistemological values I had unquestioningly experienced as part of the process. In this manner, I was implicitly giving credence to my students that this didactic way of teaching and learning, which many of them would be accustomed to from their own school experiences, was the only appropriate way to teach science. By doing this I was also reinforcing a particular view of science and the knowledge that it produces. The epistemological influence much of western science has had on society and therefore my practice will be developed further in Chapter 2.

The following section now focusses on how I came to question this teaching approach and formulate my initial thesis research question.

1.2 The significance of starting masters studies

At the time of joining my higher education institution there was an expectation that senior lecturers should all attain masters degrees. Consequently I started the process of achieving this qualification. It was this pivotal moment which provided the initial impetus and motivation for this research. My masters studies compelled me to identify the values and beliefs which underpinned my practice. For this reason, it became necessary for me to be critical and question, for the first time, the Why? How? and What? of my teaching. Previous reflection had not really taken these aspects into consideration and, in the main, its purpose had been to achieve; “personal mastery,” (O’ Neill 2007, p. 64) of my subject area with the ultimate goal of helping students to achieve good exam grades in an engaging and stimulating manner. In essence it was, as Elliott (2007, p. 82) proposes, reflection in a; “trivial sense.”

As part of the interrogation of my practice I started to question the power that had been conferred on me as a school teacher and the subsequent consequences of this. I now appreciated Foucault’s (1980) argument that those who have knowledge, and therefore power, decide what is accepted as truth or appropriate education. Although I did not feel I wielded this power directly, I can see how I channelled governmental and school policies, and an acceptance of what counts as knowledge, from those in power to my pupils. While in school there had been no need to ask difficult questions and consider what I believed to be the purpose of the education system in which I was involved. Embarrassingly, I concede that at no point in my teaching career had I questioned the science syllabuses from which I was expected to teach or the manner in which science was being portrayed. In my compliance it had not been necessary to engage with the transformational nature of science and I had equated the learning of certain propositional knowledge and the development of particular skills with the process of science.

Being recognised as having a talent for helping children to achieve good exam grades reinforced this ‘blindness’ and with it created a desire to get better at the process. While Alford (2001) has noted that this has often been used in some organisations as a possible strategy of manipulation and control, I concur more with Chomsky (2000). He suggests that many teachers are unthinking implementers of normative theories who are carrying out a service that is expected of them by the schools in which they teach and, as a consequence, they are willingly fulfilling the requirements of what he calls; “the doctrinal system,” (ibid, p. 17). It is worrying to realise that the purpose of the doctrinal system as considered by Chomsky (1993) is to reinforce passivity and submission to authority. While I can now see how I had been ‘indoctrinated’ into this system I do not believe that most teachers in schools are conscious of how they are complicit in the process.

From undertaking a critical appraisal of my values I am now aware that, during my time as a secondary school teacher, I was subconsciously driven by the need to develop trusting relationships to gain mutual respect from those I taught and with whom I worked. It is these relationships which I consider to underpin all my teaching. It was difficult for me to work with those pupils who did not respect themselves or me and so I worked harder with them to gain this respect. This is still the case in my current role. I understand how my practice concurs with Dewey's (1916) view that a successful learning environment is one where individuals' learning experiences are valued as well as the sense of collaboration that is experienced by the members of the community. My masters studies required me to question how best to conduct my practice so that it was commensurable with this value and develop these relationships based on mutual respect. Although I had not identified explicitly these were the first steps in the development of the curriculum for ecoliteracy and consequently an ecological approach to my practice.

Previously, underpinned by my commitment to forms of propositional epistemology, I had subscribed to Freire's (1970) banking concept of education whereby students are deemed empty vessels ready to be filled by the teacher's knowledge. However, at this point in 2007, I started to ask whether promoting myself or being promoted by my students as an expert knower was in line with my value of mutual respect. While I espoused the importance of developing such relationships I questioned whether this manifested itself in my practice. At the same time there was a realisation that I too was a learner and, in order to identify myself in relationship with the students as part of a learning community, it was necessary to challenge the traditional teacher/student role and attempt to redress the power imbalance on which it was premised.

Having studied three sciences at A level (between the years of 1988-1989) and having a degree in biological sciences (1990-1993) I had only ever been exposed to the traditionalist research methodology of the natural sciences premised upon linear cause and effect relationships. Unquestioningly, I believed research into the social sciences, such as education, would also conform to this methodology; a methodology which was modelled on the underlying positivist epistemology of the natural sciences. McNiff (2014) notes that from this research viewpoint, knowledge is seen as separate from those who create it. Winter (1989) feels much the same and argues that researchers who accept these epistemologies believe, if enough situations are studied with enough care that generalisations can be made about how humans function. I had given little thought about subscribing to this view which implies that human behaviour can be predicted and therefore controlled, in effect reducing humans to agents who do not have the ability to think for themselves. Yet despite this commitment to positivist research and propositional knowledge I always had difficulty in accepting any research that had been produced by scholars with no in-school experience and was heartened to learn that questions were being asked by several teachers about the usefulness of knowledge that was produced outside of a practical context (outlined in Clandinin & Connelly 1995; see also Ghaye & Ghaye 1998).

My masters studies introduced me to the then novel methodology of action research, which places the researcher in a community with those they are researching. This form of research rejects positivism and is grounded in relational epistemologies. This was the first time my views on the purpose and nature of research had been challenged and, as a result, my methodological viewpoint of research. It was at this point that my emerging understanding of the relationship between ontology, epistemology and methodology was starting to form.

While cautious about the nature of this methodological approach to research I could see its benefits because it allowed me to interrogate my practice and identify ways in which to improve it. However, I could see that this form of practitioner research which combines theory and practice, and which potentially results in a recognised qualification, was also one way of raising the perceived status of the teaching profession; something I am passionate about. I had not, at this time, identified the emancipatory nature of action research (as McNiff 2014 points out) and was adopting a surface-level approach which was based on problem-identification and solving. I did not comprehend that action research could be about generating a form of moral accountability which can help realise human potential. I was also not committed to its epistemological underpinnings which view knowledge as provisional and open to transformation.

While I was beginning to understand that the significance of my research could be thought of in terms of developing new forms of epistemologies, I was not convinced that generating a theory of my practice (my own living theory of practice, according to Whitehead 1989) would be of interest or legitimated by others in both the academic and professional field. It was also difficult to recognise that any publication of my work was contributing to debates surrounding the nature of education and pedagogies and what constitutes educational knowledge (as outlined in Schön 1995).

The section so far has identified the emergent first steps I took in developing an ecological approach to my practice. It has outlined how my masters research required an interrogation of the previous assumptions I had held about education and in particular the forms of knowledge and curricula I had unconsciously promoted. It has charted how I was introduced to the relational methodology of first-person action research and how I thereby identified that my teaching practice was rooted in developing mutual respect and so, must by definition also be relational. It has also outlined how, at this stage, I was unaware of the interrelated nature of research and my mutualistic practice which I had so far viewed as separate.

The following section will now address the concerns I currently have about planetary well-being and why this has emerged as an integral focus for this thesis. This may initially seem unrelated to the previous sections which have outlined the manner in which I had been schooled and the positivist epistemologies I adopted in subsequent practices. However, during the course of this chapter I will also suggest the mechanistic education system into which I was inculcated has perpetuated the myth that humans are disconnected from their lived environment resulting in the planetary degradation currently being witnessed in the contemporary world.

1.3 Planetary well-being – why be interested?

At the same time as questioning my teaching practice I was engaging with issues regarding planetary well-being. This section will briefly outline some of the deep concerns I was having for the Earth's occupants; this was predicated on the ever-declining ability of the planet to provide hospitable environments for its inhabitants. This, therefore, provided the stimulus for the research and justifies why I felt compelled to use the science teaching sessions to help develop the students' understanding of these planetary issues.

The Earth tends to be seen by many humans, whether unconsciously or consciously, as an infinite sink to absorb the waste from human activities and as a limitless provider of all of its needs. The Earth's biocapacity (WWF 2016) is estimated as the productive land and water surfaces which have the dual capability of providing renewable ecological resources and sequestering any pollutants produced. Global Footprint Network (2016), however, have currently calculated that humans are using 1.6 Earths to do this. On August 8th 2016 the human population had used more from the planet than it was able to regenerate. This was 6 days earlier than in 2015. These problems have increased since the human population reached 7 billion inhabitants and currently there is little evidence to suggest that the situation is improving. It is predicted that by 2030 the equivalent of 2 Earths will be required to satisfy human needs (Global Footprint Network ibid). This ecological deficit and ignorance can only continue for a short period. Indeed, so extreme are human's effects on the planet that Crutzen (2002) has indicated that there is a sufficient enough distinction in the global stratigraphic signature to define a new geological epoch – that of the Anthropocene; one whose features have been produced solely by human activity. This signature will include evidence of the rapid redistribution of organisms across the planet and the massive loss of plant and animal species which Leakey and Lewin (1996) have termed the sixth extinction. Lovelock, however, highlights that it is not the planet which is at risk but human civilisation. He notes that; "what we are doing weakens her but is unlikely to destroy her [sic]. She has survived numerous attacks in her three billion years or more of her life," (Lovelock 2006, p. 77). This blindness to our relationship with the planet is exemplified by the following. Plummer (2005) describes an incident when taking undergraduate students on a field trip and explains how they discovered a dying fawn and the distress this caused to those that saw it. In his mind this exemplifies the disconnect humans have with nature. These students had become so far removed from an understanding of natural processes that a dying wild animal caused a frantic reaction. Gray (1993) explains this by noting that, unlike our ancestors, many humans are now no longer able to perceive their direct reliance on natural systems because they are cosseted by technological advances which hide the fragile mutualism we have with the Earth. This is perhaps most apparent when young children are asked from where their food is derived. Many believe that it comes from the supermarket with no association being made to its origin or the processes undertaken for it to arrive in their home. Research by the Dairy Farmers of Britain (Manchester Evening News 2007), into perceptions of children aged between eight and fifteen, showed that many had no comprehension how yogurt was made or that pork chops came from pigs. Perhaps most alarming is the fact that 2% of city-based children thought that eggs came from cows.

Abrams (2010) notes that many of our visual experiences are related to two-dimensional images many of which are received through the medium of television or telephones. Here the viewer cannot perceive any depth or make any engagement with the scenario portrayed. While there may be more television documentaries around the subject of nature than in previous years, viewers are positioned as unconnected voyeurs. This sense of disconnection is strengthened even further by the beautiful and iconic image of the Earth taken from an orbiting satellite. Again, the viewer is being situated externally to the Earth and not in relationship with it. Well-intentioned arguments that human beings need to care for the planet because we are its stewards tend to take an anthropogenic viewpoint which places humans at the centre of the Earth. From this, the understanding of the mutualistic relationship that we are situated in is lost. Abrams (2001) also points out it is not only technological advances which have strengthened this disconnect but a deep-rooted history within philosophy. He highlights Socrates' response to Phaedreus when asked why he never leaves the city; "Look Phaedrus: I'm a lover of learning, and trees and open country won't teach me anything, whereas men in the town will," (Abrams 2001, p. no page). This barrier between humans and nature has further been promoted by Descartes' belief in mechanistic reduction and his understanding that complete entities and systems can be understood purely by studying their component parts in isolation. Newton's work reinforces this and has set the standard for most of modern day science based on the mechanistic understanding of cause and effect relationships. Issues related to Descartes and Newton will be developed further in Chapter 2.

Through further engagement with these ideas I became increasingly aware of, and concerned about, the future prosperity of the Earth. I concurred with Sterling (2003) who argued that a new value should enter education, that of care for the Earth. I acknowledged that this value was underpinning the way I lived and therefore was also impacting on my practice. I was beginning to identify that humans do not perceive themselves as part of nature but as an external force capable of controlling it (Schumacher 1973) and that this has led to a disconnection from nature, where the symbiotic relationship we have with our planet has been misconstrued. However, because of my science background, I considered that I had a grounded appreciation of my relationship with the planet and I understood the impact of my actions on planetary well-being. At this point of the research process I am confident that I was exhibiting this aspect of ecological thinking.

I believed the planet's functions could be explained primarily through scientific principles and therefore the curriculum area of science could be utilised to address these issues. I questioned whether my practice as a science teacher educator, and therefore this research, could contribute to developing starting teachers' ecoliteracy and whether, as a consequence, this would influence their teaching practice.

1.4 Planetary well-being - what is the education system doing about it?

The following section will emphasise the importance of children and young adults engaging with issues concerning planetary well-being. I suggest that a personal critique of the literature highlighted below provided justification for appropriating the science curriculum to develop a curriculum for ecoliteracy. Despite this perceived need I will also highlight the low status that environmental issues have been ascribed in schools and how learning about them had been removed from the curriculum that the starting teachers from Cycle 1 would be working from.

I was buoyed by evidence which suggested that in a global context, there has been a trend towards more education about planetary well-being over the previous 50 years and the impact this had achieved. In fact, it has been established that because of such education, 95% of all Americans believe that there should be environmental programmes in place in schools, with 80% also agreeing that businesses should provide training for employees to solve environmental issues (Coyle 2005). Coyle also found that there is a correlation between those which are environmentally knowledgeable and their subsequent behaviour;

> 10% more likely to save energy in the home
> 50% more likely to recycle
> 10% more likely to purchase environmentally safe products
> 50% more likely to avoid using chemicals in yard care.
>
> (Coyle 2005, p. xi)

Similar findings have been found in the United Kingdom. A body of research studies show that it is imperative for children to engage with ecological and global issues highlighting benefits at both individual and school level. For example, Ofsted (2009) have reported that, in those schools that placed specific emphasis on sustainable development, the related teaching was good, that these lessons were stimulating and that pupils took an active part in improving the school and the wider community. The DEA's (2010) research also shows that young people's engagement with issues around climate change reduced by half the proportion who felt it was pointless to take personal action. The report also highlighted that; "without an opportunity to learn about global issues in school, over a third of the population (34%) are neither involved in, nor interested in getting involved in, any form of positive social action. Amongst those who have learnt about climate change, poverty or world politics and trade at school, this figure drops to around one in ten (9%, 12% and 12% respectively)," (DEA ibid, p. 3).

Yet despite this research and their own, Ofsted's framework (Ofsted 2012) for judging the overall effectiveness of schools made no reference to how a school was performing in these areas. These are the schools that the starting teachers would be teaching in once qualified.

Further evidence of the value planetary issues are given, or lack of, within the English school system comes from the following two examples.

The National Framework for Sustainable Schools (NFSS) (Department for Children, Schools & Families; DCSF 2006), which was devised to assist every school in becoming a sustainable school by 2020, had been abandoned by the incoming government in May 2010. The DCSF envisioned that the NFSS would provide an integrated approach to sustainability which would involve the curriculum, campus and local community. The NFSS required that a whole-school approach and ethos to sustainability was devised. Since the advent of the new government, support for the NFSS has been withdrawn. My personal experience of the down-grading of this knowledge came as a governor at a local primary school where I had been working with staff to develop the school's vision of the NFSS. After removal of support for the framework I was told my work was no longer a priority and my efforts would be deployed elsewhere.

In addition to this, following its implementation of its most recent National Curriculum for England (Department for Education; DfE 2013), the UK government stated that learning about planetary issues (including climate change) would not be part of the statutory teaching content until the age of 14, arguing that it should be up to schools to decide how and if they will teach about it. In short, they had actively removed the opportunity to learn about one of the biggest issues that young people now face. The removal of sustainability from the school curriculum is a specific example of how planetary issues are currently positioned as low status knowledge and how ecological illiteracy (Orr 1992) is being left unaddressed. The students I worked with during Cycle 1 were training to teach children between the ages of 5 and 11 years old and therefore would have had no requirement to engage with such matters. The following section will address how this aspect partly contributed to the emotions I held about introducing the curriculum for ecoliteracy to the students.

1.5 Tensions when developing a curriculum for ecoliteracy

I have previously commented that the process of developing and adopting a curriculum for ecoliteracy caused personal tension. This section will go into further detail regarding what contributed to this tension and by doing so will provide a context for some of the actions I undertook while working with the students. The generation of this tension can be explained by highlighting two broad but overlapping categories. The first is associated with student expectations and whether the curriculum for ecoliteracy would match their assumptions for the course. The second is related to whether I was abusing my power by deliberately choosing this specific focus for the module, given that it was a personal preoccupation.

The first tension was related to what would count as a student's primary focus for participating in higher education: generally this is construed as increasing their chances of employability at the end of the course (Kandiko & Mawer 2013; Temple, Callendar, Grove, and Kersh 2014). With no statutory requirement to teach about sustainability it would be understandable that the students on my course may not have seen the relevance to their teaching practice of learning about planetary issues. I was concerned that they may have questioned the importance of engaging with such matters. In addition to this the students chose this science specialist course on the understanding that it was to assist their general practice in primary school science; there was no specific mention of developing ecoliteracy or of studying planetary issues.

Furthermore, many students are understandably driven by the assessment process and the desire to receive good grades. It is clear why such an emphasis is placed on assessment. This is because these grades affect their degree classification. Failure of these assessments could mean non-completion of the course and ultimately result in the student not achieving their ambition to gain qualified teacher status.

Bloxham and Boyd (2007) argue that for many students their impression of their course is influenced more through their experiences of the assessment process than any teaching and learning with which they have engaged. The assessment for Cycle 1's module focussed on whether the students could demonstrate how they would arrange an educational visit for primary-aged children to learn science. It was not related to their understanding of ecoliteracy or planetary issues. For this reason I was apprehensive that the students may not have seen the worth of extracurricular material that might be studied (such as ecoliteracy) within a module if it was non-assessed.

Kandiko and Mawer (2013) make it clear that the commodification of higher education has culminated in a consumerist ethos as the dominant attitude amongst students on higher education courses. They highlight that most students have clear expectations of what their courses should entail and want value-for-their-money. For the reasons outlined above I was concerned that the science course I was introducing may not have matched these expectations.

The second tension was as follows. I was acutely aware from the start that this form of research, a first-person action research, was premised on something I personally value; that of care for the planet and its inhabitants. In contrast with traditional positivist research, the boundary between the researcher and those being researched is not distinct in an action enquiry. As a consequence the personal knowledge created by the researcher in relation with the participants is also blurred. McNiff (2013) maintains this form of research must encourage change and that this change must start from the premise ‘I change me’, and, through doing, so help the researcher to; “reconsider their positionality in relation to others and their environment,” (McNiff 2016, p. 42). However, despite the changes occurring from within, it was imperative to remember that the relational nature of this form of research would always have a consequence for those with whom I was working. While this thesis documents how ‘I changed me’, I now concede that the primary focus during Cycle 1 was on developing the students’ ecoliteracy and therefore centred primarily on teaching with far less emphasis placed on my learning. This might stand as further evidence of my non-ecological epistemology at this point. I have outlined in Sections 1.3 and 1.4 why I believe it was important to support the development of my students’ ecoliteracy but this was based solely on my value system. For this reason I was concerned that the research process had the potential for me to abuse my position of power by attempting to influence my students to adopt attitudes and values about issues which may only have been important to me.

With regards to this awareness about the interrelated aspects of possibly not meeting the students’ expectations of the module and my apprehension about abusing my position of power, it was imperative to demonstrate research and personal integrity and ensure that I was considering the value systems of the students even though they may not have been commensurable with my own. This was in line, not only with my personally held beliefs, but also the guidelines set out by the British Education Research Association (BERA 2012) which state that research should be conducted within a culture of respect. Chapter 4 will outline the specific strategies I used to ensure that this was the situation, which I believe allowed the students opportunities to critique their teaching and learning experiences while simultaneously enabling me to demonstrate to myself and others that I was contributing to improving the well-being of the planet.

The following section will develop ideas introduced earlier in Section 1.2, which considered how I had identified that my practice was underpinned by a motivation to develop positive educational relationships with my students. It will explain how I cultivated this relational pedagogy, predicated on mutual respect, as another way of dealing with the tensions I have previously explicated. It will demonstrate my evolving understanding of pedagogy and demonstrate the binary and non-ecological perspective (which Alexander 2008 notes is common) I had adopted which separated the activities I asked the students to undertake from the manner in which I worked with them.

1.6 Dealing with the tensions – a mutualistic practice

The following section will detail an aspect of my practice that I felt was imperative to develop while introducing the curriculum for ecoliteracy. It provides evidence that during Cycle 1 I had not yet made the connections between the content of what I was teaching from the manner in which I was doing so. However, it will suggest the relational nature of this approach demonstrates that there was an ecological aspect to my thinking, in part, and this might be seen as the rudimentary beginning to developing an ecological approach to my practice. This section will outline that this practice, which I have termed a mutualistic practice, and which drew upon my previous experiences with students was strengthened by my engagement with literature that proposed how education systems might mimic natural processes (Webster & Johnson 2010). In particular I will aim to establish how I believed that my mutualistic practice, which was premised on mutual respect, could assuage the tensions I felt about incorporating the curriculum for ecoliteracy within the science sessions.

I was by this time starting to appreciate Sterling's assertion that; "most mainstream education sustains [the] unsustainable," (2001, p.14). Yet despite this I still did not comprehend the epistemological ramifications of this position and at this juncture believed that my mutualistic practice could also be understood as Schumacher's (1997, p. 54); "education of a different kind."

As my understanding of the symbiotic nature of the relationship between the planet and its inhabitants (Abrams 2010; Lovelock 2006) developed I was drawn to using an overarching metaphor, that of 'Nature as Teacher' (Webster & Johnson 2010), to guide my practice. While Lovelock's ideas (2006, p. xv) refer to the connection between humans and the planet when he comments that there should be; "a lasting relationship of mutual benefit," I believed this could also be applied in an educational context and be used as a framework for informing my practice. This thesis outlines the form of positive action which emerged from the relational form of systems thinking communicated by Capra (2005) to meet the aim of developing lasting educational relationships. I will outline how I believed I had developed these relationships, founded on the premise of mutualism in the natural world, which had been enhanced by encouraging mutual respect between members of our learning community; I have termed this manifestation of systems thinking in action to describe a way of working with my students as a ‘mutualistic practice’.

In order to explain my mutualistic practice I have used metaphors from nature to highlight the type of relationships I hoped to develop with my students. In the natural world a symbiotic relationship is defined as the association between two organisms of different species which live closely together and where one or both of the members benefits from this link. There are two main forms of symbiosis; that of mutualism and parasitism.

Parasitism is the form of symbiosis where one of the organisms benefits at the expense of the other. One of the many examples of this is the human tapeworm, *Taenia solium*. Humans become infected when they eat meat containing this parasite’s cysts, when it has not been cooked sufficiently. Subsequently the cyst evaginates inside the intestine forming the adult tapeworm. This adult form then attaches itself to the intestinal wall where it will start to produce eggs while absorbing the already digested food provided by the human. Other examples of human parasites are the head louse and mosquito, both of which feed on blood while contributing nothing beneficial to their host. In parasitic relationships, there is an asymmetric power balance where the host is relatively powerless and forcibly accepting of the parasite. In attempting to make sense of this metaphor I propose that this is seen as a dynamic and lived process that is embodied in my practice and one which will develop over time. I have used this living metaphor as a starting point and framework to help me better understand my relationship and role with my students.

I am suggesting that the current UK education system can sometimes mimic this parasitical form of symbiosis. Members of the government, exam boards, schools and teachers can be understood as parasitical in terms of benefitting from unquestioning hosts, that is, the students that are being taught. This is especially the case if students are solely viewed as human capital. Their potential as members of a workforce with specific sets of skills and dispositions is encouraged in order for them to compete successfully in the market place (Apple 2006). In this instance these individuals or organisations possess the power a parasite may hold over its host.

Fromm (1979) highlights the unquestioning nature of the host, in a similar way, when he describes a particular kind of student; that is, those that exist in a having mode. He characterises students in the having mode as owners of a collection of statements produced by someone else without the need for the creation of something new; that is, the creation of new knowledge. They; “will write down every word in their looseleaf notebooks – so that later on, they can memorize their notes and thus pass an examination,” (Fromm ibid, p. 25). Ramsden (2003) has used similar terms when he describes some students’ approach to learning. Those students that adopt a surface approach often do not see the need to integrate and evaluate the ideas of the lecturer and simply act as the host for teacher’s ideas. Worryingly, previous research (Sinclair 2007) had substantiated this viewpoint and refers to one student who, when asked if they should be working independently, commented that; “well although it is important I feel that in paying for the course I should have more teacher input.” Elliott (2007, p. 67) also uses this term when he describes the utilitarian model of teacher accountability as; “weakening educational institutions by making them totally parasitic for their values on other institutions.”

Mutualism, on the contrary, is where there is a positive reciprocal relationship between the two individuals with mutual benefit to both parties. The Nile crocodile and Egyptian Plover are an example of this and are believed to exist in this mutualistic relationship (see Figure 1). The teeth of Nile crocodiles often contain decaying pieces of food, leeches and other parasites. Persistence of these would lead to a number of deleterious effects for the crocodile. The crocodile allows the Egyptian Plover to rest inside its open mouth and feed on the food and parasites without harm. The advantage for both is that the crocodile has its teeth cleaned while the Egyptian Plover gets fed. Using this metaphor, I believe, I can be seen to be positioned in the same way as the crocodile, and the students as the Egyptian Plover. The crocodile has the decision-making power to close its mouth and, in so doing, harm the bird. I was, and still am, in the position to behave in this manner if I desired.

Figure 1.1: Nile crocodile and Egyptian Plover

It may appear audacious to assume the role of the crocodile, but I feel it is necessary to outline how this metaphor of the asymmetric power balance between university teachers and students is derived. Understandably, university practitioners are often positioned by their students as expert knowers, almost in a parasitic way, and a large proportion of student teachers, at the outset of their course, anticipate that they will download information from them while operating in a having mode (Fromm 1979). Rudduck (1991) stresses that if these expectations are not met, students will often criticise tutors for not delivering the nuts and bolts they require. In parallel with this, most students are understandably driven by the assessment process and the desire to receive good grades. Unlike the situation in schools I am also the auditor of the students' assessments and therefore have the power to attribute grades and pass or fail their work.

This relationship, at first glance, may appear to be parasitic in nature and it was these elements that I hoped to address through my research by developing my mutualistic practice. However, throughout the research process I became aware that I would probably be unable to redress this power imbalance fully nor that this was necessarily desirable. Nixon (2008, p. 119) suggests we should; "take responsibility for the positional power invested in us." He notes that the authority invested in the university teacher/student relationship should not be denied in the interests of truthfulness, respect and authenticity. Dewey (1916, p.21) confirms this when he argues; "it does not follow that all authority should be rejected, but rather that there is a need to search for a more effective source." It is Dewey's notion of effective authority in relationship with my students that I wished to develop. To return to the metaphor, it must be noted that in the mutualistic relationship between the crocodile and Egyptian Plover, without the birds the crocodile's health can be seriously affected. Both organisms are required in relationship with each other for them to flourish. This interdependent relationship based on my value of mutual respect was the form of practice I hoped to develop.

To develop this living metaphor I described it to my students. Allowing them to critique my ideas had a dual purpose. Its first goal was to help me to clarify the metaphor in dialogue with them. It was also one of the strategies I used in helping my students to be critical of the teaching they had received from me. I hoped that a range of activities which gave the students the opportunity to question their educational experiences within their science sessions would empower them so they felt they were in a position to challenge what I had presented them. In this manner I believed it would reduce the tensions I have explicated earlier about using my influence in developing the curriculum for ecoliteracy. Consequently, developing the students' criticality became one of the primary aspects of my mutualistic practice and which is a defining principle of ecoliteracy (Orr 1992). Analysis to determine whether I had been successful in this regard, however, showed that this had been a misguided intention. In reality

I had conflated the desire to help the students develop their criticality by providing them with opportunities to be critical *of* my teaching.

This section has outlined how I had envisioned the development of mutual respect as a set of strategies to engender critique and how I had not regarded it as epistemological in nature. This, however, does demonstrate the embryonic beginning to the ecological approach to my practice and towards an ecological epistemology. Engagement with Buber's (1958) ideas about inter-human relationships and in particular his philosophy of education (Buber 1947), helped me to theorise my mutualistic practice further and assisted in articulating how the mutualism had manifested itself in my teaching. Chapter 5 will highlight how I used Buber's educational conceptual frameworks to show how this initial concern, that the mutualism had manifested itself solely in a set of critiquing opportunities, was relatively unfounded. I will suggest my desire to develop mutual respect was integral to many of my implicit actions with the students and this had been explicitly appreciated by them.

The following section will briefly outline how I came to an appreciation that Buber (1958), while not specifically referring to environmental issues, was making similar points to Orr (1992) and Capra (1996) that planetary well-being is premised upon ecological epistemologies. This realisation had implications for my practice; I now understood that my epistemological stance influenced what and how I taught and this was the start of providing a unifying and ecological pedagogical explanation of how I worked. This developed understanding provides a contextual background for the shift in focus of this research and how it transformed from developing a curriculum for ecoliteracy (in Cycle 1) to an ecological approach to science teacher education (in Cycle 2).

1.7 How did I transform from a curriculum for ecoliteracy to an ecological approach to science teacher education?

This section will explain how I synthesised the perceived disparate strands of knowledge, curriculum, pedagogy and planetary well-being to articulate an ecological approach to my practice. It will justify the movement away from using the term 'ecoliteracy' which was founded upon a misinterpretation of the concept and my perceived incorrect assumption that this involved a curriculum with fixed aims and objectifiable knowledge. It will substantiate that much of this ecological practice drew upon Orr's (1992) 'true' meaning of ecoliteracy which is underpinned by developing relational epistemologies. It will clarify that the reconceptualisation and personalisation of my new way of thinking required 'rebranding'. In addition to this I will highlight how this research has helped me to acknowledge that, despite the call by many for new educational paradigms (Orr 1992; Sterling 2001), my teaching was situated within a mechanistic education system to which the students were accustomed. There was therefore need for me to be creative in ensuring that ecological thinking was developed while subsequently meeting the needs of the students as future teachers of science.

Following the work with the cohort of students from Cycle 1, analysis of the data revealed compelling suggestions about their learning and mine. At this stage my understanding of ecoliteracy was developing as I further engaged with literature supporting it. It became apparent to me that the authors I was engaging with were all recommending that in order for planetary well-being to be improved it must be underpinned first and foremost by a relational, ecological epistemology. While Buber (1958) does not explicitly discuss concerns over planetary well-being his appreciation that individuals enter into encounters (whether animate or inanimate) which oscillate between objective and subjective relations has many parallels with the founding epistemologies of Orr’s ecoliteracy (1992) and Capra’s systems thinking (1996, 2005). Guilherme and John Morgan (2009) draw comparisons between the objectification of individuals described by Buber and the disconnect humans have with the planet and each other. Lim Cheng Hin (1998) has also suggested that Buber’s philosophy of dialogue could provide a foundation for environmental ethics.

In tandem with this developed understanding of ecoliteracy, and perhaps the most important aspect of my learning at this stage, was gaining an appreciation of the role science has played in promoting linear, non-ecological epistemologies and the impact this has had on humankind’s current worldview including my own. Skolimowski (1994) outlines how the many successes of science, founded upon Descartes’ and Newton’s belief that knowledge is gained objectively has resulted in the unquestioning adoption of a scientific epistemology which promotes the objectification of knowledge. In Chapter 2 I will demonstrate how this has subsequently led to the objectification of the planet. This dominant epistemology is supported and replicated by businesses and education systems. My educational habitus (Bourdieu 1990) was founded upon this form of thinking, as I outlined in Section 1.1, where I explained how my time as a pupil and teacher had been within a system which utilised content-based curricula whose purpose was to prepare students for exams (Elliott 2007). Consequently I perpetuated the reification of the forms of knowledge which were discrete, objectifiable, and which could be tested.

I offer this contextual information to justify my epistemological stance and to help explain the difficulties I faced in comprehending the discourses around ecoliteracy and subsequently the form of curriculum I presented to the students during Cycle 1. Earlier work demonstrates this when I wrote that; “Defining ecoliteracy has been problematic,” (Sinclair 2012a, p. 4). In attempting to do so, I synthesised Orr's (1992) writing to provide a brief overview, while still not fully understanding its deep and rich complexity;

> Orr (1992) argues that ecoliteracy is "driven by the sense of wonder, the sheer delight in being alive in a beautiful, mysterious, bountiful world" (1992: 86) and that "the goal is not just mastery of subject matter but making connections between head, hand, heart, and cultivation of the capacity to discern systems" (Orr 2005: xi).
>
> (Sinclair 2012a, p. 5)

While Orr makes the relational nature of ecoliteracy explicit, and emphasises that it is not mastery of specific subject knowledge, the relational epistemology that underpins it continued to elude me. By providing an interpretation of Orr's definition in the following writing, it would appear that I was still placing a primary focus on objectifiable subject content;

> I would argue that the 'head' refers to specific areas of scientific ecological knowledge necessary to understand how the planet works… Orr's 'heart' is that the student has the desire and the drive to want to make a difference. Subsequently with this desire, coupled with the necessary knowledge and skills, follows action or to phrase it in Orr's terms, the 'hand'.
>
> (Sinclair 2012a, p. 5)

This understanding of ecoliteracy was enacted in my practice and excerpts from draft thesis writing provides further evidence of my non-ecological mindset and how this manifested itself in how I worked. The following were criteria and questions I devised to demonstrate how successful I had been in developing ecoliteracy; "a) had I raised awareness of planetary issues? b) had the students' subject knowledge improved? c) how willing were the students to incorporate teaching about these issues into their future practice and d) how confident did they feel about teaching about these issues?" (Sinclair 2015). I now understand, and concur with Sterling (2001, p. 15), that this form of teaching took place within; "accepted boundaries… that *left* [leaves] basic values unexamined and unchanged."

The two pivotal, yet related, moments provided the impetus for the new focus of this research to emerge and the desire to develop an ecological approach to science education. The first was the realisation that planetary well-being could only be improved through a paradigmatic shift from linear to relational thinking and that this is what Orr (1992) had been proposing as ecoliteracy all along. The second was my appreciation that I had misinterpreted the relational nature of science which has the capacity to generate knowledge which is emergent, interdependent and transformational. This version challenges the Newtonian mechanistic worldview of science as a method of producing a set of immutable facts or a search for an absolute truth (Capra 1996) to which I was accustomed. I realised that both ecoliteracy and science are therefore ultimately underpinned by a particular way of thinking. I propose that how you view science will affect your epistemological and ontological relationship with knowledge and vice versa.

This understanding that the dominant and traditional epistemologies of much of the western world had been formed through the adherence to a particular, but potentially erroneous, view of science helped me to refine the purpose of my practice. It was now my belief that future science modules could be utilised to help students reconceptualise their perception of science and therefore science education. By doing so I hoped that they would help the students develop an ecological way of thinking. This provided the focus for developing an ecological approach to science education.

I believed that an ecological approach to science education involved incorporating ideas concerned with systems thinking (Capra 2005; Stirling 2005) into teaching and learning activities about science. This process will be detailed further in Chapter 2. As a consequence of this three questions were formulated to act as standards of judgement. These were to provide evidence of how successful I was in developing an ecological approach to science education in both Cycles 1 and 2. They resulted from my understanding that an ecological epistemology involves perceiving the three domains of the individual, the physical environment and knowledge as existing in an interrelated mutualistic relationship. The questions were as follows:

- Did I help the students to develop an understanding of the relational nature of scientific ideas?
- Did I help the students to develop an understanding of the temporal and transformational nature of relationships in science?
- Did I help the students to develop an understanding of the symbiotic relationship they have with the planet and those that share it?

1.8 What did I find out?

1.8.1 What did I find out? Cycle 1

The students' learning during this Cycle parallels my understanding of science and ecoliteracy and my practice in general. At this point of the research my comprehension of ecoliteracy was poorly framed and the work we undertook was premised upon this misinterpretation. Much of the time I had replicated practices which I had experienced as a student and a teacher of science in schools. In addition to this were the concerns I have outlined previously about ensuring that the students' prior expectations of the course were met and how this manifested in the way I acted. Analysis of the data suggests that I had helped to raise the students' awareness of planetary issues, provided them with activities which they could use in their teaching practice and raised their confidence to teach about such matters. This mirrors the criteria which I first proposed to judge the quality of the curriculum for ecoliteracy (outlined in 1.7). It suggests that at this stage of the enquiry I had been successful in what I had set out to achieve.

Understandably, analysis of the data demonstrates that in terms of the three criteria specified earlier there was limited evidence to suggest that I was developing the first two aspects of an ecological approach to my practice. My misconception of science had resulted in my not systematically helping the students to appreciate the spatial and temporal aspects of science knowledge and the process by which it is generated. I assisted in compartmentalising much of what they learnt and in doing so had not challenged the way in which they thought. Making knowledge links between and within science sessions happened but was not consistent and only really ensued because of the recurring theme of growing. I have identified that I introduced this topic because of my personal interest in this area. Although I noted from the beginning that I could appreciate how the topic of growing could be used as a stimulus to raise awareness of the interrelated nature of how the planet functions there is scant evidence to demonstrate that this actually manifested itself in practice. I argue in Chapter 6 that this was because of my fixation on providing clear activities relevant to the curriculum that the students would be teaching, thus satisfying my preconceived notion of their expectations. The growing sessions included a number of opportunities for learning science outside of the classroom, a component which I will argue later is necessary for an ecological approach. Studies are available which tentatively suggest that these sorts of experiences, which provide an opportunity to interact with the natural world, assist in helping individuals to appreciate the symbiotic relationship they have with the planet (Louv 2010; Mayer & Frantz 2004).

While there is little evidence that I had helped the students to think in a different manner, outlined so far as a key aspect of an ecological approach to my practice, this cannot be fully attributed to the process I experienced with the students. I have highlighted previously the form of ecoliteracy I was hoping initially to develop. As a consequence this influenced the forms and type of data I collected. I argue that I was not specifically collecting data to show occasions when the students may have demonstrated an ecological way of thinking and therefore may have missed opportunities to evidence their learning. This highlights the difficulties that researchers of their own practice can face when setting their own evolving criteria. More of these kinds of methodological issues will be revisited in Chapter 4. However, this aspect of the research does clearly show how my thinking transformed over time.

The act of explicitly collecting data to judge whether I had developed a mutualistic practice could also provide a partial explanation for the success of another facet of my ecological practice. While I have mentioned previously the dislocation I made between how I taught and the curriculum content, I will suggest that the students cherished the emphasis placed on developing a learning community where educational relationships, founded upon mutual respect were at the heart. I interpreted Buber's (1958) works on relationships, specifically those that he notes are found in educational situations, to provide criteria for this. The following questions arose from this:

- Did I outline my value system to my students in order to make the reasons for introducing a curriculum for ecoliteracy transparent?
- Did the curriculum for ecoliteracy allow for the students to develop their interests, needs and critical thinking?
- Did I create a dialogic learning community while working with this group of students?

The first two criteria afforded the means by which to identify whether the tensions that I have described throughout this writing, about coercion and relevance, were manifested in reality. In brief the data show occasions where I was explicit about my values and intentions for the course and the process I underwent to negotiate whether developing a curriculum for ecoliteracy was an abuse of my power. While some students initially expressed some concerns over this focus these seem to have been unfounded. A number of them appreciated the respectful manner in which I had approached introducing this. At the end of the course, feedback suggested that these students had a greater awareness of the pressures the planet is facing and that learning about these issues, and how they could be incorporated into their future practice, had meaning and relevance to them. This was despite my initial incorrect preconceptions about the lack of potential significance this may have had to their future teaching career. Analysis of the data also showed that I had respected that their science module could not solely focus on planetary issues and had accommodated a range of different learning opportunities associated with teaching science in the primary classroom. On a personal level was the realisation that many of these moments had been provided without thinking, and as a natural part of my teaching, and any future planning had to make explicit these occasions as it would be a dereliction of my professional duty otherwise. In relation to the third criterion about creating a dialogical community it became obvious that my mutualistic practice went further than creating the possibility for them to be critical of their teaching experiences. The analysis process facilitated the articulation of mutualism in my practice and made my tacit interactions with the students personally visible.

1.8.2 What did I find out? Cycle 2

The work carried out with the new group of students had a specific focus on the nature of science. This was founded upon the knowledge I had gained around the relational epistemologies I believe are necessary for the development of planetary well-being. I wrote earlier in the introduction that part of the stimulus for this research came from my concern that as a secondary school teacher I had helped to propagate a form of ecological illiteracy (Orr 1992). I identified that this was because of teaching from a curriculum which had little or no reference to planetary well-being. It was only at this stage of the research that I appreciated that it was not this facet of my practice but my unquestioning and unconscious promotion of linear epistemologies which cultivated this ecological illiteracy. My newly found appreciation that these linear and compartmentalised epistemologies had been promoted through an incorrect perception of science provided the stimulus for this cycle's research emphasis.

I am somewhat ashamed to recognise that up until this point I had little awareness of the history of science which would have provided me with many examples of the transformative and evolving process of knowledge generation. In addition to this I engaged with ideas about quantum mechanics and the relationship between space and time. These aspects of science challenge the Newtonian mechanistic worldview, on which most science curricula are premised, which searches for objective and absolute truths. I propose that science is still emerging from a paradigmatic shift (Kuhn 2012) which has yet to filter down to most education systems. Capra (1996, p. 13) outlines how the new paradigm of science celebrates the principles garnered from life sciences and is in opposition to much of physics which was once (and is still by some) believed to; "provide the most fundamental description of reality."

It is difficult to describe the enormity of the influence this acquired understanding had on my thinking and attitudes towards science education. I have already detailed in Section 1.7 the effect this had on my understanding of ecoliteracy and ecological thinking. My belief was that my practice could now be the basis for developing an ecological way of thinking through reconceptualising science. I thought that, by highlighting science as a relational discipline with the potential to produce dynamic knowledge, the students may have started to develop an ecological way of thinking.

In particular, one aspect of the nature of science stood out and perhaps was the biggest revelation in how my perception of science had changed; this was that many scientific concepts have changed over time and, therefore, some of the content currently specified in curricula will most likely be different in the future. Taber (2012) provides some consolation for the way I had been thinking previously when he suggests that teachers' understanding of the nature of science is often very poor. Despite being aware of paradigmatic shifts in science, such as the transformation from a geocentric to a heliocentric explanation of the solar system, I had not applied this to current endeavours and had compartmentalised them as historical events. This personal epiphany provides justification for why this became one of the foci for the science course with the new group of students from Cycle 2. Reassurance for this focus was also strengthened by a change in the National Curriculum for England and the inclusion of the following statutory learning objective that children; “should also begin to recognise that scientific ideas change and develop over time,” (DfE 2013, p. 24). Because of this I introduced the nature of science into science sessions and developed strategies to demonstrate how the students could help teach children about the evolving nature of science knowledge. The form these strategies took will be discussed in Chapter 7.

Analysis of the data, using the three criteria outlined in this section, suggests that my primary focus was on helping to develop an understanding that many scientific ideas transform over time. I had not made explicit links between the differing areas of science. There was also not a sustained focus in helping the students to appreciate the relationship humans have with their planet. Additionally, little time was given to learning about planetary issues.

I argue that this focus on a specific aspect of an ecological science education was a result of a number of interrelated factors. Despite reassurance the students from Cycle 1 valued learning about planetary issues the ever-present tensions around coercion and the need for me to meet their course expectations were still prevalent. I believed I could justify that by using an approach which developed ecological thinking there was no need for them to engage with matters concerning planetary well-being. As I was not introducing controversial subject matters I also felt there was no requirement to provide strategies so they could be critical of my teaching as I had done in Cycle 1. Additionally, publication of the strategies that I had trialled with students related to helping teachers and children comprehend how scientific ideas over time (Sinclair & Strachan 2016) were becoming established in the primary science teaching community. This tacitly reinforced and concentrated further efforts in this area.

While the singular focus in Cycle 2 demonstrates the personal negotiation I undertook between what I thought the students needed to know and what I believed the students wanted to know, it also provides further evidence of my developed understanding of how my practice could be used to develop ecological thinking. Learning from this process will be detailed in the next section which will make suggestions for how an ecological approach to science teacher education might manifest itself in my future practice.

1.9 So what is an ecological approach to science education?

The following section provides a brief synopsis of what I have discovered from undertaking this research and which has, for the purpose of this writing, been organised into two cycles of learning. Based on these findings it will make recommendations for my future practice and argue what an ecological approach to science teacher education should entail.

In Section 1.5 I wrote that I thought I had relative freedom over the content of my teaching sessions and that I was only constrained by loose guidelines outlined in policy documents. However, I will demonstrate that I also possessed an unarticulated awareness that I had less autonomy than I had first envisioned. This tacit understanding, which was fuelled by the tensions I have mentioned throughout this chapter, manifested itself in my ensuring that the science modules were not wholly subsumed by issues relating to planetary issues or to do with developing ecological thinking. Most of the sessions placed a firm emphasis on how they could be related to the students' teaching practices.

The explicit appreciation that I have a professional responsibility to help prepare the students to feel confident to teach science in school has helped me to ascertain what should be included in any aims of future modules I may teach on. These should include the professional aims highlighted above alongside my personal aim of developing ecological thinking.

Throughout the research it became clear that the form of curriculum the students had experienced, although premised upon unclear aims, was focussed on process and not product (as outlined by Elliott 2007). Further evidence of my developed ecological epistemology is my deepened understanding of the relational nature of this form of curriculum. I had appreciated that there is no fixed point or measure when defining ecoliteracy or ecological thinking and that there is no specified curriculum which can achieve this (Barlow & Stone 2005). However, I suggest that I had interpreted this as requiring a minimal curriculum plan and not as Stenhouse (1975) has recommended, that there was a need for clear provisional curriculum outlines from the outset of the course. I now understand that while these are liable to change the identification of strategies and guidance at the outset of curriculum planning can further clarify what the aims of the course are and how the students can work towards them.

I highlighted in Section 1.7 how I had identified that the study of science could be used to develop an ecological way of thinking. Chapter 7 will identify the relative success of studying a famous scientist's work as a strategy to promote an understanding of the temporal and evolving nature of some scientific knowledge. As I have detailed previously, it will also demonstrate that this was the primary focus to developing ecological thinking.

I propose that any future curriculum should also draw upon Harlen's (2010) concept of 'big ideas'. These are key ideas both *of* and *about* science. An understanding of the 'big ideas' can help to explain a range of different phenomena and by doing so help to demonstrate the related nature of scientific knowledge. This may help shift the common perception that science is a body of unrelated facts which need to be learnt in order to pass exams.

Additionally I recommend that the students study a specific scientist; Alexander von Humboldt. His work helps to bridge the following which underpin an ecological approach to science education; a) challenging the dominant worldview of science, b) promoting an ecological way of thinking and c) providing an opportunity to introduce planetary issues. Von Humboldt's methods of performing science show that they are underpinned by an ecological epistemology. His emphasis is on the importance of relationships over objects. Wulf (2016) has also referred to him as the first ecologist because of his identification of humans' far reaching effects on the environment.

Studying von Humboldt's work therefore provides an example of how both my personal and professional aims could be met within a module. However, it is important to remember that the findings from Cycle 1 demonstrate wholeheartedly that this group of students were interested in planetary well-being despite it potentially not having direct relevance to their teaching. Cycle 2 eschewed this focus in favour of concentrating solely on the role that science and science education could play. There is a need for me to have greater conviction in the manner in which I negotiated the curriculum with the students from Cycle 1 and greater faith in their willingness to engage with issues that are not stipulated by the National Curriculum (DfE 2013). For this reason there would also need to be explicit engagement with planetary issues (similar to Cycle 1) in any future curriculum and not an exclusive reliance on changing the perception of science.

1.10 Chapter summary

This chapter has provided a summary of the thesis. By outlining my previous experiences as a student and as a teacher it has contextualised the way that I was thinking prior to starting this research; especially regarding my non-ecological view of science and science education founded upon the linear epistemologies I had previously experienced. This information has been included to justify the type of curriculum for ecoliteracy which I provided for the students during Cycle 1. Additionally it provides base-line evidence to show the transformation in my thinking between Cycles 1 and 2 and to the point of writing this thesis.

This chapter has also introduced the forms of knowledge that Newtonian science has perpetuated and suggested that these linear epistemologies have manifested themselves in the education systems of much of the western world. The following chapter will demonstrate in greater detail how this way of thinking has led to the planetary crisis we are now facing.

Chapter 2 will also outline a different perception of science; ecological science. I will highlight how ecological science differs from Newtonian science and provide the types of educational activities that could be undertaken which may help students to view it a different manner. I will suggest that this reconceptualisation of science may help to develop the ecological epistemologies necessary for the improvement of planetary well-being.

Chapter 2. Thinking and Acting Ecologically

2.1 Introduction

The previous chapter provided an overview of the research. It outlined the experiences I had gained as a student and as a secondary school science teacher and suggested that this background had influenced the way I acted and thought throughout the research process. I proposed that the education system I had experienced was founded upon an epistemology that viewed knowledge as objective and knowledge generation as linear. This dominant way of thinking had been founded upon a worldview of science which is predicated on the search for absolute truths. I advocated that an inculcation into this worldview and lack of criticality into my own practice had ensured a replication of this form of education which the students encountered during Cycle 1 of my practice and subsequent research.

According to Bourdieu, individuals are socialised into a habitus which is the culture and ways of thinking of the society in which they develop. Wacquant describes habitus as; “the way society becomes deposited in persons in the form of lasting dispositions, or trained capacities and structured propensities to think, feel and act in determinant ways, which then guide them,” (Wacquant 2005, p. 317). In Bourdieu’s own words it is; "society written into the body, into the biological individual," (Bourdieu 1990, p. 63).

This chapter outlines the habitus in which I was schooled and the education system within which I studied and worked. It will identify the historical context in which this research is situated and by doing so present justifications for how I conducted my practice. To do this it will draw upon theoretical frameworks which propose that a misconception of western science has resulted in the celebration and replication of non-ecological epistemologies and that these have been accepted as the dominant way of thinking across most aspects of western society. In particular, it will highlight Descartes’ division between mind and body and therefore mind and nature. It will demonstrate how this division has created a disconnect between the two. It will also suggest how a Newtonian view of science has reduced the perception of how the universe operates to that of a machine where little regard is given to the symbiotic relationship that humans have with the biotic and abiotic aspects of the biosphere. The result of this has been the overriding perception that nature is an object that can be controlled and dominated.

Parts of this thesis will therefore introduce a particular focus on the effect this worldview has had on western schooling systems and how specific forms of knowledge are promoted and the subsequent curricula produced to achieve this. It will make suggestions that these types of education systems have created the detachment between many humans and the planet which has resulted in the current planetary crisis. It will be argued that any form of education which attempts to improve planetary well-being while operating within a system that fails to challenge and change such epistemologies may result in the production of students that are; “ecologically illiterate,” (Orr 1992, p. x). This chapter will propose that the first step towards improving planetary well-being is to develop ecological thinking (which draws upon the work of Capra 1996; Capra 2005; Sterling 2005); a way of thinking which perceives the world as a form of interrelating patterns and one that appreciates the mutualistic relationships involved in an act of becoming.

As part of challenging dominant non-ecological epistemologies I suggest that a reconceptualisation of science is a requirement of any future science education and science teacher education. This chapter will focus on science as a transformational and generative process; an ecological act. It will recommend studying the history of science to demonstrate this. It will challenge the notion that scientific enquiry is capable of producing absolute truths. In doing this it will draw upon examples from science (such as quantum theory and spacetime) which contest its ability to be objective. I will suggest it is useful to adopt Feynman’s (1998, p. 27) attitude that; “scientific knowledge is a body of statements of varying degrees of certainty — some most unsure, some nearly sure, but none absolutely certain.” I propose, therefore that an additional role of science education is to help others gain an understanding that there is no finite point to knowledge generation and science should be promoted as a process of asking questions, developing and sustaining curiosity and not solely of finding answers.

The discussions surrounding the interrelated nature of developing ecological epistemologies and reconceptualising science will provide the theoretical backdrop and justification for an ecological approach to science teacher education. These discourses will also include matters to do with curriculum. The chapter will recommend that any endeavour to develop an ecological way of thinking must be grounded in a curriculum which is founded upon aims instead of objectives (similar to that proposed by Reiss and White 2013) and that the developmental process is celebrated before any specific outcome (Stenhouse 1975). While these forms of curricula are often referred to as process curricula (Stenhouse ibid) I suggest that these too are ecological in nature. This author’s vision that curriculum research and the teacher’s personal research are intertwined supports this. While Stenhouse alludes to the form of teacher-interactions which should be developed I will also draw upon Buber’s (1958) ideas about educational relationships to suggest a way of working necessary to implement this type of curriculum.

Alexander's (2008) definition of pedagogy will provide a focal point to frame the related aspects of my ecological practice. He refers to pedagogy as the; "act of teaching together with its attendant discourse about learning, teaching, and curriculum," (2008, p. 3). This view of pedagogy helps to assimilate the themes of this thesis and demonstrates the relational nature of ideology, epistemic and ontic standpoints, curriculum content and the manner in how I worked with students. By doing this I will outline an ecological approach to science teacher education.

2.2 The dominant perception of science and its influence on how we think

This section will address the claim I have made throughout this thesis that the habitus I was socialised into was premised upon a particular worldview of science. It will briefly outline how a particular model of science which I term Newtonian science, one that adheres to a belief-system which promotes value-free knowledge and has the capability to produce absolute truths, has become the dominant perception of how science operates and therefore how scientific knowledge is generated. It will suggest how the previous successes premised on this model have further strengthened beliefs in the forms of knowledge it can produce and has thus been adopted as the dominant way of thinking in much of the modern world.

Toulmin (1990) proposes that much of western thinking has been generated through the methods of Newtonian science and the logic and epistemology of Descartes. Descartes' radical division of the universe into mind and matter implies that reality exists as a separate identity independent of how we think. This false dichotomy, between subject and object, created both an ontological and epistemological disconnect between humans and the natural world which is still being perpetuated today. This division signalled the separation of values from facts and heralded the search for absolute, objective truths and a quest for certainty (Capra 1991). Skolimowski (1994) suggests that as a consequence of this schism the physical has been exalted while the spiritual suppressed with Orr (1992, p.138) arguing that; "what one knows is assumed to have little or no bearing on what or who one is." Russell (1956) suggests that this way of thinking, which has dominated our society, has been left unchallenged and therefore become so ingrained that it is now considered common sense.

In addition to this value-free approach to knowledge acquisition, Descartes suggested that complex phenomena could best be understood through an analysis of a system's constituent parts. This approach advocates that the behaviour of these parts can subsequently be used to determine a phenomenon as a whole. Newton's scientific successes appeared to confirm Descartes' reductionist ideas by demonstrating that; "the universe is considered a sort of mechanical clock, moving according to well-defined deterministic laws," founded upon mathematics (Skolimowski 1994, p. 133). Both Newton and Descartes believed that knowledge could be gained objectively through empirical observation of physical phenomenon in a real world 'out there'. They proposed that it is possible to comprehend reality through the methodology of science and specifically through the discipline of physics. Midgley (1992) points out that if this view is subscribed to then scientists are not only objective in the ways that they produce knowledge, but as a consequence, nature must be objective too. This mechanistic view of observing reality set the standard for most of modern-day science and therefore provided the dominant perception of the scientific process. Capra (1996) highlights that the progress of science can be seen in the further reduction and analysis of a system's parts with its effect being the intense specialisation of scientific disciplines.

Within this mechanistic framework, science has ensured that huge advances have been made in human welfare and because of this it is easy to appreciate why such a privileged status has been afforded the discipline. Waddington (1941, p. 170) demonstrates how it is now perceived by some that;

> Science by itself is able to provide mankind [sic] with a way of life, which is, firstly, self-consistent and harmonious, and, secondly, free for the exercise of that objective reason on which our material progress depends. So far as I can see, the scientific attitude of mind is the only one which is, at the present day, adequate in both these respects. There are many worthy ideals which might supplement it, but I cannot see that any of them could take its place as the basis of a progressive and rich society.

It is worrying that often little critique is given to the devotion placed in such knowledge and the method by which it is produced. In fact, Chalmers (2013) and Skolimowski (1994) have noted that, in many cases, science has replaced religion as the new faith. Okasha (2002, p. 121) argues that scientists are now often perceived in a similar way to religious leaders from the past in that they are; "possessors of specialized knowledge that is inaccessible to the laity." Interestingly though, despite our acknowledgement of the many deleterious effects of science and its subsequent technological dangers, it has not really altered our perception of its importance and; "the main anthem is still one of praise," (Midgley 1992, p. 3).

2.3 The effect of the dominant science view on society

In the previous section it was suggested that the many successes of science have resulted in the idolisation of a certain way of thinking. It highlighted that such a particular worldview contributed to the objectification of the natural world. I initiated the suggestion that as a result of this that many humans have become epistemologically disconnected from their natural environment. The following section will briefly demonstrate how this detachment has manifested itself in the commodification of the planet and the ramifications this appears to have had on western society's education.

2.3.1 The influence of scientific epistemologies on education systems

The previous section suggested that a particular Newtonian scientific epistemology had been appropriated as the only way of thinking in much of the modern western world. Understandably, education systems will replicate these epistemologies in the way they operate and the knowledge they promote. The following section will seek to make connections between this way of thinking and how it is evidenced in practice. I will suggest that there is a celebration of objective and absolutist knowledge and knowledge generation processes which have culminated in industrialised education systems. These are premised upon business models which rely on specialisation and an assessable form of knowledge.

Kelly (2009) advises that curriculum planning (and for this I concur with Young 2014 who states that the term curriculum can often be interpreted as the purpose of education) is never value-neutral and reflects the ideological stances of the society within which it is subsumed. He supports my previous argument that the scientific worldview has influenced all areas of society when he suggests that many current curricula are based upon an objectivist and rationalist view of knowledge. He synthesises links between education, the scientific method and industry and refers to curriculum planning as; "the kind of precise, scientific methods that had begun to yield dividends in other spheres of human activity and especially in industry," (Kelly 2009, p. 68).

This standpoint is subsequently translated into a curriculum which focuses on content and the transmission of facts. These content-based curricula (Elliott 2007), which are analogous to technically-orientated syllabuses (Kelly 2009) have the additional function of training students as a potential workforce. Elliott (2007) notes that content-based curricula, based on prevailing scientific epistemologies, are produced to teach for exams and they separate 'ends and means', with the former driving the latter. In this case, the 'ends' are a specified value-laden set of propositional knowledge which can be tested at the 'end' of schooling. The 'means' are a curriculum and a style of teaching and learning which reinforces the significance of such knowledge. Kelly (ibid) asserts that this results in a linear depiction of knowledge acquisition.

Reiss and White (2013) suggest that while current curricula may have lists of overarching aims, these camouflage the hidden content driven nature of them. They propose that these aims have been 'tacked' on to historic structures whose purpose have never been challenged. This has resulted in specialisation of subject matter and curricula which contain a narrow number of specified but uncontested discrete learning disciplines. This is akin to the process which has occurred in the field of science, whereby the natural unbounded relationship between separate disciplines is often ignored. The effect of this is to stratify and reify certain ways of thinking with high status being assigned to absolutist knowledge. Science (including its often separated three sub-disciplines; biology, chemistry and physics) has been ascribed this prestigious position. In section 2.4.2 I will outline how learning about planetary issues has been perceived as low status knowledge and is often viewed as a tokenistic add-on within many schools. I will argue that this is because of the false dichotomy between learning and living (Orr 1992).

A reflection of these curricula and adherence to training young people as a workforce can be seen in the assessment systems that have been adopted. Gipps (2004) states it is a universally held view that governments link economic growth with educational performance and see the passing of exams as a measure of this ability. As a consequence, this has resulted in an education system which is fixated on the forms of knowledge which are testable, the type of curricula which are produced to accomplish this and the performance of the teacher or school in achieving good test scores. This provides a top-down accountability system which only requires teachers to be ‘successful’ at replicating someone else’s curriculum. In the same way that knowledge has been detached from mind the curriculum has been separated from those that teach it. This technical rational model of pedagogy has been described by Alexander (2008) as teaching divested of the relationship between the classroom and the wider world. Issues related to this will be revisited and developed in Chapter 4 when a call for teacher empowerment will be made with suggestions that this can be achieved through a critical view of pedagogy.

Stobbart (2008) acknowledges that the exam grade is valued far more than what is learned or the learning process that has taken place. Clear parallels can be seen between this linear epistemology and the cradle to grave model of industry (Braungart & McDonough 2002). From this standpoint, knowledge can be perceived as an object, something which can be commodified, in the same way as nature has been. Such assessment schemes rank relative performance instead of describing meaningful learning with students being labelled as either winners or losers. The values and processes of the business world are being transformed into the epistemological values of the education system. As Bourdieu (1990) has pointed out, schooling of this sort socialises learners into the dominant culture; Stobbart (2008) adds that assessment systems have the capacity not only to determine what and how we learn but also to shape and create learner identities.

2.3.2 The influence of education systems on shaping my view of science and science education

The previous section addressed how a particular Newtonian scientific epistemology has manifested itself in education systems and as a consequence the subsequent high status that value-free and objective knowledge has been afforded. The following section will draw upon these ideas to provide justifications for the Newtonian model of science I adopted throughout my educational experiences. In doing so it will provide a context for my thinking as I initiated this research and provide an understanding of why and how I viewed and taught science.

Reiss (2007) notes that there is a vast array of aims for school science education. However, he suggests in reality that these are usually underpinned by the general assumption that the learning of set science knowledge is the overriding purpose. As a consequence, planning a curriculum proceeds with the unproblematic view that science content is the drive for such a science education (Reiss & White 2013). While I propose that I was aware there were other purposes for learning science the following section will make suggestions for why I still conformed to a misguided view of science as a linear process which provided incontestable facts.

My time as a student, in school and at university, was mainly spent studying specialised science subjects; botany, chemistry and zoology. The focus of my grammar school was to prepare students for entry into higher education. During the economic difficulties of the late 1980s it was argued that 'qualification chasing' was the key component to securing a job. This resulted in 'qualification inflation' (Dore 1976 in Stobbart 2008, p. 90) whereby higher exam grades were deemed an advantage in this selection process. This was a view that my school, parents and I subscribed to and I did everything I could to achieve the best possible exam results. During this time, I was taught in such a way that I viewed science as infallible and assumed that the; "value of science centres on never making a mistake – on precision, specialisation and infallible correctness," (Midgley 1992, p. 5). As far as I was aware the curriculum I followed did not require questioning the tentative nature of science knowledge. To be successful in my science exams and therefore to become a good scientist it was necessary for me to replicate these facts. I was good at doing this. In addition to this, studying a degree in Biological Sciences at university did not change this viewpoint that I had inherited from learning science at school.

There are many parallels between how I believe science education proceeds and how Kuhn (2012) describes how science knowledge develops. Kuhn (ibid) ascribes the term 'normal' science to a period of time in which scientific ideas are relatively stable. He argues that during this epoch scientists tend to agree on the theoretical and methodological frameworks within which they work resulting in a unified scientific outlook. I consider that, during my time as a student, the science education community was in a state of 'stability' with the dominant discourse being, as mentioned earlier, of promoting scientific realism. Feyerabend (2010) also provides an explanation for how I initially perceived my role as a science educator. He posits that the education system is about making science appear uniform and objective resulting in the simplification of its parts. In agreement with Kuhn (2012) he also states that little regard is given over to developing an understanding of the historicity of the scientific process and this has had the effect of stabilising scientific facts which are subsequently viewed as independent of; "opinion, belief and cultural background," (Feyerabend 2010, p. 11).

It is with this particular scientific epistemology, coupled with the belief that 'qualification chasing' was important to an individual's economic prosperity, that I entered the teaching profession. It is easy to envisage how, without the tools of critique, I helped to replicate the existing system. By doing this I assisted in confirming the legitimacy of normative epistemologies through helping my pupils to be the most competitive they could be. As has been mentioned previously it was my role to help children achieve the highest grades possible in their science examinations (GCSEs). Teachers who could help their students achieve high grades were not only greatly respected, but also held accountable for such achievements. This form of accountability was, and still is, underpinned by a number of factors. Since the mid-1990s there has been a legal requirement to publish GCSE results so that parents can make comparisons between schools. Schools are ranked based on these results in league tables. This implicitly demonstrates the economic worth or value for money that a school or individual teacher can deliver. In addition to this, Ofsted made judgements about how good individual teachers were in this 'grade-achieving' process. Being graded highly for this ability only served to strengthen the linear and propositional epistemology I promoted and to which I subscribed. As a consequence of this success, there was no need for me to question my approaches to teaching science. While I believed that I was a reflective practitioner this was only concerned with the 'act of teaching' (Alexander 2008) and did not necessitate a critical interrogation of the dominant ideologies which influenced the curricula I taught from.

2.3.3 The influence of education systems on how the planet is viewed

The following section will outline the influence that education systems, premised upon Newtonian epistemologies, have had on many humans' relationship with the natural world. It will suggest that the objectification of knowledge has resulted in the objectification of the natural world and that this has manifested itself in an ontological and epistemological separation between humans and their planet. It will briefly demonstrate how this disconnect has exhibited itself in the commodification of the planet and the subsequent deleterious consequences this has had on the Earth's well-being.

Orr (2004) provides assertions, similar to those from the previous section, that a particular perception of science has caused the fragmentation of reality, an understanding that the universe is mechanically operated, and the belief that humans have domination over the planet. Bacon was influenced by Descartes' division of mind and matter and as such influenced the prevailing belief that humankind could; "conquer and subdue nature, [to] shake her to her foundations," and; "discover the secrets still locked in Nature's bosom," (cited in Soble 1998, p. 207). Heisenberg proposes that at the time of Bacon and Descartes there was a shift in attitude and it became a question of not being; "interested in nature as it is," but asking; "what one could so with it," (1989, p. 136). In essence, there was an advancement from understanding how the planet operates to one of technicality and consumerism.

Porritt (2005, p. 85) notes, as a consequence of this, that society's desire is; "to transmute every aspect of the environment into a commodity which can then be bought and sold like any other commodity." Many products are designed and produced using a one-way cradle to grave model mentioned earlier, where; "resources are extracted, shaped into products, sold and eventually disposed of in a 'grave' of some kind, usually a landfill or incinerator," (Braungart & McDonough 2002, p. 27). This conquest over nature (which has mainly been driven by the abundant energy provided by fossil fuels) has resulted in vast economic gain for certain countries and individuals throughout the world. Since the end of World War 2 there has been an increase in individual materialism which has led to the fixation that economic growth, founded upon the exploitation of the planet's resources, is the answer to solving current world problems (Porritt 2005). In addition to this drive for economic growth, Heisenberg (1989) comments that the form of science itself is self-perpetuating. He suggests this is due to the interplay between 'natural' and 'technical science'. He proposes that the invention of new tools and technical devices have delivered more accurate and empirical ways of observing natural phenomena. In turn this newly gained knowledge of the natural world is being applied to the realm of technical science.

It is wholly understandable that education systems will reflect this worldview. Offei Manteaw (2008) states that the language and values of education are in line with a fixation on economic growth with Apple (2006) arguing that students are now positioned as human capital. This means they are viewed simply as a potential workforce who should be trained with the necessary skills and attributes to compete in a materialistic marketplace. Apple (2000) also notes that any attempt to finance schools whose goals are anything other than economic is deemed suspicious. Any action to derail this economic vision is viewed as heresy and suggestions to critique the underlying epistemological assumptions are seen as radical.

In order to produce a workforce trained for such an economic marketplace it has been necessary for the education system to mimic the industrial process. The following sub-section will propose that the same scientific epistemologies which have influenced business also underpin western education systems. It will highlight the forms of knowledge which are promoted and perpetuated as a result of this.

2.4 The influence of education systems on learning about planetary issues

In the previous sections I have argued that the success of certain scientific endeavours has promoted a worldview which celebrates the objectification of knowledge and the Cartesian separation of mind versus body. I have suggested that this artificial disconnect has resulted in the lack of understanding of the symbiotic relationship humans have with the planet and that this has led to the current predicament which the Earth faces. I have proposed that the education system I experienced, premised upon the aforementioned epistemologies, had a direct effect on the type of teacher I became. I appreciate that I assisted in replicating this worldview through the way I was misrepresenting the process of science and the forms of knowledge which it can produce.

This section will now turn to reporting how and why these education systems ascribe a particular status to the subjective knowledge related to planetary well-being. It will also briefly outline the relative lack of progress gained through years of environmental education and return to the premise outlined in Chapter 1 that; "if still more education is to save us, it would have to be education of a different kind," (Schumacher 1997, p. 54). By doing this it will provide a justification for the lack of success of the curriculum for ecoliteracy in which I engaged with the students. This is borne out by Sterling (2001) who states that environmental education taught within the current mechanistic schooling paradigm, however worthy, will achieve nothing to improve planetary well-being. Kahn concurs with Sterling and points out that; "the field of environmental education has been altogether unable to provide either solutions or stop-gaps for the ecological disasters that have continue to mount…over the last few decades," (2010, p. 6). I have already suggested in Chapter 1 that I was entrenched within this mechanistic way of thinking during Cycle 1. Gradually I became aware that I was part of what Kahn (ibid) coins 'a crisis in environmental education', and that this was because of my lack of understanding and therefore an absence of developing ecological thinking.

2.4.1 The limited success of learning about planetary issues

I have previously highlighted how the Cartesian dualism between mind and body has influenced the perception of relationships with the natural world. In particular I discussed how this artificial disconnect has been translated into the commodification of the planet and, in turn, how education systems have evolved in order to reflect this. The following section will draw upon this context in order to explain the relative lack of progress made from over fifty years of environmental education. It will suggest that, despite a greater focus on learning about environmental issues, the effect has been minimal. It will propose that there is even contention around whether an increased exposure to such issues has had any effect in gaining greater knowledge *about* planetary issues. Regardless of this, research advises that for many, it has only evoked superficial changes of habit which require minimal commitment or effort.

The following will propose, albeit tentatively that environmental education to this date has been relatively ineffective. It is important to note that the reports used to provide the predominant argument for this stance have come from countrywide research from the United States (Coyle 2005; National Environmental Education Foundation 2015) which attempt to make a connection between environmental education programmes and the effect these may have had on the population's attitudes and behaviour towards planetary well-being. Any suggestions taken from this therefore must bear this is mind. While I recognise that this does not provide the specific context in which this research is situated I will suggest that it is indicative of what is occurring in the UK and in many other areas of the world. Whole scale reports such as those outlined below do not appear to have been carried out in the UK. Bamber, Bullivan and Stead (2013) emphasise this suggesting that the evaluations of the effects of initiatives concerned with sustainability and global education are still in their infancy.

A review of current international literature suggests that there is limited research specifying how developing an ecological way of thinking may influence a participant's perception of their relationship with the planet and their actions towards it. While Liu and Lin (2014) provide an example of such an enquiry it should be noted that it only refers to a small-scale research project with 29 participants. I therefore contest that such research is not representative of what is occurring in most education systems.

The National Environmental Education Foundation compiled reports in 2005 and 2015 (Coyle 2005; National Environmental Education Foundation 2015) which summarise a range of research into the success of environmental education in the United States within the periods preceding the publications. There is a lack of consistency in focus and criteria between both reports making it difficult to make comparisons. However, worryingly, while they both highlight the 'good' work being undertaken, they propose similar findings to those suggested by Kahn (2010) that little seems to have occurred to the overall improvement of the population's actions towards the planet.

The 2005 report (Coyle 2005) showed initial promise that greater knowledge about planetary well-being seemed to lead to greater pro-action in environmental behaviour. However, this was tempered by the finding that this increased knowledge only produced simple positive behaviours such as those related to saving water and electricity. It is proposed that this is because only a small commitment is required for these changes in behaviours and only a small disturbance to the participant's way of life is required. It was also suggested that these behaviours can be brought about through a surface understanding of the issues which the planet is facing. This also seems to be supported by research cited in the 2015 report (McBeth & Volk 2010 in National Environmental Education Foundation 2015) which states that older children, while having increased environmental knowledge, are not more likely to have greater sensitivity to planetary well-being nor a commitment to action above and beyond that stated earlier.

There appears to be contradictory information about the improvement of the nation's planetary understanding. Leiserowitz, Maibach, Roser-Renouf, and Hmielowski's research (2012, cited in National Environmental Education Foundation 2015) suggests that Americans' knowledge is not as good as was claimed in the previous paragraph. While they specifically refer to knowledge about climate change I suggest that this provides a fairly accurate guide in relation to the United States' understanding of all of the complex aspects of planetary well-being considering this is often the most cited of environmental issues.

Comparable findings have also been replicated in other countries. Despite the Australian Government introducing a national initiative (Australian Government 2009, cited in Dyment & Hill 2015, p. 23) which positioned education at the centre of establishing a sustainable future, Dyment and Hill's research of starting teachers indicates that this had had only a limited to moderate effect on their understanding of issues concerning sustainability and global development. Bamber, Bullivant and Stead (2013) have highlighted in the UK that learning about such matters has also been a feature of many secondary schools especially since 2000. Yet Mintz (2006) provides evidence that many future primary teachers (such as those I was working with) had significant misunderstandings regarding three specific planetary aspects. While I argue in Chapter 6 that much of the work carried out during Cycle 1 was related only to awareness raising and the learning of planetary facts it is clear that this is still an important aspect of a trainee teacher's education. The following section will provide reasons for why many of the students from Cycle 1 displayed similarly poor subject knowledge to those reported by Mintz (ibid).

2.4.2 The lack of status afforded to learning about planetary issues

The previous section has highlighted the lack of progress in influencing positive change towards planetary well-being despite an increased exposure to learning about the predicament the planet is facing. This section returns to the premise outlined in Chapter 1 that; "if still more education is to save us, it would have to be education of a different kind," (Schumacher 1997,

p. 54). It will suggest that it is the mechanistic process of education and the objective forms of knowledge which are promoted that have ensured that minimal development has occurred. I have argued previously that subjective forms of knowing, which include caring and conserving and the need to think in terms of patterns and relationships, are necessary for an understanding of how the planet operates and to influence any changes in behaviour. This section will suggest that these relational epistemologies are currently shunned and knowledge about planetary issues is therefore assigned as low-status.

The following section will propose that, despite the vast evidence of humans' negative effect on planetary well-being, learning about planetary issues is often perceived as a low priority and because of this is often not included in relevant curricula. I have previously highlighted how in England, any reference to environmental matters has been removed from the National curriculum until the age of 14 (DfE 2013). The imposed content of this government-stated school curriculum gives credence to the argument highlighted in Section 2.3 that the purpose of any education is to train students for a workplace. Offei Manteaw (2008) suggests that there is a distinction between high and low-status knowledge. He outlines that high-status knowledge is anything that is seen to promote economic growth and technological progress. Low status knowledge is perceived as being noneconomic and is either prohibitive of this or does not benefit it. I wrote in Chapter 1 of personal experience that knowledge relating to planetary well-being is often perceived as low status; this was related to my work as a governor in assisting the school to become a sustainable school (DCSF 2006). Following a change of legislation and the removal of the need to obtain sustainable status all the work that I had completed with the school was abandoned. I was informed that this was because there would no longer be a focus on sustainability in any future school inspection.

Where sustainability is included in curriculum content there is often an inconsistent approach to teaching about it and, in many cases, it is reliant on interested individuals to drive the agenda (National Environmental Education Foundation 2015). While there are many consequences of the lack of status afforded to this form of knowledge and knowing I suggest that the basic lack of exposure to these ideas provides one explanation for the students' poor understanding of how the planet operates.

While it has been argued that learning about planetary well-being can either be absent from certain curricula or have poor coverage, Orr (1992, p. 90) argues that; "all education is environmental education. By what is included or excluded, emphasised or ignored, students learn that they are part of or apart from the natural world." Therefore, due to the low-status that knowledge about planetary well-being is currently ascribed, students are implicitly taught that it is not important. Orr (ibid) also includes the hidden curriculum that students experience.

If an institution promotes the importance of understanding waste yet provide non-disposable cups for a water fountain the unspoken message is that their espoused values are not lived out in their actions. A clear example of this was provided by a school whose assembly drew attention to the issues to do with sending waste to landfill and the promotion of recycling. The following week information about a school trip was received outlining the need to provide lunches in disposable bags which was in complete contrast to the school's prior declaration.

Another reason for the low status ascribed to learning about planetary issues is the subjective nature of the forms of knowing which are required and the status ascribed. Both Orr (1992) and Stirling (2003) have argued that the development of care and conserving should be one of the core aims of any future curriculum. The relational and subjective nature of caring is in antithesis to many current schooling systems. Skolimowski (1994, p. 47) expounds this and asserts that the western education system claims; "to be objective and value-free and support(s) a view of the world in which the physical is elevated and the spiritual suppressed; in which the values of objectivity, rationality and efficiency are constantly upheld, whilst the values of compassion, empathy and altruism are ignored or SUPPRESSED (author's emphasis)." Hicks (2010) gives a specific example of this when he overheard a participant asking whether his workshop on global issues would be 'touchy feely' or not. In his words this went to highlight the; "200 year distinction between head and heart, intellect and emotions," (Hicks ibid, p. 10) promoted by Cartesian dualism. He further discusses how a colleague was not interested in the 'affect' only the 'intellect' which further demonstrates the detachment of emotion from learning.

2.5 Challenging the dominant scientific epistemologies by developing ecological thinking

The previous sections in this chapter have highlighted how a particular way of thinking, premised on a particular model of science, has promoted the perception that knowledge is linear, objective and static. Throughout this I have argued for the need to develop relational epistemologies, which I have termed ecological thinking, which can challenge the dominant ways of knowing. This next section will define in broad terms what comprises ecological thinking and provide examples of how this might be developed in an educational setting and how it might relate to the methodology that underpins this thesis. It will contrast how this relational way of thinking differs from the aforementioned dominant scientific epistemologies.

In order to define what an ecological epistemology is I draw upon Capra's (2005) and Sterling's (2005) frameworks of relational thinking (Capra defines this as systems thinking and Sterling as Linking Thinking). Capra (2005) argues that to develop an ecological way of thinking five interrelated facets should be considered. Sterling (2005, p. iv) suggests that this type of epistemology is simply premised upon; "thinking about the nature and consequences of relationships," and about focussing on making connections rather than distinctions. What should become apparent is in opposition to the current western education system which has been outlined earlier in this chapter and favours more fragmented forms of knowledge. Throughout this section I will use Capra's (2005) aspects of systems thinking and transform them into educative principles which do not only apply to learning about the natural world.

1. *Studying the whole and not the parts*. This is unlike reductionist science and school learning where the object is to separate and understand repeatedly smaller and more abstract aspects; an ecological epistemology values the system as a whole and recognises that the whole is more than the sum of its parts. Senge (2006) postulates that our current ecological and social problems are in direct proportion to our inability to comprehend the Earth as a whole. In relation to the global picture of learning and studying I believe this requires an understanding that science can be seen as a set of interrelated ideas. This is best explained by Harlen (2010) who suggests that understanding the 'big ideas' of and about science (the whole) may help students to move away from the perception that it is a disparate collection of discrete knowledge (the parts). The 'big ideas' will be detailed further in Section 2.7.1.1.

   At this point it is worth briefly referring to the methodological issues related to this thesis. Pring (2001) suggests that classrooms are fluid, dynamic and emergent places determined by the interactions and relationships of the 'actors' involved and the environment in which they are situated. Over time, context-specific hidden and tacit rules have been negotiated which determine how the class acts. These connections are determined by the value-systems of all those involved (Pring ibid). Learning and teaching is therefore always a value-led activity which builds upon the relationships developed within a setting. Pring (2015) believes that the main aim of educational research is to identify the forms of 'transactions', which I interpret to mean relationships, between the teacher and his student which can best help the learner to develop – this was one of the key components for developing my mutualistic practice. I suggest that it is not possible to do anything but study the 'whole' when trying to make sense of the interactions within my classroom.

2. Capra (2005) also promotes the *study of relationships and not objects.* The previous paragraph recommended that when studying science children should be helped to make links between the differing areas of science which, I argue, is an example of studying relationships. However, I also believe this can occur at an even deeper level.

Much of science's primary aim is to do with classifying and grouping even within the same subject area. Bateson (1979) suggests otherwise and uses the study of leaves to exemplify what a study of relationships might entail. He says that to define a leaf as flat and green is to objectify it. He suggests the leaf should be studied in relation to the other parts of the plant and could be defined as; "a leaf is that which has a bud in its angle," (Bateson ibid, p. 8). I argue that this form of learning may play a role in helping children to move away from viewing the forms of knowledge that science produces as objective. In addition to the importance of promoting a spatial understanding of the relationships between objects I suggest there is also a temporal aspect. The issue that knowledge is both generative and transformational over time should be celebrated. That scientific ideas have changed over time can be used to demonstrate this and reinforce the dynamic nature of such knowledge. By developing an awareness of this aspect of knowledge generation I believe that a culture which celebrates uncertainty can be cultivated.

3. *Contextual knowledge and not objective knowledge*. This suggests that using the real world as a basis for learning is of great importance. By inference, if a real-world learning context is employed then this will understandably occur in an area local to the learner and a greater understanding of how one is related to their locality may also ensue. As part of developing ecological thinking I propose that there is a need for humans to reconceive their ontological connection so that they view themselves as part of the natural world and not as separate from it. Orr (1992) has suggested that ecoliteracy draws upon indigenous epistemologies. While these forms of epistemologies embrace all of Capra's facets of systems thinking it is an understanding of place which is of relevance here. David Peat (2005, p. 27), referring to indigenous Native Americans, suggests that they have an; "alternative view of space, time and causality." He outlines that the primary focus is not of the individual but of their relationship as a group and with the environment within which they live. The way in which knowledge is learned, is entwined with both people and place and therefore becomes inseparable. This contextual knowledge may be difficult to replicate fully within many western education systems but there is research to suggest (Sobel 2013) that direct contact with nature is vital in countering a disconnect between children and their local natural community. Meaningful science learning that can occur in the outdoors may provide the first-hand learning and contextual experiences which Capra (2005) and Orr (1992) are calling for.

These contextual experiences are also relevant to the methodological approach of my research and the forms of knowledge most valued. I suggest that it is not possible for an ‘outsider’ researcher to visit places such as the classroom and make professional judgements on proceedings without an explicit understanding of the dynamics in operation. First-person action research emphasises the importance of tacit, and therefore contextual knowledge (Polanyi 1958) and an ecological ontology which decrees that the person best placed in the research process to explain actions are the individuals within their own context. I understand that from this ontological and epistemological stance; “knowing becomes a real-life practice,” (McNiff 2014, p. 51). I suggest these personal theories are ‘living theories’ because they are; “embodied in [mine] yours and other learner’s living practice,” (Whitehead 1989 p. 145). They are living and dynamic because these theories are in a constant state of emergence needing modification in light of new experiences (Whitehead & McNiff 2006).

4. *Quality over quantity*. This is a reaction to an education system which is assessment driven and which reifies what can be measured and therefore quantified. The assessment of relationships and context cannot be measured in the same way. With regards to my practice I hope that the non-measurable aspect of developing mutually respectful relationships with the students provides another barometer for how successful my work with them has been.

5. *Process is more important than structure*. Capra (2005, p. 21) broadly defines this as an; “understanding of living structure [which] is inextricably linked to understanding renewal, change and transformation.” While I concur that there is a need for students to gain an understanding of this aspect of ‘process’ I believe that there are other areas of educational importance that this can relate to. I have previously highlighted the significance of studying the history of science to demonstrate how ideas have changed as more evidence has been accrued. I have related this to the importance of studying temporal relationships. In addition to this, ‘process’ could also refer to a curriculum approach. Stenhouse (1975) promotes a curriculum which is transformational and developmental and focusses on the process of learning. This form of curriculum does not have a rigid structure comprising short-term goals (such as exams) and objectives but rather a set of principles and aims where process is valued more highly than the end result. The importance of this for developing a curriculum for ecoliteracy is recognised by Barlow and Stone (2005, p.6) who suggest there is no; “homogenised one size fits all curriculum.” This also relates to the methodology of self-study action research which is not premised upon hypotheses or achievable outcomes but on the process of studying whether an individual’s values are realised in their practice.

Both Capra (2005) and Sterling (2005) provide generic suggestions of how these facets may manifest themselves in education systems but much remains at a level of abstraction. I have added some detail in this section to outline how this might relate to science education and my practice. Section 2.6.2 will draw on these facets of ecological thinking and make recommendations for how science education can be utilised specifically to develop ecological epistemologies. However, before attending to science education, I will propose that there is another model to Newtonian science. This ecological model of science is premised upon the principles of ecological thinking highlighted above.

2.6 But what if we have got it all wrong? Challenging the dominant epistemologies by realising an ecological model of science

The previous sections have drawn upon the suggestion that the Newtonian model of science has resulted in the perpetuation of epistemologies that are linear, objective and static and that these are the dominant ways of coming to know in much of the western world. The following section will recommend that there is another model of science which does not conform to these epistemologies; an ecological view of science. Rather than promote the static nature of knowledge, which is often how science is portrayed in schools, it will highlight the dynamic nature of many current scientific ideas and demonstrate how they are in a state of transformation. It will challenge the overriding perception that knowledge is objective by proposing that an epistemology of ignorance is cultivated; one that promotes asking questions over finding answers. It will recommend that science and science education should be reconceptualised and by doing this can help to promote an ecological way of thinking.

2.6.1 An ecological model of science - celebrating uncertainty and ignorance

Kuhn (2012) provides an ideological concept which helps to frame the concept that scientific ideas change over time. He describes science as existing in two states; ‘normal’ and ‘revolutionary’. Previously I have outlined that ‘normal’ science tends to occur in a period where there is a general consensus within the scientific community around intellectual and methodological frameworks. It is an epoch where the ‘status quo’ is preserved and any anomalies from experimental data are explained through minor changes to the current conceptual frameworks. However, he argues that the accumulation of anomalies can generate enough dissonance so that old ways of thinking have to be discarded and a new (what he terms) paradigm be adopted. He calls this ‘revolutionary science’. The process when radically new worldviews replace the prevailing and dominant set of ideas is referred to as a paradigm shift. Kuhn (ibid) uses the example of the Copernican revolution, whereby the heliocentric model of the solar system replaced the geocentric model, as one such paradigm shift. The epistemological implications for this form of thinking are immense. Science can no longer be perceived solely as a set of immutable facts or about a search for an absolute truth.

Similar to Kuhn (2012), Firestein (2012) proposes that science does not progress via the slow accumulation of facts but through the acknowledgement of ignorance of the scientist and the scientific community and the desire to ask further questions. This was exemplified in a recent episode of ‘The Infinite Monkey Cage’ (a popular science podcast; The infinite monkey cage 2015, p. no page) when the presenter professed that; “one of the things that I find most often misunderstood about science is that research scientists are operating on the edge of the known and unknown.” The reply from the quantum physicist this was directed at highlighted how he embraces this lack of knowledge and reasoned this was because it gives him an opportunity to learn something new. Bronowski (Knowledge or certainty 1973, p. no page) echoes this when he states that; “every judgment in science stands on the edge of error and is personal. Science is a tribute to what we can know although we are fallible.” He also defines what a revolution might look like in schools when he clearly calls for a stop to the promotion of objective knowledge. Bronowski encourages learners to bring an; “irreverence to their studies,” arguing that; “they are not here to worship what is known,” (Knowledge or certainty ibid, p. no page). The sentiment of celebrating uncertainty is also reinforced by Feynman, arguably one of the most revered scientists of recent times, in this oft-quoted statement;

> I think it's much more interesting to live not knowing than to have answers which might be wrong. I have approximate answers and possible beliefs and different degrees of uncertainty about different things, but I am not absolutely sure of anything and there are many things I don't know anything about, such as whether it means anything to ask why we're here. I don't have to know an answer. I don't feel frightened not knowing things, by being lost in a mysterious universe without any purpose, which is the way it really is as far as I can tell.
>
> (The pleasure of finding things out 1981, p. no page)

The terminology that Feynman uses here is important as he discusses his understanding based on what he is unsure of rather than anything that is certain. Firestein embraces the premise of uncertainty and proposes that society, and therefore educational institutions, should challenge the dominant way of thinking by asking the following questions; “what if we cultivated ignorance?” (2012, p. 12) and; “can we construct an epistemology of ignorance like we have one for knowledge?” (Firestein ibid, p. 30). The implications of advocating for ignorance and how this could be incorporated into an ecological approach to my practice will be discussed further in Section 2.7.1.2.

2.6.2 An ecological model of science - challenging the objective nature of knowledge

The previous sub-section discussed the transformational nature of the knowledge that science can produce and the need to celebrate and promote ignorance. It provided evidence that knowledge should be viewed as tentative and with relative degrees of uncertainty (The pleasure of finding things out 1981). The following will develop this and challenge the perception that science is capable of producing absolute truths. It will do this by drawing upon examples from physics to suggest that knowledge is both subjective and relative.

Davies (1989) has suggested that in the first thirty years of the twentieth century there has been a paradigmatic shift in the perception of physics. This epoch of science was founded upon ideas from quantum theory and Einstein's arguments about relativity and, because of the radical ideas which were being proposed, has been dubbed by Davies as the 'Golden Age of Physics'. The claims brought about by these disciplines about the nature of reality were (and probably still are) so revolutionary that Bohr professed that; "if quantum mechanics hasn't profoundly shocked you, you haven't understood it yet," (cited in Hulsroj 2015, p. 60). Greene (2005) classifies the shift from classical Newtonian science to this as a paradigm change (Kuhn 2012).

The revolutionary science at this time challenged Newton's mechanical worldview based on the simple premise of cause and effect, which up until now had served science so well in explaining the laws of nature. Section 2.2 detailed how, because of the many successes of this model of science, that this way of thinking has become ingrained in many modern societies. However, Heisenberg, the renowned theoretical physicist, refers to this as 'dogmatic realism' and explains that those who subscribe to this view accept that; "there are no statements concerning the material world that cannot be objectivated," (1989, p. 43). He argues that quantum theory demonstrates that science does not need to rely on such a premise. Capra (1996) develops this further and suggests that the ramifications of this are not only relevant to science but also education and everyday life. He proposes that this particular branch of science, once believed to have total predictive powers and able to determine absolute truths, has given way to an ecological worldview.

While there is possibly no need to give detailed descriptions of the physics here it is important to give a brief outline to demonstrate how revolutionary these ideas were at the time. Einstein's theory of relativity (both special and general) challenged the nature of space and time which up until this point had, based on Newton's work, been thought to be absolute. Einstein demonstrated that both space and time are variable and, in fact, are not discrete entities; they are in relation with each other in a continuum known as spacetime. Quantum theory also throws up similar objections to an objective reality. A quantum particle can have both momentum and a position. However, unlike a moving object in the macroworld you can only observe one and not the other. In between observations it is not possible to determine its precise momentum or precise position. Davies (1989) suggests that it is the act of observing which creates the reality of this particle. In addition to this, the sub-atomic ‘element’ can exist as a wave or a particle. This again is determined by the observer. In response to whether these particles are waves or particles, Davies’ (ibid, p. xiv) response is; “neither and both.” According to Capra (1996), these particles also cannot be perceived as existing as discrete entities (much as space and time). It is only by considering the related nature and interconnectedness of the process between observation and measurement that these sub-atomic ‘elements’ can be fully understood. Capra (ibid, p. 53) consolidates this by indicating that; “in quantum theory we never end up with any ‘things’; we always deal with interconnections.”

The predictive power in the quantum world is also different from the classical Newtonian world of cause and effect. Because of the act of measuring and observing has an effect on outcomes (Colbeck & Renner 2011) it is only possible to make predictions based on probabilities and these are based on the relationships outlined earlier. These probabilities are what Feynman (The pleasure of finding things out 1981) has previously referred to as degrees of uncertainty. Importantly, where in classical physics the prediction is founded upon the reduction of evermore abstract phenomena, in quantum mechanics it is only possible to make generalisations about the whole system (Capra 1996). These differing models of what science can or cannot predict can be also seen within research based in the social sciences. This will be developed further in Chapter 4. This chapter will recommend that research into how humans may act or behave should not be founded upon the Newtonian model of science. This form of research treats humans as objects whose actions can be generalised and predicted. Instead I will suggest that research which hopes to explain humans’ behaviour, as exemplified by this thesis, should be premised upon the principles of ecological science which embraces the tentative and subjective nature of knowledge. This form of research values and seeks to identify the uniqueness of the individual and the relations developed during human interactions.

This section has challenged the classical Newtonian model of science and proposed that there is a differing model of science premised on ecological thinking and that this understanding could also be applied to research in the social sciences. The following section returns to science education and suggests that this ecological model of science can be used to reinforce the principles of ecological thinking which were highlighted in Section 2.5.

2.7 Using the ecological model of science to develop an ecological approach to science teacher education

This section will draw upon the ideas from the previous section which outlined how an ecological model of science, one which focusses on relations and connections and which views the process of knowledge generation as transformational, could be used as a basis to help reconceptualise science education and science teacher education. In doing so it will provide the context and justification for my claim that I have developed an ecological approach to science teacher education. It will seek to provide examples of how this can be achieved for students training to be primary school science teachers and whose expectations of their course may not be radically different to what they have experienced in school.

2.7.1 Using the science curriculum to promote an understanding of the relational and transformative nature of knowledge

This section will place an emphasis on the role that studying science can play in coming to an understanding of the relational nature of knowledge; both spatially and temporarily. I will advocate for the adoption of the 'big ideas' (Harlen 2010) as a starting point for syllabus content in order to help demonstrate the interrelated knowledge of many scientific ideas. In addition to this will be a recommendation that science teacher education programmes also focus on the nature of science. By doing so I will suggest that this will assist students in coming to understand how scientific ideas change over time and the subjective character of knowledge that is generated through science. In particular, I will recommend that a specific scientist, Alexander von Humboldt, is studied to reinforce these principles. I will argue that his way of thinking and carrying out science demonstrates an ecological epistemology. He is considered the 'father' of the environmental movement (Wulf 2016) and therefore provides the connection between a relational way of thinking (which I am suggesting can be nurtured through an ecological view of science) with the need to address concerns for planetary well-being.

2.7.1.1 Developing an understanding of the relational nature of scientific ideas

In Section 2.5 I outlined how both Sterling (2005) and Capra (2005) have suggested that there are a number of overlapping and interconnected facets of ecological thinking. This following section will draw on Capra's (ibid) suggestion that to develop ecological epistemologies there is a focus on 'studying the whole and not the parts'. He gives examples from the natural world to demonstrate this by stating that; "in systems, the relationships between individual parts may be more important than the parts. An ecosystem is not just a collection of species, but includes living things interacting with each other and their non-living environment." (Capra ibid, p.

35). However, I believe that this form of thinking can also be cultivated by helping students to appreciate the interrelated nature of *all* knowledge. In this instance it would be the interrelated form of knowledge specified in the science National Curriculum (DfE 2013) across all disciplines. Demonstrating these relationships would emphasise that science is founded upon a range of perspectives which all contribute to describing a world without artificial borders (Mutvei & Mattson 2015). There would be a recognition of science as a 'whole'. This is not the perception that many schools promote which sometimes can make the false distinction between the disciplines of Biology, Chemistry and Physics.

Millar and Osborne stated as far back as 1998 that the-then UK science curriculum presented; "science as a body of knowledge which is value-free, objective and detached – a succession of 'facts' to be learnt," (1998, p.8). Despite these concerns raised by Millar and Osborne (ibid), Harlen (2010) noted in 2009 that science curricula internationally still suffered from the same problems. She highlighted that overcrowded and fragmented curricula resulted in many students' perceptions of science being a corpus of separated and disconnected facts which did not necessarily help them to gain a deep understanding of how the world works. As I also have noted previously, she commented that older children believed the main purpose of learning science was to pass examinations.

Harlen (2010) has suggested that there are ten big ideas *of* science and four *about* science which can be used; "to explain and make predictions about a range of related phenomena in the natural world," (Harlen ibid, p. 13). She references the 'big ideas' as goals of science education which I believe could be construed as curriculum 'aims'. The progression towards an understanding of the 'big ideas' can be seen as both developmental and transformational and takes into account the learning of science from very young children to young adults. This mirrors Stenhouse's (1975) suggestion that curricula should be founded upon process and not fixed objectives (ideas related to curriculum as a process will be revisited in Section 2.9). At an early age, children should be able to understand the unique context-specific scientific experiences they encounter. As their scientific understanding progresses their experiences should help them to explain related ideas which become less context-specific**.** By doing this they should be able to draw upon the abstract 'big ideas' in order to explain a wide range of interrelated phenomena. The 'big ideas', therefore, provide a framework by which to demonstrate the related nature of scientific knowledge that I believe is necessary for ecological thinking. This would allow children and students to make the connections between different areas of the curriculum. Although not mentioned by Harlen (2010) this educative principle may also provide a more realistic impression of the multi-disciplinary manner in which many scientists work.

Prior to the current National Curriculum (DfE 2013), Millar and Osborne (1998) noted that there was a lack of consensus outlining how children would develop their scientific capabilities from primary through to the secondary phase of their learning. They argued that this resulted in primary teachers not having clarity about how the science that they had been taught would be developed in secondary schools. Conversely the secondary teachers found it difficult to know how to build upon the work that the children had already undertaken. There have been many bridging projects whose aims have been to unite primary and secondary school teachers and provide both continuity and progression for the children. Their format has mainly been as stand-alone activities. However, these have had little impact other than to aid the (important) transition of children from the primary phase into secondary education (Braund & Hames 2005). Symonds (2015) also notes there are no nationally agreed procedures for bridging projects and that recently far fewer schools are undertaking them.

Despite the National Curriculum (DfE 2013) providing clear progression in content and skills throughout the key stages (Allen 2016) it is still apparent that Millar and Osborne's concerns about the absence of a developmental model for science education are still current. I believe that this curriculum model can be provided by the 'big ideas' and concur with Harlen (2015, p. 11) who is convinced that; "learning experiences [which] are linked to key ideas can provide the understanding that all students need to make sense of what they observe in the world". While I appreciate that I have minimal influence over national policy I am aware of the authority I possess regarding decisions over the content of sessions in which the students participate. The incorporation of the 'big ideas' into teaching sessions would become another aspect of an ecological approach to my practice. I hope that it would help the students to appreciate the related nature of the science knowledge that they, and their children, would be learning and also support them in acknowledging the progressive and ongoing process which is undertaken in developing an understanding of the 'big ideas'.

Harlen (2015) notes a number of challenges that primary school teachers, and therefore the students, might be faced with when adopting this approach. The main challenge is due to the teachers' own experiences of school science education. As has been discussed in this chapter, and throughout the thesis, the dominant perception of science propagated by current forms of science education is of immutable and unrelated knowledge (Millar & Osborne 1998). It is easy to deduce from this that those that have had experience of such an education system may not have had the opportunity to develop ideas around the relational nature of science knowledge which the 'big ideas' promote. Harlen (2015) suggests that a second challenge is that the scientific activities which young children participate in usually only lead to an understanding of 'small ideas'; making connections to the 'big ideas' is often difficult and may seem tenuous.

Encouragingly it is proposed that the ideal is that all teachers have an understanding of the ‘big ideas’ (Harlen 2015) which I suggest can easily be developed with my students during their teaching sessions. A provision for the students to develop an understanding of the ‘big ideas’ will be made which will assist them in relating their own science knowledge across the different domains of science. Alongside this would be the chance to identify age-related learning activities which would initially be used to develop an understanding of contextualised ‘small ideas’ but which also show a clear connection to one or more of the ‘big ideas’. The statutory content specified in the National Curriculum for science (DfE 2013) outlines the key conceptual understanding that is expected but is not prescriptive of the strategies and examples that are used to achieve this. This autonomy affords teachers the flexibility to specify the learning context and therefore a choice of activity which has clear relevance to the ‘big ideas’. Interestingly, Harlen (2010) seems to suggest that at an early age of learning science it is enough for the teacher to be aware of how particular learning activities relate to the ‘big ideas’ even if this is too abstract a concept for the children. In addition to the teacher being able to justify the adoption of certain learning activities she argues that it should be obvious to an observer how these are connected to a ‘big idea’. Harlen and Holroyd (1997) identified that those teachers who lacked secure subject knowledge and confidence for teaching science used coping strategies such as following prescriptive texts and schemes of work from which to teach. I hope that by gaining a firm grounding of the ‘big ideas’ in sessions and by applying these in a practical manner that the students will feel empowered to take ownership of teaching science and not take such a dogmatic approach.

2.7.1.2 Developing an understanding of the temporal and transformational nature of relationships in science

As part of developing these ecological epistemologies I have highlighted how Capra (2005) suggests that there is a need to modify our thinking from ‘structures to processes’ and for the need to think in terms of ‘relationships and not objects’. I briefly stated that if viewed from the perspective of science education this could be demonstrated through an epistemological position that understands how scientific ideas change through time. The following will provide clearer guidance of what this might look like in practice.

As part of helping students to think in a different manner there is need for them to identify the transformative nature of scientific enquiry and how scientific developments proceed. This is often referred to as the nature of science. While I appreciate that the nature of science attends to issues pertaining to philosophy, sociology as well as history (Taber 2012), the National Curriculum for Upper Key Stage 2 only refers to one element of this which is that;

"Pupils…should also begin to recognise that scientific ideas change and develop over time," (DfE 2013, p. 24). To be assured that the teaching strategies used with students are relevant to their experiences in school I suggest this element from the National Curriculum is utilised as a way of addressing an understanding of the process of science. Issues surrounding the role of teacher education have run throughout this thesis. Questions about how closely the students' experiences should be linked to the curriculum they will teach in school are dealt with in Section 1.5, but I argue that this focus on a specific statement from the National Curriculum provides a valuable starting point. In addition to this the National Curriculum does not provide any guidance for how it is expected that this objective would be achieved other than the following two statutory statements;

> EARTH AND SPACE: Pupils should find out about the way that ideas about the solar system have developed, understanding how the geocentric model of the solar system gave way to the heliocentric model by considering the work of scientists such as Ptolemy, Alhazen and Copernicus.
>
> FORCES: Pupils might find out how scientists, for example, Galileo Galilei and Isaac Newton helped to develop the theory of gravitation.
>
> (DfE 2013, p. 30)

To gain an understanding of how scientific ideas have changed over time, and therefore to demonstrate that knowledge is emergent, I suggest this could be achieved with there being a far greater emphasis on studying famous scientists from the past. There would, however, be a different emphasis in learning compared to the work that is currently being undertaken by many schools. Research has shown (Sinclair & Strachan 2016) that many schools are studying specific scientists to demonstrate substantive facts like their date and place of birth, whether they were married, or the number of children they had. An ecological approach would promote recognition of where the scientist's work fits into a continuum of scientific ideas; what preceded theirs and what came after. It would encourage students to ask what they would want to find out if they were the scientist, demonstrating that the start of a scientific enquiry is initiated from a position of informed ignorance. A template for how this might be achieved in the classroom is provided in Appendix 1 and forms the background of the work with the students from Cycle 2 of this thesis (also see Sinclair & Strachan ibid).

I suggest that there is a need to include contemporary scientists in this process. Sinclair and Strachan (2018) have shown how the work of contemporary scientists builds upon the achievements of famous scientists from the past to demonstrate this continuum of ideas. At this point it is also useful to return to the suggestions of Firestein (2012) who proposes the need to cultivate ignorance. He provides specific strategies that could be adopted to realise this. He recommends that students gain exposure of talking to scientists. Firestein (ibid) suggests that instead of asking them what they do, a far more productive question would be to ask them to detail what they are trying to find out. He offers a number of probing questions which students could ask, which include; ‘What would you like to know? What do you think is critical to know? What will happen if you find this or that thing out? What might happen if you don’t?’ (adapted from Firestein ibid).

However, it is important to realise that there is a dichotomy within science education. While I have proposed that some scientific knowledge should be viewed as tentative in nature there is also the contradictory view that science is also comprised of a consensually accepted body of knowledge that is highly resistant and unlikely to change. For example, it is improbable that in the future it will be discovered that plants do not require light to photosynthesise or that matter is not made up of atoms. It is this corpus of knowledge which has helped science in being so successful and one of the reasons or this is that it is viewed as being able to provide absolute truths. It is easy to perceive how this situation is translated into goal-driven curricula. The difficulty lies in the appreciation of the difference between ‘frontier’ and ‘consensually agreed’ science and of the epistemological implications of only focussing on one and not the other. Pleasingly, however, Millar (2004) states that it is essential to study the ‘history of science’ if a full understanding of the nature of science is to be garnered. I would suggest that while the discussion here is about gaining scientific knowledge this understanding is also imperative in developing ecological epistemologies. While Taber, Billingsley, Riga and Newdick (2015, p. 370) stress the difficulty in persuading; “students that scientific knowledge is generally robust and reliable, yet also in principle always open to challenge and modification,” this is every reason to attempt to demonstrate this. In addition to this, Millar (2004, p.6) highlights that while it is imperative to learn the ‘core’ science knowledge it should be acknowledged this is a process which inducts the student; “into a particular view of the world.” He points out that little acknowledgement is given that science learning is helping students to move towards a worldview of the scientific community or how this consensually agreed knowledge has been created. It is useful to return to Feynman’s (The pleasure of finding things out 1981) view of science knowledge regarding degrees of uncertainty. Time should be given for students to express their opinion about how uncertain the scientific community are about specific science topics.

This section has attended to the suggestion that the science curriculum could be utilised to help develop epistemologies which focus on ‘process’ instead of ‘structure’ and ‘relationships’ over ‘objects’. It has recommended that this could be achieved by studying a range of famous scientists’ work and detailed how this fitted into a continuum of evolving ideas. A methodology was provided to carry out this process. I propose in the following section that one scientist in particular should be studied; Alexander von Humboldt. I will argue that the way he carried out science provides a model of ecological science. By doing this I will propose that he possessed an ecological epistemology. Being termed the first environmentalist (Wulf 2016) he therefore provides the bridge between ecological thinking and concerns about planetary well-being which has been missing so far.

2.7.2 Alexander von Humboldt - providing a model of ecological science

Wulf (2016) notes that von Humboldt is most renowned for his worldview and not for making a specific discovery or inventing a new law of physics. In this section I will outline what I believe to be von Humboldt's worldview and show how he practised to demonstrate that science can be perceived as an ecological act. Capra's (2005) ideas about ecological thinking can be seen recurring throughout von Humboldt's work which will be detailed below. In particular is his perception of his relationship with his lived world which is in antithesis to Cartesian dualism. In previous sections I called for the need for an appreciation of the symbiotic relationship humans have with the natural world but, up until this point, this had mainly focussed on a physical appreciation. Sachs suggests that von Humboldt's science was not solely premised upon formulating networks between the living and inanimate but also (quoting von Humboldt) that it was the search; "for the connection between the physical and intellectual world," (cited in Sachs 2003, p. 123). Walls (2009, p. 3) concurs with this suggesting von Humboldt's science was; "inseparable from the study of the mind in its material, social and cultural context." I believe this dissolution of mind and matter is what Bateson (2000, p. 491) is referring to when he argues that the mind does not exist within the brain and what thinks is; "man [sic] plus environment." I suggest this is similar to the indigenous epistemologies which were denoted in Section 2.5 (Orr 1992; David Peat, 2005). I argue that this lack of distinction between mind and nature underpins how von Humboldt worked which is the focus of the following writing.

2.7.2.1 Von Humboldt – helping to develop an understanding of the temporal and transformational nature of relationships in science

Perhaps the most obvious of von Humboldt's approaches to science is his search for connections and relations. Sachs (2003) has noted that he was a fanatical empiricist and discovered and named as many new species as the renowned 'father' of classification, Carl Linnaeus. However, he argues that von Humboldt viewed classification as a false construct and his driving purpose was to; "study the great harmonies of nature," (Sachs ibid, p. 114) by identifying a unity between environment, climate, and living and inanimate phenomena. Wulf (2016) states that, by shunning the dominant fashion of taxonomic categorisation, he was able to determine relationships between types of plants, climate and geography. Sachs (2003, p. 120) denotes his work; "sought to determine how ocean currents affected mean temperatures all around the world, how geological formations affected vegetation patterns, and even how deforestation and monocropping affected the health of nearby rivers and lakes," adding that by doing so he was seeking to understand; "organic messy connections," rather than gaining definitive answers. Von Humboldt envisioned the planet and those that lived upon it as an interconnected and interacting organism which Wulf (2016) proposes was a precursor to Lovelock's Gaia (2006).

A fragmentary attitude to science education is evident within the current English National Curriculum (DfE 2013, p. 4). In the section which specifies what should be taught and learnt about the nature, processes and methods of science it states that children should;

> use a variety of approaches to answer relevant scientific questions. These types of scientific enquiry should include: observing over time; pattern seeking; identifying, classifying and grouping; comparative and fair testing (controlled investigations); and researching using secondary sources.

It is encouraging that the inclusion of these six different methods of scientific enquiry has resulted in an understanding that there is more to science than the comparative and fair test (promoted by the previous National Curriculum; DfES 1999). However, the simplicity in which the scientific process has been exemplified, that it is either one enquiry type or another, is misleading. Feyerabend (2010) provides a convincing argument that it is implausible to conceive there is one unifying scientific method and each scientist's methodological choices are based on personal bias. While I do not suggest that this anarchic approach should be adopted in schools, the issue that many of the enquiry types overlap should be emphasised. Currently there is a preoccupation with teachers that children should be able to identify and use a particular enquiry type in a similar fashion to the previous slightly myopic adherence to the fair test. In addition to this, and referring back to Humboldtian science, it is important to note the different weighting the National Curriculum places on 'identifying and classifying' and 'pattern seeking'. The terms 'classify' and 'identify' are four times more prevalent than the enquiry terms 'patterns' and 'relationships' and provide the predominant suggestions for how to work scientifically. The subliminal message from this is that to be good at science you need to be good at compartmentalising.

Von Humboldt's ecological and relational way of thinking influenced the way he communicated his ideas causing Ette (2010) to suggest that von Humboldt's prodigious writing over seven decades should be viewed in their entirety and not as separate entities. While Ette notes that each of the writings can be viewed discretely he believes von Humboldt wrote them as a; "dynamic network of mutually intertextual relations," (ibid, p. 123). Walls reiterates this when she quotes von Humboldt stating that he is not writing a; "mere encyclopaedic aggregation," of the results of science. He is, rather, trying to find their unifying thread; “to show the simultaneous action and the connecting links of the forces that pervade the universe,” (Walls 2009, p. 7). Wulf (2016) refers to von Humboldt as one of the last polymaths before scientific disciplines became tightly specialised as most have become today. Von Humboldt’s way of perceiving science as interdisciplinary could therefore be exemplified by referencing the ‘big ideas’ outlined in the previous section in conjunction with identifying how he worked which will be detailed below. However, it should be noted that his opus Kosmos attempts to provide a unified theory which includes; “the assemblage of all things in heaven and earth, the universality of created things constituting the perceptible world,” and which represents the; “order of the world, and adornment of this universal order,” (von Humboldt 1883 cited in Walls 2009, p. 5). In a similar fashion to the ‘big ideas’, Kosmos may give the unwitting impression of completion and of absolute truth with Walls (ibid, p. 6) commenting that von Humboldt saw Kosmos as a; “harmoniously ordered whole.”

I have argued that von Humboldt’s methods provide exemplification of a multidisciplinary approach to science. His studies, however can be aligned more with the life sciences and that of Biology. An ecological model of science would need a strong emphasis on the study of biological aspects and in particular those which demonstrate the interdependent nature of how the planet functions. I have previously shown there is a fixation on the forms of science that produce objective knowledge and that the discipline of physics is most celebrated in this regard. Despite his helpful guidance on formulating a view of knowledge founded on degrees of uncertainty, Feynman still concurs with the Newtonian model of science maintaining that; “physics is the most fundamental and all-inclusive of the sciences, and has had a profound effect on all scientific development,” (Feynman, Leighton & Sands 1963, p. no page). He then proceeds to outline how biology is underpinned, and can be explained, by physical elements. This is further evidence that a fragmentary model of knowledge production is still evident amongst scientists who understand the uncertain and tentative nature of coming to know. It demonstrates the need to study elements of science, such as practised by von Humboldt, which demonstrate the ‘messy’ nature of researching living organisms and systems which cannot be compartmentalised and explained by linear cause and effect relationships. I have argued throughout this thesis that a change in how we relate to the planet is not predicated on specific subject knowledge but an ecological way of thinking. However, this section has argued that the learning of subject knowledge which is established on relational biological principles is important. There appears to be some consensus that these biological principles should be founded upon an appreciation of how ecosystems function (Orr 2005; Capra 2005). Orr (ibid, p. xiv) is clear that an understanding of life is established from three fundamental phenomena and these are; “life’s basic pattern of organisation is the network; matter cycles continually through the web of life; all ecological cycles are sustained by the continual flow of energy from the sun," Orr (ibid) summarises these as the web of life, the cycles of nature and the flow of energy. These have direct correlation with several of the 'big ideas of science' but in particular with the premise that; "organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms," (Harlen 2015 p. 16). Capra (2005) alerts us that not everything which needs to be learned can be taught through ecosystems but this area of science could obviously act as a starting point when designing a curriculum for an ecological approach to science education.

2.7.2.2 von Humboldt – helping to develop an understanding that process is more important than structure

A further demonstration of von Humboldt's ecological thinking can be seen in his loyalty to the process of science rather than its structure. Ette (2010) argues that von Humboldt's approach was one which celebrated his fallibility and which understood the necessity of building upon his errors. Ette (ibid, p. 121) coins this as the; "art of failure". He states that von Humboldt saw his work as in a state of transformation and never as absolute and that he; "celebrated an ascent without an arrival: the happiness of being always in motion, always on the move," (Ette ibid, p. 121). This transformative epistemology of von Humboldt's transcended the then (and current) Baconian obsession with breaking the 'code of nature'. Von Humboldt's view of science was reflected in how he understood the planet functioned (or I argue it could be that his view of how the planet operated was reflected in how he perceived the nature of science). The fact that he believed nature could not be defined in absolutist terms was mirrored by the way in which he undertook his scientific work; a transitory process of asking questions to seek further clarification (Sachs 2003). This is similar to Firestein (2012) (highlighted in Section 2.7.1.2) who proposes a celebration of ignorance in scientific enquiries. Von Humboldt's views on the nature of science can be used to provide a context for the forms of scientific enquiries undertaken in schools. In this instance I advocate the adoption of scientific enquiries which are founded upon open-ended questions. These open-ended enquiries did not necessarily provide finite answers but afford an opportunity to ask further questions with which to investigate. It is relevant to mention that the methodological approach which I adopted for this thesis has many parallels to this form of enquiry. This research was not initiated from a hypothesis and a pre-conceived outcome. I have championed throughout this writing, similarly to von Humboldt, how I understand my work and learning as a developmental process which has no fixed end-point.

2.7.2.3 Von Humboldt – helping to develop an understanding of quality over quantity

The suggestion of Capra's (2005) that thinking should be shifted in terms of quality over quantity has been given little attention in this thesis so far. While Capra (ibid) alludes to the fact that there are elements of science which cannot be reduced to figures and that there is no way of quantifying certain relationships such as those found in food webs, he does not develop ideas regarding the subjective nature of undertaking science. Section 2.6.2 referred to the quantum world and it was argued that scientific observations can never be 'objective'-free. This section will develop this and focus on the need to embrace personal emotions, in the manner von Humboldt did, especially in terms of the way science is communicated to those who are not science specialists.

Another underling principle of von Humboldt's appears to be his purpose in communicating science. Both Sachs (2003) and Wulf (2016) propose that while other contemporary scientists were focussed on providing universal laws, von Humboldt's desire was to evoke a love of nature. This viewpoint emanates from his ecological epistemology which perceives the physical and intellectual world as entwined. Walls (2009) suggests von Humboldt thought the common perspective of undertaking science should dampen any emotional response as incorrect. Nichols (2006) notes that von Humboldt's interactions with the real-world locations he studied were of great importance and were not just limited to empirical observations. While Capra (2005) has suggested there is a need to appreciate quality over quantity, Nichols suggests that von Humboldt's form of science was capable of delivering both. Von Humboldt was providing the measurable and quantifiable data 'required' by science while not denying the accompanying personal emotional and aesthetic responses. Wulf (2016) suggests this stance culminated in the composition of Kosmos being given similar priority to the scientific content. Further to von Humboldt's approach to communication I draw upon comments made on a BBC radio interview (The infinite monkey cage 2013) by an astronaut who had visited the Moon. He implored for the inclusion of artists on future missions as he detailed he did not have the capability to describe and explain his experience in a manner which anyone other than a scientist could comprehend. This resulted in him not being able to communicate what he has seen and learnt.

Recently there has been a push for the inclusion of the arts when teaching the STEM subjects (science, technology, engineering and mathematics) in an approach called STEAM learning (science, technology, engineering, the arts and mathematics). Many of the debates surrounding the STEAM method are to do with the relatively few students studying traditional STEM subjects because of their perceived lack of appeal. Those that do take STEM subjects are often said to lack creativity and innovation (Land 2013). Proponents of STEAM suggest there is a need for students to engage in practical problem-solving based on real life contexts (Land, ibid) and that this improves curiosity, self-motivation and develops an understanding of the nature of science (Minner, Levy & Century 2010). Its detractors posit problem-based, experiential, and inquiry-based teaching and learning is just not effective (Kirschner, Sweller & Clark 2006). These are important debates but, for the purpose of this section, there will be a focus on how a STEAM approach may help in improving the communication of scientific ideas and in doing so assist in changing the perception of science. The following briefly discusses why this is of importance.

Nisbet and Scheufele (2009) highlight that scientists are positioned as high-status individuals who are both respected and deferred to as figures of authority. Yet they also propose, despite this reverence, that the larger population is either not able to or are uninterested in engaging deeply with issues to do with their work. Dietz (2013) suggests this may be because science communication often only concentrates on the dissemination of scientific facts and as a result science is perceived as a value-free endeavour which eschews the need for emotional investment (a further Cartesian divide). He writes that engagement in scientific debate may reach a wider audience if this personal element is attended to. Nisbet and Scheufele (2009) make similar claims and recommend that a wide range of communication tools should be adopted to achieve this. Of particular interest is their suggestion that 'storytelling' could be one of the strategies used. They do not, however, provide examples of the way this might be achieved in practice.

I perceive the art of 'storytelling' and the use of the 'Arts' in STEAM learning as the same (by the Arts I embrace the disciplines of poetry, literature, art, music and drama). This aspect of science communication draws upon von Humboldt's writing which celebrated both content and composition in equal measure. Capra (2005, p. 22) provides a further argument for the integration of arts into the curriculum because of their effectiveness in developing; "a children's natural ability to recognise and express patterns." While there appears to be limited research into this aspect of STEAM learning, I am confident that strategies could be elucidated which provide effective communication methods that recognise the value-laden and emotive aspects of science yet do not dilute the scientific content.

2.7.2.4 Von Humboldt – helping to develop an understanding of contextual knowledge over objective knowledge

The following section returns to my argument that the combination of Cartesian dualism and the success of Newtonian science, which reduces the universe to operating like a machine, has perpetuated the myth that humans are separate and distinct from their lived world. I have highlighted how this disconnect has resulted in the perception that nature can be dominated and controlled indefinitely and solely for human purposes. This disconnection is the core tenet for those highlighting the current plight of the planet (Schumacher 1973; Orr 1992). Previous sections have discussed the importance of developing relational epistemologies to combat this. As part of this epistemological development I also suggest there is a need for many humans to physically connect with their lived environment. Von Humboldt's work, once again, can be used to demonstrate how studying and participating in ecological science can help to promote this.

Another defining aspect of von Humboldt's science was his commitment to fieldwork. In line with the central tenet of science, he strictly adhered to making empirical observations to gain an understanding of the world. It is important to note that these observations were obtained in situ which is the antithesis of much of modern science. I have argued previously that much of the science which is currently practised is reductionist in nature. This form of science reduces the study of complex systems to the level of understanding its constituent parts in isolation. This abstraction has to occur to ensure that other interrelated factors do not interfere with findings and has culminated in scientific enquiry being undertaken out of context. The consequence of this is that much of scientific research occurs in clinical laboratories and not in the field; further reinforcing the stereotypical view of the scientist.

Sobel (2013) highlights the dichotomy children are currently facing. He points out that while there has been an increase in understanding and interest in global issues (such as studying deforestation and endangered species) this has also been accompanied by an increase in those that are disconnected from the natural world. Sobel (ibid) suggests that while there has been a greater focus on global ecological problems both in schools and in the media, this has resulted in the abstraction of nature. He argues this is because many young children are missing out on the first-hand sensory experiences which are gained from exploring local environments. Hunt, Burnt and Stewart (2015) provide an example of this, pointing out that approximately 12% of young children in the UK had not visited a natural place in the year preceding their research. Dayton and Sala (2001) suggest this abstraction has also materialised in the US because many students have only been taught ecological principles through the use of textbooks. Abrams (2010) also highlights that many of our visual experiences are gained through the two-dimensional images from televisions (and mobile phones) and these cannot provide the necessary depth and engagement with what is being watched.

Leopold (1949, p. vii) clarifies this by stating; "we abuse land because we see it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect." He further notes the symbiotic relationship of care; that care of nature and care of people are interchangeable. Studies by Mayer and Frantz (2004) support Leopold's hypothesis. Mayer and Frantz (ibid, p. 512) are cautious of making generalisations but suggest; "if people feel connected to nature, then they will be less likely to harm it, for harming it would in essence be harming their very self."

Leopold (1949) and Sobel (2013) also afford a direction that could be exploited in an ecological practice. Leopold (1949) suggests that direct contact with nature is central in reconnecting the individual with the planet and by doing so helping to develop a worldview that is not egocentric. Sobel proposes that children could develop this connection by being provided with first-hand experiences within their locality. Encouragingly, it has been demonstrated even simple activities can go some way in helping children make a connection with their natural environment. Lindemann-Matthies (2005) has shown that children who were encouraged to identify their local plants and animals showed greater care of those organisms.

Dickinson (2013) provides evidence that learning science in a natural setting is a significant aspect of providing both experience and knowledge. However, she is keen to elucidate that often science learning can place sole emphasis on cognitive gains with little regard paid to any emotional response. This facet of science education has already been discussed and consequently may result in distancing rather than reconnection. It perhaps provides further credence to my position that a reconceptualised science education must embrace both quality and feelings. In contrast to Lindemann-Matthies (2005), and in keeping with my previous argument about identification and classification, Dickinson (2013) suggests that naming animals and plants can have this distancing effect by reinforcing difference and justifying fragmentation. She recommends that children should still learn scientific names but that this is in tandem with a process she terms 'no-naming' which focusses on the sensory experiences garnered from an animal or plant.

In addition to the role learning science in a natural environment can play in reconnecting humans with their planet are the effects this may have on mental and physical well-being. Wilson's (1984) 'biophilia hypothesis' states that humans have a deep-rooted affinity with the natural world, with Louv (2010) commenting that lack of contact has resulted in 'nature-deficit disorder'. While nature-deficit disorder is not officially recognised as a disease, there is growing research to suggest that prolonged exposure to natural settings has improved physical and mental well-being (Chawla 2015). Wells and Evans' (2003) studies also conclude that being close to nature may improve children's cognitive abilities and attention spans.

Louv (2010) also recommends that time spent in nature should not be viewed as leisure time but as an investment in a child's health. While Dickinson (2013) does not question Louv's intent, she is critical of his recommendations that contact with nature is enough. She states that unless the underlying cultural framework and epistemologies which have created this disconnect are challenged then not much will have been achieved. I believe Louv (2010) provides a justification for learning science outside of the classroom while Dickinson's (2013) claim strengthens my argument that this needs to be through a particular model of science.

This section has highlighted the importance of humans making mental and physical reconnections with the natural world. I have suggested that part of this reconnection can be provided through learning science outside of the classroom as a way of developing ecological thinking. However, I have stressed that the form of science learning which is used to develop this reconnection is significant and must be premised on hands-on sensory experiences which garner emotive responses. I have argued that this can be developed though the process of ecological science and any learning founded upon a 'Newtonian' model of science may continue to reinforce the disconnect.

2.7.2.5 Von Humboldt - summary

This section has provided a justification for studying von Humboldt as part of developing an ecological approach to science education. It exemplified that his way of thinking and working demonstrated an ecological epistemology and in doing so provides a holistic view of how science proceeds. I suggested Humboldtian science as focussed on discovering connections and that in future, classification in schools should place greater emphasis on the study of relationships over identifying similarities and differences. I also discussed how the nature of von Humboldt's science was based around the biological principles related to ecosystems and that there was a clear relation to the 'big ideas of science' which could be used as a starting point for defining a curriculum for ecological thinking. In addition to this I proposed that von Humboldt's manner of communicating science, which incorporated values and emotions, could be adopted in an approach termed STEAM learning. This section has provided specific examples and guidance for using von Humboldt's way of practising science as a stimulus to develop ecological epistemologies. However, I am mindful that the manner in which education proceeds is as important as what is learned. The following section attends to this.

2.8 Teaching in a manner that promotes the value of developing trusting educational relationships and the benefits of learning from one another?

The previous two sub sections have attended to issues which could be regarded as syllabus content in relation to my development of an ecological approach to science teacher education. While I argue that developing an ecological view of science can play a role in undermining the current mechanistic educational paradigm I also concur the pedagogies employed for learning are as important as what is being learned. This section therefore develops the ideas put forward about developing an ecological approach to science teacher education by providing a theoretical framework which reconceptualises the dominant lecturer/student relationship and one which is underpinned by an ecological way of thinking. I have referred to this in Chapter 1 as a mutualistic practice. This practice draws upon Buber's (1947) philosophy of education which is founded upon inter-human relations (1958) and I suggest three aspects by which to develop mutually respectful educational relationships.

Capra (2005, p. 27) makes it clear that classrooms (or lecture halls) are located in, and in relation with, what he terms; "nested systems," which include the whole school or university and the wider community. He advises that what happens in individual classrooms is influenced by the multiple layers of the nested system and that strategies of change need to be targeted and addressed at all levels. While I appreciate the necessity to think in this manner I am also cognisant that my most powerful and immediate influence is at the classroom level. Stenhouse (1975) recommends the starting point for change should be the classroom, the curriculum and the teacher's and students' learning. Kelly's (2009) view of curriculum is encouraging and provides a purpose for the need to be explicit about the educational approaches that a teacher could adopt within his [sic] classroom. He proposes that any curriculum is mediated through the interactions between teacher and learner and the educational and social discourses they bring to this relationship. Stenhouse (1975) proposes it is incumbent on each teacher to research the negotiated process of this curriculum in relation with a particular group of students. The following therefore focusses on the forms of relationships and educational interactions I feel are necessary to develop ecological epistemologies and which I term a mutualistic practice

The conceptual frameworks of Buber, which focus on the types of relationships humans encounter, are useful in helping to theorise this position. Much of his work focusses on the interactions between humans although I will first draw upon a specific example he gives of how we may view inanimate objects. Buber (1958, p. 20) asks the reader to; "…consider a tree, it can be looked upon, its movement perceived, classified, recognised as an expression of law, counted, but in all ways the tree remain as an object which occupies space and time." Buber describes the object as an 'It'. This linear relationship clearly provides a rationale for the type of thinking which has led to previous claims about the objectification of nature. In a similar fashion to Bateson (2000) he argues that if the viewer understands the relationship they have with the tree it no longer becomes an object.

Buber (1958) highlights that human relations, and therefore those that can occur in the classroom, exist in flux between two aspects, that of 'I-thou' and 'I-it'; a relational or objectifying positioning. He believes the I-thou relationship is based on a mutual understanding where each respects the other as an equal and the recognition of the future possibilities within and from that encounter. He suggests it is only through the process of encounter that one can truly profess to understand oneself and fully discover one's humanity. He refers to this as entering into dialogue. To Buber, dialogue does not only involve 'talk' but is the relational encounter to one's self, others and all other inanimate objects. I believe Fromm's (1979, p. 71); 'being' mode of existence refers to the same type of relationship and that; "it is only in the process of mutual alive relatedness can the other and I overcome the barrier of separateness."

Buber refers to an 'I-It' relationship as one where there is an asymmetrical power balance where one individual objectifies the other and in particular, differences are highlighted; resulting in no equality, no respect. The 'I' remains separate and unique. Fromm (1979, p. 63) refers to a similar mode of existence as 'having' and suggests this type of relationship excludes others as there is; "no alive relationship between me and what I have."

In setting out his vision for developing ecoliteracy, Orr (1992) makes similar claims to Buber and Fromm. He makes it clear that the current formal western education systems, which are premised upon a conversation of monologue directed from those in power, are achieving little. While he specifically suggests that education should occur, in part, as a dialogue with place (which I have outlined when referring to the importance of understanding place), he also provides guidance for the forms of teacher/student relationships which might assist in mirroring this. He argues that dialogue can define individuals but this must be in a relationship of acknowledgement with the other.

Importantly, Buber (1958) rejects there is a distinct dualism between the two forms of relationships and that an individual operates in flux between the two. Fromm (1979) also states that having and being tendencies are both present in individuals. I am, however, in agreement with Guilherme and John Morgan (2009) who, despite noting that Buber felt that the 'I-Thou' relation is real and perceivable, feel there is difficulty in conceiving how this might materialise itself in reality. In addition to this I also question how likely this form of relationship is to occur. Trainee teachers who have been through schooling systems which have continually reinforced that; "teachers rather than learners control what is said," (Alexander 2008, p. 92) are likely to find any reconceptualisation of the teacher/student role difficult to accept. Perhaps more importantly for this thesis is whether or not educators, such as myself, can truly 'unlearn' habits which have been ingrained for many years. Therefore, I propose that realising 'I-Thou' relationships is not an educator's ideological goal. I argue that it is the process of identifying what is required and how one advances towards it which is of most tangible importance.

Buber (1947) appeared to have foresight into many of the current debates around education which are dichotomised between a teacher-centred and student-centred approach. His view on teacher-centred approaches are affiliated with Freire's (1970) banking model of education, and Fromm's (1979) 'having' view of knowledge. Consequently he suggests this approach may prevent the 'I-Thou' relationships from forming. However, he also appreciates the expertise a teacher can bring to an educational experience by proposing that, without it, a student-centred approach often may leave students contending for direction due to lack of guidance (Guilherme and John Morgan 2009). As part of developing 'I-Thou' relationships, it is therefore incumbent upon educators to first appreciate the power and expertise that is endowed upon them and then to plan educational experiences which place an appropriate emphasis on the teacher's influence and knowledge and on the student's capacities, interests and needs. This has obvious implications for methodological choices in educational research. I hope this thesis demonstrates the consideration of my position of power and that the research process has contributed to developing 'I-Thou' relationships. In particular, I hope in researching with the students they realise their capacity as having their own voice.

Buber (1947) first suggests a teacher's role is to set a curriculum which provides a value platform for students. He also proposes this values-based curriculum should ensure the students' interests, needs and creativity are developed. I argue in addition to this must be the opportunity for students to develop their criticality so they have the capability to identify their deep-rooted, and not peripheral, interests and needs. It is gratifying, however, that Buber's (ibid) perception of the role of the teacher is in accordance with how I introduced and developed the curriculum for ecoliteracy founded upon my mutualistic practice.

Infed (no date) argue that; "the quality of life in a community or society will depend on the extent to which I-you (Thou) relations exist," and that mutuality and dialogue, based on 'I-Thou' relationships, can only develop if a relationship of trust is evident, and one where the student feels accepted; this I argue is premised upon mutually respectful relationships. One of the founding principles of my practice (the mutualistic practice) was the development of a community where each student felt a sense of belonging, purpose and the freedom to express their opinions. The freedom to express their ideas and be critical of my teaching was crucial in assuaging the imposition of a curriculum that was founded upon my values and which may not have been in the best interest of the students.

In addition to stimulating criticality as a way of developing mutual respect I also sought to show that as an individual I too was a learner. I hoped this would reinforce an understanding of the dynamic and evolving nature of knowledge. Su and Wood (2012) surveyed 100 undergraduates from 20 higher education institutions to identify their perception of excellence in teaching. They identified a range of technical and emotional traits which students wanted to see in their lecturer's practice. However, while I would argue that 'exhibiting' these traits may assist in garnering respect at the level of competence, it does not help to reconceptualise the student/teacher relationship. Not surprisingly, considering the schooling systems which these students have experienced, they did not comment upon lecturers acting as; "partners in learning rather than 'experts in the field'," and that they did not invite; "students to actively share with them in a search for knowledge," (Fried 2001, p. 23). This is what Fried suggests is a characteristic of 'passionate' teachers. I propose this is probably not a search for common knowledge (which is characterised by Wenger's 1998 communities of practice) but a demonstration that the lecturer is still a learner. It was the belated realisation that my learning did not have to be equivalent to the students' which most informed my understanding that I could demonstrate I too was a learner. Making my intentions explicit about my research with the students assisted in this process.

Buber's (1958) ideas about 'I-Thou' relationships are premised on encounter and dialogue. While Buber does not reference dialogue specifically to the physical act of talking, I suggest Alexander (2008) provides useful guidance for how talk can contribute to an act of dialogue. He refers to these processes as 'dialogic teaching', which I contend are premised on the forms of relations which Buber proposes. Alexander (ibid, p. 92) claims that;

> Talk vitally mediates the cognitive and cultural spaces between adult and child, among children themselves, between what the child knows and understands and what he or she has yet to know and understand.

He specifically refers to dialogical talk as;

> Achieving common understanding through structured, cumulative questioning and discussion which guide and prompt, reduce choices, minimise risk and error, and expedite 'handover' of concepts and principles
>
> (Alexander 2001, p. 527)

Alexander does not reference Bohm (1996) in his definition of dialogue. However, Bohm similarly asserts dialogue is a creative and emergent process which is developed through the mediation of shared meanings. Of particular relevance to this thesis is Alexander's (2008) reference to Bakhtinian dialogue. Bakhtin (1986) states that answers should give rise to further questions. This is of particular significance as it mirrors a model of scientific enquiry, premised on ignorance (Firestein 2012), which I have promoted previously. Both Alexander and Bohm's concepts of dialogue are rooted in epistemological thinking which values quality, process and context and are the forms of communication I hoped to develop while working with the students. However, I suggest that dialogue can only be achieved if the teacher provides opportunities where both parties are genuine learners. It is at this point where the power imbalance between student and teacher may be partially and transitorily shifted and shares similarities with Wenger's (1998) community of practice. Part of developing an ecological approach to my practice was negotiating the balance required between highlighting that I was a learner while also providing the support and guidance which the students expected and needed from their course.

I am now cognisant that dialogical talk does not materialise naturally and it has to be learnt by the student (Alexander 2008) and, I suggest, by the teacher. Perhaps this is better rephrased as, traditional forms of monological talk and questioning, have to be 'unlearnt'. As part of this learning/unlearning it is important the teacher recognises the forms of educational activities, and specifically the questions students are asked, which either promote or expunge dialogical talk. An example of this is provided by Lehesvuori (2013) who suggests that in secondary school science there is an evident lack of dialogic interaction. He suggests this is due to teachers' adherence to a Newtonian model of science premised upon objective correctness. I will highlight later that as part of my ecological practice I provided opportunities for talk, which I considered to be dialogical in nature, but it has only been through an act of critical reflection I realised I needed to 'unlearn' many previous habits and experiences.

In support of what I initially viewed as a failing, Alexander (2008) provides examples, of what he refers to as pedagogical hybridisation, when teachers exhibit complex and, sometimes, conflicting approaches to developing talk. He appreciates that the interplay between previous experiences and current values can manifest themselves in this fragmented hybridisation. Similarly to Buber (1958) who suggests humans exist in flux between 'I-Thou' and 'I-It' relationships I propose that what is of most importance is awareness of when to promote dialogic talk and this cannot be achieved, nor needs to be, all of the time.

This section has attended to the forms of everyday actions and relationships which I maintain were evinced within my practice. The forms of educationally intimate relationships which I have discussed are located within small groups of students and are under the control of the individuals involved within that setting. The following section will discuss whether these can materialise separately, or in despite of, institutionally driven agendas and whether they play a role in defining my identity as an 'academic' within a higher education institution. In particular it will provide a situated context for this research and suggest the differing layers of accountability I experienced and how this implicitly and explicitly shaped my actions with the students.

2.9 Developing an ecological practice within teacher education – the uniqueness

The following section establishes another context for this research and in doing so provides justification for some of the tensions I felt for imposing the curriculum for ecoliteracy on the students. It focuses on my dual role as an academic in a university and as a teacher educator. As part of this process it will identify the contrasting agencies to which those in teacher education are accountable; which include the university itself, the schools where it sends its students to, governmental agencies and the students themselves. While I was cognisant there was a need to prepare students for their future careers in school I suggest I was only implicitly aware of how beholden I was to this point of accountability. As part of defining my pedagogy (Alexander 2008), and therefore articulating an ecological approach to my practice, it has only been through the process of critically evaluating the influence of these factors that I have come to an understanding of how significant they were in shaping the way I acted. This section will also establish the forms of research which are valued and expected from a teacher educator and consequently frame initial discussions about my methodological choices for this thesis.

In Chapter 1 I highlighted my concerns about introducing the curriculum for ecoliteracy to the students from Cycle 1 and the subsequent tensions I felt. I initially believed, and wrongly, that these were founded upon the belief that most students had certain pre-course expectations which I thought they felt should be fulfilled (Kandiko & Mawer 2013). I have argued previously this is because of the consumerist ethos I thought the students might hold predicated on the commodification of higher education courses and their previous experiences in school. This commitment to an outward facing focus had sheltered me from considering the accountability measures I was facing and subsequently how this had prevented me from authentically questioning the educational freedom I professed I possessed.

Furlong and Lawn (2010, p15) provide a reminder of this reality when they describe teacher education and teacher educators as prevailing in a; "national framework of accountability," and suggest they are beholden to a practice of obedience. Murray, Czerniawski, and Barber (2011) recognise this accountability is two-fold. They acknowledge on one hand there is a requirement for teacher educators to demonstrate their practical knowledge in the classroom while simultaneously showing they are engaged in academic research. The following will propose teacher educators' practical knowledge is only valued if replicated as a matter of compliance and that research and knowledge generation, underpinned by personal epistemologies, is often not recognised as legitimate.

McNamara Murray and Phillips' (2017) review of primary initial teacher education (ITE) suggests it is no longer possible to distinguish policy documents for ITE providers from those related to school. I argue this is because ITE courses, and their curricula, are perceived as ‘conveyor belts’ for providing trained teachers who are ‘classroom ready’ for schools. Evidence for the obscuring of these boundaries comes from governmental recommendations for ITE providers (DfE 2016) and the framework by which they are judged (Ofsted 2018). Both refer to the Teachers’ Standards (DfE 2011) which are also used to assess the effectiveness of teachers in schools. The Ofsted framework for ITE unequivocally states that;

> Inspectors evaluate the extent to which initial teacher education (ITE) partnerships enable trainees to meet the minimum level of practice expected of teachers by the end of their training. This is defined in the Teachers’ Standards, the Teachers’ Standards (Early Years), or the 2014 professional standards for (further education (FE) teachers and trainers).
>
> (Ofsted 2018, p. 26)

The drive to locate teacher training in schools suggests an ideological positioning which does not require a critically thinking profession. This relocation of training can reduce the teacher to a technician capable of unquestioningly replicating what is asked of them from those in power. This implication is evidenced from the previous education secretary’s statement that;

> Teaching is a craft and it is best learnt as an apprentice observing a master craftsman or woman. Watching others, and being rigorously observed yourself as you develop, is the best route to acquiring mastery in the classroom.
>
> (Gove 2010, p. no page)

Following this Gove denigrated many in teacher education, who encouraged the forms of critical thinking that I have espoused throughout this thesis, as possessing purely political motivations. As a consequence, he made accusations that they were actively preventing children’s chances of receiving a good education (Gove 2013).

This standpoint has only been reinforced by the telling terminology used by the Carter Review of ITE (Carter 2015) which, encouragingly, promoted a need for students to engage with research about teaching. However, the report suggested students needed to be; “intelligent consumers,” (Carter ibid, p. 14) who could apply others’ theories. It also recommended that executive summaries of key research were provided for students, unconsciously undermining the need for critical engagement. In addition to this it highlights that; “sometimes ITT (ITE) focuses on trainees conducting their own research, without necessarily teaching trainees the core skills of how to access, interpret and use research to inform classroom practice,” (Carter ibid, p. 8). While I recognise the importance of the latter, I propose this positions a teacher’s personal research as inferior which subsequently can devalue their professional knowledge. It suggests that teachers may not have the capacity to generate their own theories and they are, therefore, only capable of applying others’ unquestioningly. Issues regarding the legitimation of research and therefore knowledge are discussed below.

Unlike many other academic staff, those that enter the teacher education profession are predominantly individuals with many years teaching experience (Murray 2005) and who have been chosen because of their professional knowledge. However, Murray (ibid) notes there are often educational expectations and requirements to produce research to demonstrate the university's research performativity (linked to the Research Excellence Framework) but which does not judge this form of professional and personal knowledge as legitimate. As a result of this Murray, Czerniawski, and Barber (2011) suggest teacher educators are often positioned as 'semi-academics'. Harrison and McKeon's (2010) small scale research showed the teacher educators interviewed had all adopted practitioner research. This was in-line with their principles of being reflective practitioners and with a view to how this might have direct relevance to their practice. Murray, Czerniawski, and Barber (2011, p. 261) provide a justification for this suggesting many teacher educators still perceive part of their identity as being; "once-a-school teacher." This, yet again, reinforces the arguments previously about the forms of knowledge and research deemed of value.

I hope this thesis provides a different view to this top down model of theory production and goes some way in legitimating a practitioner's practical understanding which takes it beyond that of craft knowledge. However, it is significant that I can only make these claims at the point of writing the thesis and having undertaken Cycle 1 and Cycle 2 with the students. At the start of the process I concurred with Chomsky (2000) that the classroom teacher has been reduced to a submissive of those in authority, and that the academic practitioner is treated as an; "operative and not a decision maker," (Nixon 2008, p. 29). Now, I can only tentatively claim that I initially understood the need to study my own practice and the potential role this could play in helping to define my understanding of an ecological approach to my practice. My ability to articulate this awareness, and the empowerment gained from writing with authority, could not have been achieved without undertaking the transformational and generative process of critically reflecting on how I worked with the students.

I suggest there should be an overt expectation and culture in education to help practitioners develop the skills and opportunities for critical thinking which would allow them to study and theorise their own practices. I recommend this is necessary to overcome the prejudices highlighted in this section and that value is, not only, correctly placed on practical knowledge but also in the forms of knowledge generation which rely on personal epistemologies. The following section will briefly justify the need for educators to undertake this process and the subsequent importance of gaining ownership over their practice. Much of this will be developed in Chapter 4. It will attend to the need for educators to research their own practice with a focus on curriculum development and will draw upon Stenhouse's (1975, p. 24) suggestion that there is; "no curriculum development without teacher development." I will propose a curriculum which focusses on process over content is ecological in nature and is a necessary part of an ecological education. I will argue that articulating an understanding of curriculum is important for defining one's practice.

2.10 Further defining one's practice – the interplay between research, curriculum and pedagogy

The following section attends to the following interrelated issues; that of teacher as researcher, curriculum and pedagogy. It will use the theoretical frameworks provided by Stenhouse (1975) about curriculum and Alexander's (2008) contributions about pedagogy as a way of defining my practice. Consequently I will suggest how a critical evaluation of curriculum and pedagogy has enabled me to articulate how I have worked throughout this research process.

Alexander (2008, p. 3) defines pedagogy as; "the act of teaching together with its attendant discourse about learning, teaching, curriculum." He states that too often it is only viewed as simply what occurs in the classroom and because of this it is; "divested of that relationship with the wider world that makes teaching an educative process rather than a merely technical one," (Alexander ibid, p. 1). If this viewpoint is adhered to, Alexander suggests the teacher is reduced to a technician only capable of implementing ideas which have been selected by those in power. Alexander (ibid) insists that to ensure this does not happen it is incumbent upon educators to make sense of their wider educational context as this is as important as what occurs inside the classroom. I suggest this view of pedagogy is ecological. Ecological thinking necessitates the 'study of the whole and not the parts' (Capra 2005) and a forming appreciation of the 'nested systems' to which individuals belong.

Both Chapter 1 and previous sections in this chapter have identified many aspects of the 'wider context' of my practice to suggest reasons for the way I acted. This included the considerable thought I gave about imposing a curriculum premised upon my values about planetary well-being. In the previous section I also detailed the hidden constraints that arose due to my implicit accountability to various agencies and suggested these influenced the form of curriculum I developed. However, it is important to note that prior to this research I had given little consideration that there were differing forms of curricula other than the ones I had experienced as a teacher and as a university lecturer. I would argue that in developing a curriculum for ecoliteracy I had only partially critiqued the wider context and the nested systems in which my practice was located. I believe that in Cycle 1 I had identified the propositional epistemologies which had influenced my earlier thinking yet had not fully realised how contrasting curricula could endorse different forms of knowledge. In addition to this I had dichotomised my pedagogy (Simon 1981) as I was viewing the curriculum for ecoliteracy (which I suggest I deemed could become a syllabus) separately from the way I was working with the students (the mutualistic practice). This section attends to issues concerning curriculum which will further strengthen my claim that I can articulate my ecological approach to science teacher education

Kelly (2009) proposes there are different curriculum models and each model reflects a different educational (and potentially political) ideology. Differing curricula are underpinned by particular epistemological beliefs. He simplifies curriculum planning into two broad models; that of curriculum as content and curriculum as process. While I appreciate this separation is slightly false I also argue they could be considered in a similar fashion to how science is viewed; a Newtonian model of curriculum based on content and an ecological model of curriculum premised upon process and potential uncertainty.

Kelly (2009) suggests that content-based curricula are based on absolutist and objective epistemologies, much in the same way much of science knowledge is perceived. Previously I have argued the overall effect this viewpoint has had on education systems. In this instance the outcome is that the curriculum is viewed as a syllabus and therefore a body of neutral knowledge which needs to be transmitted. These have fixed objectives and gradable learning outcomes and provide a linear 'product' view of learning much in the same way as the planet is viewed. I have proposed they are the dominant forms of curricula in schools and which were the type I experienced as a teacher. Reiss and White (2013) suggest that curricula planned in this way begin with the unquestioning insertion of certain discrete subjects which generate the initial framework for what knowledge should be included. I initially perceived the curriculum for ecoliteracy in this manner and planned to identify science knowledge related to planetary well-being as a starting point for my teaching.

Stenhouse and Rudduck (1985) concur with Alexander (2008) that educators should be aware of the discourses surrounding their practices, in this case what drives the curriculum. They suggest that content-based curricula, which have clear objectives, are like 'site-plans' which provide all the information for where trenches should be dug but no explanation for why. Kelly (2009) develops this and proposes this form of curriculum is assumed to be value-free and therefore provides 'teacher-proof' packages which translate content within the syllabus directly to the classroom. However, previous research (Kelly 1987) highlights that curricula are always mediated and adapted by individual teachers for their own purposes and do not 'deliver' the central curriculum planner's intended outcomes precisely. If, as Kelly (ibid) proposes, there is always disparity between the planned and received curriculum, even within content-based curricula, it undermines the certainty that there ever can be fixed objectives.

With this in mind it is useful to draw on Stenhouse's (1975) ideas about curricula. In contrast to the content-based curricula, which he also identifies can never be neutral, he recommends embracing the mediatory and development aspects which teachers contribute to a curriculum and advocates focussing upon process rather than product. By curriculum he tentatively means; "an attempt to communicate the essential principles and features of an educational proposal in such a form that it is open to critical scrutiny and capable of effective translation into practice," (Stenhouse ibid, p. 4). In contrast to the content curriculum model, which relies on the transmission of discrete packets of factual knowledge which can be measured through testing (Elliott 2007), Stenhouse (1975, p. 142) proposes a curriculum is developmental in nature and; "is a way of translating any educational idea into a hypothesis testable in practice. It invites critical testing rather than acceptance". I suggest Stenhouse perceives the curriculum as an educational idea and that it is incumbent upon the educator to understand how this is translated in their practice. As the description of the curriculum specifies, it is the process one goes through from developing the curriculum which is valued over any specified objective. Kumari and Srivastava (2005) maintain that the success of this type of curriculum is dependent on the quality of the teachers involved as there is no guarantee of quality provided by prescribed curriculum materials. While I have some sympathy with their argument I do not consider it a valid enough reason not to proceed in this manner and suggest all curricula are dependent on the strength of the individual teacher. The adoption of this curriculum would, however, require a reconceptualisation of the role of the teacher and institutional support given to help teacher development.

As argued already, Stenhouse (1975, p. 24) declared that there is; "no curriculum development without teacher development," arguing that the two are synonymous. He expressed the need for teachers to research how they develop their own curriculum, using the relational and transformational nature of action research. Elliott (2007) points out it is only through undertaking an ongoing evaluation of a curriculum that greater clarity about its success can be articulated. Palmer and Zajonc (2010, p. 39) describe this exploratory and adventuresome perspective of curriculum as; "pedagogical messiness," and concur with Stenhouse (1975) that this form of learning can never accommodate fixed outcomes. If, as Brundrett and Silcock (2002) propose, a curriculum should reflect the democratic nature of society then this would require input from students about what should and should not be included; further adding to the call for the curriculum to be viewed as a developmental tool in which to negotiate this aspect. I propose that because of this, one aspect of a teacher's identity must be that of researcher. Further justification pertaining to educators researching their practice will be developed in greater detail in Chapter 4. This form of research/curriculum development has direct parallels with the ecological view of science I have promoted which I suggested deals in degrees of uncertainty and not necessarily on fixed and predictable outcomes.

Stenhouse (1975) suggests that curriculum development is underpinned by both ‘educational intentions’ and ‘principles of procedure’. He highlights that ‘educational intentions’ are not short-term objectives which are quantifiable but are developmental in nature and require an; “exploration headed towards a destination worth achieving,” (Palmer & Zajonc 2010, p. 39). Stenhouse comments that a process curriculum has underlying principles or; “principles of procedure,” (1975, p. 39) which are intrinsic to the educational intentions and are part of the developmental process. Kelly (2009) recommends that ‘educational intentions’ can constitute something which may be attained at a later stage in the process while the ‘principle of procedure’ is integral to any activity undertaken. The adoption of this framework could provide suggestions for what a curriculum for ecoliteracy might entail in the future. In simplified terms the aim may be to develop students’ ecoliteracy. The ‘principles of procedure’ might be that I hope to achieve this through developing positive educational relationships and through promoting an ecological way of thinking.

Stenhouse (1983) advocates that the role of the teacher in such curricula is as a neutral chairperson, facilitating any necessary student discussion but without disclosing personal beliefs. This ‘procedural neutrality’ is similar to Kelly’s (1986) ‘neutral impartiality’ with Stenhouse (1983, p. 7) suggesting this would validate; “the student's right to be a seeker by containing the teacher's need to declare himself [sic] as a knower.” I am not fully convinced by this and am cognisant of Kelly’s (2009) argument that any curriculum is mediated through the values of the teacher. Ghaye (2010, p.109) endorses this submitting our values emerge within practice and teaching reflects our; “values-in-action.” Bearing Kelly’s (2009, p. 90) proclamation that; “an approach to a curriculum which endeavours to face up to the value issue as the prime concern in educational planning,” is of importance to me, I am drawn to a procedural justification where there is an explicit disclosure of a teacher’s view about controversial issues. Kelly (1986) refers to this as ‘committed impartiality’. ‘Committed’ because the teacher remains dedicated to their beliefs and ‘impartial’ since the purpose is not to inculcate. This was the approach I adopted while working with the students from Cycle 1 which I hope I will have clearly evidenced by the end of this thesis. I am aware the students I work with are adults and that I may have had a different stance if I had been working with children.

I suggest this view of curriculum is ecological in nature. For example, Stenhouse’s (1975) curriculum clearly values process as more important than structure. As has been noted, it is the understanding which is developed from being situated within the process of teaching and learning that is valued the most. I argue that it is the contextual and practical knowledge which is gained by the educator which is of most benefit to the curriculum development. It is also evident that the developmental process of curriculum planning, which does not rely on fixed objectives, relies on relational epistemologies which are often founded upon uncertainty. Elliott (2007) confirms this when he describes that evaluations of the curriculum should occur within the process and which will therefore provide opportunities for flexibility and a change in direction.

While Stenhouse (1975) may have been the first to introduce the concept of the critical friend/colleague to facilitate reflection of the teacher researcher I suggest the reflection he proposed remained an insular practice which was confined locally to the classroom. This inward facing reflection did not necessarily rely upon; ‘studying the whole and not the parts’. While he was appreciative that values inform practice, I suggest that further critique of how those values developed and in what context is needed. I draw upon Alexander’s definition of pedagogy (2008), again, to provide further depth to an understanding of curriculum and how this is related to an ecological view. I believe Alexander’s call for educators to identify the attendant discourses around their teaching satisfies the need to ‘study the whole and not the parts’ and if teachers are remiss in attending to this element that they will only gain a partial view of their practice.

2.11 Chapter summary

This chapter has drawn upon the literature to provide a theoretical context for this research and a framework by which to articulate my understanding of an ecological approach to science teacher education. It has made reference to the historical aspects of how a particular model of science, which is premised upon linear and static epistemologies, has been promoted as the only way of thinking and generating knowledge. I have suggested this way of thinking has largely remained unquestioned and has been adopted and replicated within many western education systems. As a consequence of this I have argued it has resulted in the objectification of our planet. This synthesis of the literature contextualises the ‘habitus’ I experienced and provides a justification for my epistemological stance throughout this research and the difficulties I faced in appreciating there were other ways of thinking. I have also suggested the limited success that environmental education has achieved has predominantly been due to its operating within an education system that celebrates these forms of epistemologies. I have recommended the role of education must be in developing relational epistemologies and have used the literature to define what I mean by ecological thinking. In addition to this I have suggested these relational epistemologies could be developed by reconceptualisating science as an ecological act and, as a result, have theorised how this might be achieved. I have recognised that the manner in which learning takes place is as important as what is learnt and have detailed a relational way of working which I have termed a mutualistic practice. Reference to literature around curricula has been made and I have detailed the potentially transformational nature of viewing a curriculum as a process which can be defined and articulated as one negotiates it with their students. This approach which perceives research into curricula synonymous with teacher development has provided the theoretical justification for the adoption of an action research methodology which was used for this thesis. In addition to this I have proposed that the uncertain nature of this research which did not have fixed objectives or outcomes mirrors the ecological view of scientific enquiry which I have promoted throughout this chapter. As a consequence of researching my practice I have celebrated personal knowledge and have provided a unified pedagogical approach which has theorised what I have taught, the manner in which I have achieved this and the underlying principles for working in this way. This methodological position is now further explained in the next two chapters.

Chapter 3. Defining Action Research

3.1 Introduction

This chapter acts as a prelude to Chapter 4 which will outline the specific actions undertaken throughout the research process, and reasons for those actions. It will define the methodological choice of action research for this thesis by briefly outlining the literature surrounding action research and then signpost where and how this enquiry is located within it. Further, this chapter will define and outline what is meant by the terms 'Cycle 1' and 'Cycle 2' and show how such a spiral of cycles is widely acknowledged as a key element of action research. It will also make clear that part of an action enquiry involves the necessary critical evaluation of one's practice whilst providing the theoretical frameworks to explain the forms of reflection undertaken by myself and the students.

3.2 What is action research?

One way of defining this form of research is to refer to the term's constituent words; 'action' (referring to what is done) and 'research' (which refers to finding out about what is done and how it is done). The idea is used widely in relation to a range of disciplines, including environmental and ecological studies, as shown in this thesis. Its greatest applicability, perhaps, is in social studies: for example, Elliott (1991, p. 96) describes it as; "the study of a social situation with a view to improving the quality of action." Lewin (1948), usually considered as creating the term 'action research', explains it as the form of;

> research needed for social practice [which] can best be characterized as research for social management or social engineering. It is a type of action-research, a comparative research on the conditions and effects of various forms of social action, and research leading to social action. Research that produces nothing but books will not suffice.
>
> (Lewin 1948, pp. 202-3)

Both McNiff and Whitehead (2006) and Reason and Bradbury (2008) highlight the, often fierce, debates surrounding what constitutes the purpose and nature of an action enquiry. McNiff and Whitehead (2006) suggest that while there is common consensus regarding the characteristics of an action enquiry, i.e. that of 'change' and 'improvement', it is how this is interpreted which is the feature of most disagreements. These differences are epistemological in nature and are reflected in which forms of knowledge are valued and how the researcher and participants are positioned within the process. Wallerstein and Duran (2003) identify two broad categories for action research. The first is associated with systemic improvement, which McNiff (2013) argues could be seen as a misrepresentation of action research. Research performed in this guise usually takes the form of a technical exercise which is often undertaken in line with school or governmental policies; the focus is often about quality control or staff development. I have argued in Chapter 2 that this form of research is premised on a Newtonian way of thinking which deals in objective and absolutist knowledge and can have the effect of socialising educators into the dominant discourse through the implication that there is a natural and correct way of doing things. Ball (2001, p. 266) describes this, in an educational setting, as research that provides; "accounts of what works for unselfconscious classroom drones to implement."

Wallerstein and Duran (2003) describe their second categorisation of action research, as that which leads to emancipatory developments. At this point it is useful to use Reason and Bradbury's (2008, p. 1) definition for action research to help explain this position. They state that it is a "participatory, democratic practical [way of] knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview". I suggest that the ecological worldview I have espoused is similar to their participatory worldview. Chapter 4 will clarify why I adopted this relational and ecological form of action research throughout the doctoral process. Reason and Bradbury later suggest that action research is research which aims to find practical solutions for the; "well-being…of human persons and communities, and to a more equitable and sustainable relationship with the wider ecology of the planet…" (2008, p.4) and argue that its purpose is; "to liberate the human body, mind and spirit in search for a better, freer world," (ibid, p.5).

With this in mind, it is important to highlight that this methodological approach locates the 'power' that research brings to the practitioner and enables them to ask questions such as; "'What am I doing? What do I need to improve? How do I improve it?'" (Reason and Bradbury 2008, p. 7). Munn-Giddings (2012) highlights that this form of action research is contradictory to the ethic of traditional social scientific research (premised on a Newtonian worldview) which is carried out by experts 'on' practitioners from (what Schön 1995 terms) the 'high ground' of the higher education academy.

However, even within this form of action research there are often disputes regarding its nature and purpose (Burgess 2006). Reason and Bradbury (2008) maintain that there is not a set of methodological rules for an action enquiry, only guiding principles and that this methodological aspect should not be viewed as a flaw but celebrated. They argue that a diversity of approaches provides different ways of carrying out research which makes them purposeful for the enquirer. Details regarding the specificity of my research, and how the methodology was 'fit for purpose', will be outlined within Chapter 4.

The following section will use the terms outlined by Reason and Torbert (2001) which help to classify the different, and diverse forms of action research (built on original suggestions proposed by Torbert 1998). In doing so it will demonstrate how my research is located within the wilder field of action research. While, previously, I have argued against the need for classifications such as this, I hope that this framing will provide further transparency surrounding the methodological actions I took throughout the research process which Clough and Nutbrown (2012) suggest strengthen the validity of any claims to knowledge made.

3.3 Different forms of action research

This section will briefly introduce the three-person framework that Reason and Torbert (2001) have used to classify the diverse range of action enquiries. Their framework classifies action enquiries into first-, second- and third-person. This section will then use these terms to ascribe the different approaches I used throughout the research process. It will demonstrate that although these terms are useful in categorising types of enquiry there is often overlap and, in reality, the researcher is likely to move between approaches depending on the purpose and stage of their studies.

3.3.1 First-person action research

Reason and Torbert (2001, p. 17) describe first-person research as encompassing those; "skills and methods [that] address the ability of the researcher to foster an inquiring approach to his or her own life, to act awaredly [sic] and choicefully, and to assess effects in the outside world while acting." They clarify that it is research carried out by; "ourselves on ourselves." From this, I identify with Elliott (2007) who recommends that there is a need for critical reflection upon one's values and how they manifest themselves in practice. I assert that this form of first-person research has underpinned this whole doctoral thesis. I have articulated in Section 1.2 how my masters studies helped me to identify the value of mutual respect and how further reflection enabled me to appreciate that much of what motivated me, both in a personal and professional context, was related to my conduct towards planetary well-being. During Cycle 1, while I was working with the students to develop a curriculum for ecoliteracy, there was less focus on my learning and much of my reflection was related to whether I was imposing my values upon the students. However, I do argue, that the process of analysing the data from Cycle 1, and subsequently writing this thesis provides a reasonably robust example of first-person research. This will be explained in greater detail in Chapter 7 where I demonstrate how my learning has transformed in to thinking in a more ecological manner. A detailed explanation for the choice of action research as a methodological framework for the thesis, based upon my ecological principles, will be provided in the following chapter.

3.3.2 Second-person action research

Second-person research is a development of first-person research and involves others in a community of enquiry. Reason and Torbert (2001, p. 20) note; “that all those involved in the research endeavour are both co-researchers, whose thinking and decision-making contributes to generating ideas, designing and managing the project, and drawing conclusions from the experience.” Burgess (2006) describes it as a process which involves face-to-face interactions when researching an issue of mutual concern which draws similar parallels to Wenger’s (1998) ideas about communities of practice. This form of community enquiry also mirrors the development of I-Thou relationships (Buber 1947, 1958), modelled upon dialogically-oriented communication, that, I will argue in Chapter 5, I cultivated with the students.

From the start of this process there was clear intent to create a community of learners while developing the curriculum for ecoliteracy. This is shown in how I introduced my research to the students;

> You know, I think I have to be up-front about this, so what I suppose I’m asking is can we work together and I think that for me that will be quite exciting because I certainly don’t hold myself to be the expert, with 20 odd people in here, you know, the kind of knowledge we could create could be amazing, could we create some kind of curriculum that maybe we could take into schools…
>
> (Initial presentation, 10.1.12)

However, throughout Chapters 5 and 6 I will demonstrate that much of this stayed at the level of rhetoric and, despite my best intentions, much of Cycle 1 constituted a first-person enquiry. I identify that the curriculum that was developed was driven by me as a result of the tensions described throughout this writing, about coercion and relevance; the formation of the curriculum contained minimal contribution from the students. While I provided the students with Learning Diaries to give them an opportunity to reflect on their learning, I now appreciate that this was also a tool to assuage any guilt I felt about imposing my ideas and values. As a result, I understand that much of the research was ‘by myself, on myself’ (my interpretation of Reason and Torbert 2001).

3.3.3 Third-person action research

Third-person research is the establishment of communities of enquiry with the purpose of developing and reaching beyond the face-to-face groups (outlined by Reason and Torbert 2001). I draw upon Capra's work, which draws on ecological principles, to further explain this form of research in which; "all living beings are members of ecological communities bound together in a network of interdependencies," (Capra 1996, p11). Capra's idea of; "nested systems," (2005, p. 27) explains how classrooms (or in this instance, research groups) are embedded within, and related to, wider communities such as the school/university and society at large. For this reason, it may be incumbent upon first- and second-person researchers to identify the influence their actions have beyond their immediate communities.

However, Reason and Torbert suggest that research which is premised upon Newtonian ideals could also be perceived as third-person because; "the researcher is doing research on third-persons with the intent of writing a report for other third-persons," (2001, p. 16). They also say that the underlying principle of third-person research should be the creation of conditions which empower others to take ownership over their practice, research and knowledge generation. This concurs with both my ontological and epistemological values which are premised upon mutual respect. In Section 7.5 I provide suggestions how this thesis could provide a starting point for others who wish to study their own practice.

As outlined in Section 1.8.2, it was during Cycle 2 that I produced resources and writing as a result of this research and as a consequence of wanting to develop an ecological approach to science education (see Sinclair & Strachan 2016). These ideas were being disseminated within the primary science education community; a section of the 'nested systems' in which I was embedded. I propose that offering my work to public critique represented the embryonic formation of a third-person enquiry. While I recognise that I was not encouraging others to study their own practice, I suggest that I was demonstrating the principles of reflection and critique which are necessary for this process. Perhaps more importantly, I used this feedback to develop my understanding of an ecological practice which further emphasises how much of this thesis has been rooted in first-person research.

3.4 Complexity theory, systems thinking and action research

The following will develop concepts which were first introduced in Section 2.5. At this point I drew upon Capra's (2005) ideas about systems thinking which I used to establish educative principles for defining an ecological approach to my practice. This section will show how much of systems thinking is related to complexity theory, and how complexity theory can provide important theoretical and methodological underpinnings for action research (Phelps

& Hase 2002). In particular, it will provide a further justification for the need to break from the mentality of traditional Newtonian research, founded upon reduction and certainty. In contrast, I will propose that complexity theory provides a framework that enhances an understanding of complex systems (such as the classroom) which are not premised upon simple causal relationships, whilst also preserving the peculiarities of such systems (Davis & Sumara 2005). As a consequence, I will demonstrate the participatory and emergent nature of undertaking action research.

According to Morrison (2008, p. 16); "change is ubiquitous, and stability and certainty are rare. Complexity theory is a theory of change, evolution and adaptation and development for survival." Complexity theory; "is essentially a formal attempt to question how coherent and purposive wholes emerge from the interactions of simple, and sometimes non-purposive components," (Lissack, 1999 cited in Phelps & Hase 2002, p. 507). "At its most humble, it attempts to explain the 'big consequences of little things'," (Phelps & Hase ibid, p. 507). While Phelps and Hase (ibid) provide examples for how complexity theory is challenging the orthodoxy in many areas of the natural sciences (for example in evolutionary biology and immunology) they also demonstrate how it could also underpin an action enquiry.

Underwood (2000, found in Phelps & Hase 2002, p. 508) asserts that there are three main areas of complexity theory which are of relevance to action research. These have been adapted and are as follows:

- Complex systems are self-organising whose behaviour cannot easily be predicted;
- Living organisms are self-steering. 'Steering' of individuals from outside of the system has little effect;
- New systems are in a continuous state of emergence.

I will now take each of these in turn to suggest how they apply to action research.

3.4.1 Complex systems are self-organising whose behaviour cannot easily be predicted

Jess, Carse and Keay (2016) suggest that while self-organising systems can support structure and predictability that it is the complex relationships between individuals that also produces unpredictable outcomes. The interactions which Jess, Carse and Keay (ibid) describe are both dynamic and transformational. As a result of these complex interactions, Phelps and Hase (2002) have acknowledged it is almost impossible to understand the whole by deconstructing its parts and that the whole is more than the sum of its parts. To explain this phenomenon it is important to note control within such situations does not reside with the practitioner (nor should it); there are many factors that are present in a social system which can affect how it behaves. While Phelps and Hase (ibid, p. 513) state that it is important to acknowledge; "the whole range of variables impacting on any context," I suggest that it is not possible to identify (nor necessary) all of these variables and that this is an irrelevant aspect for this form of research. They further outline that it is the interaction between a system's component parts and the way that these are organised which leads to change. Kemmis and McTaggart (2005) reinforce the link between complexity and action research noting than an enquiry's focus should be on the relationships developed between individuals within their community and their interaction with their social environment. I have previously written (in Chapter 2) that this was also a principle focus for this thesis and that it was the study of relationships, within my mutualistic practice, which was of prime importance to me.

3.4.2 Living organisms are self-steering

Complexity theory suggests that organisms within complex systems are self-steering and any external 'steering' has minimal effect (Phelps & Hase 2002). In an educational setting I suggest this is a recognition that students are free-thinking and autonomous individuals who are not likely to follow dictates from those in power. This has clear parallels with the curriculum for ecoliteracy I co-developed with the students from Cycle 1 and my intention not to impose a top-down approach.

This communitive action relates to another key principle of action research; its participatory and collaborative nature (Reason & Bradbury 2008). McAteer (2013) notes that action research is not about research on practice but research which is practice and conversely practice that is research. Cohen, Manion and Morrison (2018, p. 56) develop this further outlining that it is; "research with people and communities rather than doing research to or for people and communities." The interrelated relationship of researcher, practice and participants suggests that it is a democratic form of research where knowledge is shared rather than the property of an elite. Davis and Sumara (2005) relate this back to complexity theory by outlining the collaborative nature of knowledge generation, highlighting that change of a system is brought from within and are generally not attributed to external forces. Kemmis (2006, p. 471) describes 'excellent' action research as critical and transformative which; "requires and promotes shared deliberation about important issues for our shared fate and future," and as a result it; "encourage(s) communication about the variety of ways practices are understood, from a variety of standpoints and perspectives," (ibid, p.472). I propose that Kemmis' term 'transformation' is interchangeable with the term 'emergence' which is used in complexity theory.

3.4.3 New states of emergence

Gear, Eppel and Kosiol-Mclain (2018, p.1) reinforce the importance of studying the relations within a system and how they; "lead to spontaneous organization and the emergence of new relationship structures." The form of these new structures are difficult to predict with Davis and Sumara (2005) noting that complexity cannot be scripted. Similarly, McNiff (2013) notes there are no fixed outcomes in an action enquiry. Davis and Sumara (2005, p.460) provide a theoretical backdrop for how the curriculum for ecoliteracy developed stating that outcomes; "must to some extent emerge and be sustained through shared projects, not through prescribed learning objectives, linear action plans or rigid management strategies." The idea of emergence can also be related to the ecological epistemologies that I have tried to foster. Learning is an emergent process which arises from the specific contexts in which the individuals are embedded.

Gear, Eppel and Kosiol-Mclain (2018) suggest that the dominant adherence to Newtonian research methods has helped to obscure the complexity which emerges from the interactions between individuals. This is an important consideration when choosing a methodological approach and brings into question the validity of any findings from research which is undertaken in complex systems that focus on cause and effect relationships.

The emergent process that occurs in complex systems is also a key feature of the cyclical nature of action research (Zuber-Skerrit 2001). The act of reflecting-on-action and acting-on-reflection manifests itself in new questions and new areas of enquiry. Details about the cycles of action research will be provided in Section 3.5 below.

3.4.4 Complexity and systems thinking

In Chapter 2 I wrote in detail about the form of ecological epistemology I believe is necessary to improve planetary well-being. I used Capra's (2005) systems thinking as a theoretical framework to explain this. It is clear that adopting complexity theory as a way of explaining complex systems, whilst utilising the current dominant non-ecological epistemologies is not possible. Viewing and understanding systems as a set of complex interactions requires a new epistemology. I propose this is founded upon systems thinking. At this point it is prudent to refer to the interrelated aspects of systems thinking which I outlined earlier; it is thinking which:

- studies the whole and not the parts;
- prioritises the study of relationships over objects;
- places importance on contextual knowledge and not objective knowledge;

- appreciates that quality is more important than quantity;
- that process is more important than structure.

Although there is not scope in this thesis to explore the following ideas it is important to note that there have been developments in areas of science, other than complexity, which could provide supplementary theoretical frameworks for action research (Walton 2017). There are those, for example, associated with quantum physics (which includes entanglement), which further emphasise the importance of relationships over structure.

3.5 The cyclical nature of action research

I have outlined how Cycle 1 and Cycle 2 drew upon different elements of first-, second- and third-person research. This section will explain the concept of a 'cycle' and how this concept is specifically used within this thesis. It will highlight that there is not a distinct boundary between each cycle and further emphasise the messy, uncertain and holistic nature of knowledge generation. I will propose that these terms have primarily been used to facilitate the articulation of the ideas within this thesis to provide a format accessible to the reader.

Zuber-Skerrit (2001) provides a framework (as outlined in figure 3.1 below) which describes a simplified action research cycle; this involves the process of: planning → acting → observing → reflecting → and which feeds into subsequent cycles.

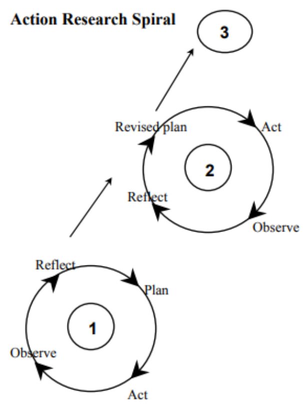


Figure 3.1: Zuber-Skerritt's action research spiral (2001, p. 20)

I have used questions developed by Whitehead (1989) and McNiff and Whitehead (2009) to help clarify how Zuber-Skerritt's (2001) framework might manifest itself in practice.

Stage of cycle	Focussed question
Reflect	What is my concern? Why am I concerned?
Plan	How do I show the situation as it is and as it develops? What can I do?
Act	How do I implement my proposed plan?
Observe	What kind of data can I gather to show the situation as it unfolds?
Reflect	How will I check that any conclusions I come to are reasonably fair and accurate? How will I modify my practices in light of the evaluation?

Table 3.1: Research questions for each stage of an action research cycle

Zuber-Skerritt (2001) seems to suggest that reflection occurs at the end of a cycle and can lead to a revised plan for further action and research. Previously I have argued that it is not possible to separate values and intent from practice or research. Therefore, as highlighted in figure 3.2, I suggest that the first stage of the cycle is the explicit reflective act of interrogating the values that underpin one's practice in order to identify genuine areas of concern and the reasons for those concerns (Whitehead 1989).

In order to specify how the cycles from my research relate to this framework I have produced the following tables. These provide a simplified outline of my actions and learning throughout the two cycles.

Stage of cycle	Focussed question	With students from Cycle 1
Reflect	What is my concern? Why am I concerned?	Identification of my values and what I value.

		Concerns about planetary well-being and a schooling system which does not value learning about such issues.
Plan	How do I show the situation as it is and as it develops? What can I do?	Plans to develop a curriculum for ecoliteracy through a mutualistic practice with a set of teaching students who have specialised in primary science.
Act	How do I implement my proposed plan?	Focus of the students' module is on developing ecoliteracy. Students are introduced to a range of activities that they can use in schools, which could raise awareness of planetary well-being.
Observe	What kind of data can I gather to show the situation as it unfolds?	See Chapter 4 for data collection methods.
Reflect	How will I check that any conclusions I come to are reasonably fair and accurate? How will I modify my practices in light of the evaluation?	Analysis of data and learning from this process identifies the limited success of this approach. An embryonic appreciation that in order to improve planetary well-being ecological epistemologies need to be developed and that this can best be achieved through challenging the dominant perception of science.

Table 3.2: Research questions for Cycle 1

Stage of cycle	Focussed question	With students from Cycle 2	With the primary science community
Reflect	What is my concern? Why am I concerned?	That I had been promoting a Newtonian version of science and that this played a part in developing non-ecological epistemologies.	
Plan	How do I show the situation as it is and as it develops? What can I do?	The production of resources to promote an ecological view of science.	
Act	How do I implement my proposed plan?	A large focus of the module was highlighting the uncertain nature of knowledge through specific science related activities.	Sharing resources with the primary science education community through conference workshops and publications to gain feedback on this approach.
Observe	What kind of data can I gather to show the situation as it unfolds?	See Chapter 4 for data collection methods.	See Chapter 4 for data collection methods.
Reflect	How will I check that any conclusions I come to are reasonably fair and accurate? How will I modify my practices in light of the evaluation?	Analysis of data from this Cycle identified that I had become preoccupied with one aspect (the uncertain nature of knowledge) of an ecological approach to science teacher education. The action-reflection process of writing this thesis culminated in my being able to define an ecological approach to science teacher education.	

		These ideas will be taken into consideration when developing my future practice.

Table 3.3: Research questions for Cycle 2

3.6 Reflection

The previous sections have referred to both the action and reflective process of undertaking this research. Farrar's (2009) review of the literature about reflection highlights that it is ill-defined. She also suggests that there is no consensus regarding the different forms or levels of reflection. For this reason, the following section will outline how reflection has been interpreted and defined within this thesis. In doing so I hope this will further strengthen the validity of the claims I have made in Chapters 5, 6 and 7 that: i) I have helped my students to think in a reflective manner and ii) the reflective process I underwent transformed the way I think and act.

At this point, it is useful to reiterate the importance of reflection to this action enquiry. Carr and Kemmis (1986, p. 165) emphasise that there are three main aims to action research, which are; "firstly, the improvement of a practice; secondly, the improvement of the understanding of the practice by its practitioners; and thirdly, the improvement of the situation in which the practice takes place." However, I concur with Kraft (1997, p.104) that what is of most importance is; "not to 'change' others, but through a process of reflection to achieve a deeper understanding of yourself and your own role, and to consequently change your actions based on that understanding". I have suggested that this can most effectively happen through the identification and realisation of one's educational values in practice (Elliott 2007). In addition to this reflective process, I have previously called upon the need to recognise the underlying discourses (Alexander 2008), and the social and cultural experiences that have informed them (Bourdieu 1990), in which one's practice is framed.

Both Dewey (1933) and Mezirow (1991) concur that this process defines reflection. Dewey (1933, p. 9) suggests that it is; "assessing the grounds of one's beliefs", while Mezirow (1991, p.14) upholds that reflection; "addresses the question of the justification for the very premises on which problems are posed or defined in the first place." In particular, I am drawn to Dewey's ideas about reflection because he sees reflection as a problem-solving process. His vision of reflection shares many of the principles that underpin action research and therefore this thesis.

> The person who really thinks learns quite as much from his failures as from his successes. For a failure indicates to the person whose thinking has been involved in it, and who has not come to it by mere blind chance, what further observations should be made. It suggests to him [sic] what modifications should be introduced in the hypothesis upon which he has been operating. It either brings to light a new problem or helps to define and clarify the problem on which he has been engaged. Nothing shows the trained thinker better than the use he makes of his errors and mistakes.
>
> (Dewey 1933, pp. 114-115)

Dewey (1933) further highlights the interrelated nature of reflection and action and how these aspects of practice should not be viewed as dichotomous; action leads to knowledge generation, which subsequently informs new practices. This further emphasises the cyclical nature of action research, as outlined in Section 3.4.

While Farrar (2009) suggests there is no consensus about reflection, for the purpose of this thesis it has been necessary to differentiate between the levels of reflection I refer to throughout the rest of this writing. While I appreciate the difficulty of classifying reflections, I agree with Kember (1999) who states that without such a framework it is difficult for any reader to gauge whether reflection has taken place. This is a necessary pre-requisite when testing the validity of the claim that prolonged reflection has brought about my epistemological transformation and change in practice.

Later in this thesis I use the terms ‘superficial’ and ‘efficient’ to ascribe the forms of reflection I believe the students and I were adopting at different stages of this doctoral research. As I mentioned previously Dewey (1933) and Mezirow (1991) both refer to reflection in a similar manner, with Dewey stating that it involves the; “active, persistent, and careful consideration of any belief or supposed form of knowledge in light of the grounds that support it and the further conclusions to which it attends,” (Dewey 1933, p. 9). This form of reflection I refer to as ‘efficient’.

I have ascribed the term ‘superficial’ to the form of reflection which did not critically appraise how and why my (and the students’) beliefs, values and actions have manifested themselves in practice. However, it is important to note that neither Dewey (1933) nor Mezirow (1991) recognise this form as reflection at all. Mezirow (ibid, p. 13) describes this process as; “non-reflective action,” Dewey (1993, p. 9) as; “action that is routine,” and Habermas (1976, p. 16) as; “non-reflective learning.” Habermas claims that this form of learning; “takes place in action contexts in which implicitly raised theoretical and practical validity claims are naïvely taken for granted and accepted or rejected without discursive consideration”. However, I appreciate the difficulty of interrogating one’s practice using the same form of logic that has defined it (Bourdieu 1971) and argue that ‘superficial’ reflection is the first step to ‘efficient’ reflection.

3.7 Chapter summary

This chapter has provided the theoretical backdrop for Chapter 4. It has engaged with literature to describe the form of action research that this thesis has adopted. In doing so I have aimed to explain the cyclical nature of action research and demonstrated how I have defined the term ‘cycle’ for this doctoral work. I highlighted the necessity for reflection when studying one’s practice and provided detail of how this term will be used in the rest of this writing. The following chapter will attend to methodological issues in greater specificity. It will explain why the methodology of action research was chosen in relation to my epistemological and ontological standpoints. It will describe in detail the actions that were undertaken during Cycle 1 and 2. In addition to this it will outline the standards which I used to judge my claims to knowledge.

Chapter 4. An Ecological Methodology for an Ecological Practice

4.1 Introduction

I wrote in the introduction of this thesis that I made a conscious decision in Chapter 2 to provide detail of my current understanding of an ecological approach to science teacher education. I felt that this was a necessary signpost and hope that this insight will benefit the reader in coming to an appreciation of the changes in the way I thought and acted throughout the research process. With this understanding outlined, the following chapters will now address how I have come to what I now regard as my ontological, epistemological and educational standpoint.

This chapter will attend to methodological issues. It will provide an outline of the research design and a justification for the methodological approach I adopted. It will suggest that the methodology for this research emerged from my epistemological and ontological stances which have already been explicated in Chapters 1 and 2. This is in line with Clough and Nutbrown (2012) who propose that issues concerned with methodology should be interwoven throughout the research and not just limited to one chapter. In addition to this I will outline the practicalities of the research making specific reference to the aims of Cycle 1 and Cycle 2. The aims of the different cycles will afford a context for the methodological decisions I made. This chapter will provide detail of when and where the research was carried out and the reasons for the selection of the participants. It will also describe and justify the work I undertook with the participants and the data collection methods used. I will outline the standards which I used to judge my claims to knowledge and specify the analytical process I undertook to generate evidence from the data.

I have claimed previously that an ecological approach to science teacher education needs to be grounded in relational epistemologies. This chapter explains how the methodological approach I adopted, that of action research, draws upon the ecological principles highlighted in Chapter 2. I suggest, therefore, that the research process could be described, broadly, as using an ecological methodology.

I will demonstrate how action research offered me the opportunity to live out my articulated values in practice whilst working alongside the students. I will suggest that the relational and practical nature of this form of research culminated in blurring boundaries between my practice and my research. I will explicate how the process of living out these personal values in relation to the students resulted in subsequent tensions of coercion and, as a consequence, that many of the methodological choices I made throughout this work represented and reflected an endeavour to overcome this.

This chapter will also demonstrate why the aims of the research differed between Cycles 1 and 2. This will be explained by reference to my developed and emerging understanding as I came to appreciate what an ecological approach to science education might entail. Specifically, I will show how my emergent thinking at each cycle influenced the actions I took with the different cohorts of students and subsequently how this affected the forms of data I collected.

This chapter will also illustrate why I did not implement the currently dominant technical rational form of research which can view participants as others and the researcher as isolated from what they are researching. Building on the ideas introduced in Chapter 2, I argue that this model of research could be conceived as working in a more Newtonian way because of the absolutist and abstract epistemological assumptions upon which it is founded (Toulmin 1990). I concur with Clough and Nutbrown (2012, p. 21) that the purpose of the methodology chapter is not necessarily to justify why certain methods were chosen over others but also to highlight; "why this way was unavoidable." I am comforted by Reason and Bradbury's (2008) confidence that there are not a set of methodological rules for an action enquiry, only guiding principles (although they suggest that these are often contested in the literature). The research methodology I have adopted, therefore, very much mirrors the 'messy' contextualised and process nature of curriculum development which Stenhouse (1975) proposes and that is unique to each learning setting. A main purpose of this chapter is, therefore, to outline the guiding principles of this action research and justify why they have been adopted.

4.2 Why action research? Prelude to Cycle 1

The following section will outline how my concerns about planetary well-being, and my desire to develop a curriculum for ecoliteracy, were translated into the initial focus for my research during Cycle 1. I have already identified that I wanted to exercise my educational influence in helping the students to develop their ecoliteracy. Consequently I propose that there was no methodological option other than undertaking an action enquiry which studied how this could best be achieved in my practice.

In Chapter 1 I detailed how I was becoming increasingly aware of various aspects concerning the future well-being of the planet and the global difficulties it was facing. I aligned myself with Sterling (2003) who argued that care of the planet should become a prime educational value. I also identified that authors of the National Curriculum (DfE 2013) had actively removed learning about such issues until the age of 14 and an initiative which was devised to assist schools to become sustainable (The National Framework for Sustainable Schools; DCSF 2006) had also been abandoned. It was at this time that I was engaging with Orr's (1992) concerns regarding western education systems which he suggests were promoting a form of eco illiteracy which only assisted in escalating the planet's current problems. I appreciated as a teacher and teacher educator that I had implicitly played a role in propagating this illiteracy and was keen to rectify this.

The key point for my methodological choices was my desire to help develop the students' ecoliteracy came prior to conducting doctoral research and identifying a relevant research question. When I started this research, and as a consequence of this priority, I understood there was a need to adopt a methodology which was commensurate with my desire to change my practice in a way which would cater to my planetary commitments. The following outlines how an action research methodology was utilised to explore critically the changes that I implemented in my practice in order to achieve this aim.

As a starting point in defining action research, Carr and Kemmis (1986, p. 162) say it is;

> a form of self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own practices, their understanding of these practices, and the situations in which the practices are carried out.

Elliott (1991) adds to this by stating that the fundamental aim of such research is to improve one's practice through a form of purposeful action. Therefore, seen in this manner, action research was a methodology which was appropriate for explaining the actions that I took to contribute to developing the students' ecoliteracy.

However, I was keen to acknowledge that if research is simply perceived in terms of 'improving practice' then it may be regarded as a technical exercise and not as a legitimate form of knowledge generation. I have previously noted that my Masters studies (published as Sinclair 2010) helped me to appreciate that research in this guise tends to be undertaken in line with school or government policies, further socialising educators into the dominant discourses of those already in power (Chomsky 2000). In Chapter 2 I provided evidence of this assumption when I referenced the Carter Review (Carter 2015) which recommended that student teachers should be 'consumers' of others' theories. I have made it explicit throughout this thesis that it was my hope to create a personal account of my research and theorise the actions that I took in my practice. I concur with McNiff (2014) that research, such as this, is more than a technical process and has social and (in my case) environmental intent. Bridges (2003, p. 187) provides further justification for the adoption of this methodology adding that action research; "is a practice or set of practices in which a whole set of social and political principles, and by extension an educational philosophy, are embedded." Action research is even being suggested as a methodology by editors of more traditional science education journals (Lederman & Lederman 2016). However, I consider that the terminology they use suggests an objectifying ontology. They comment that this methodological approach is one; "in which the science teacher educator/researcher looks in the mirror and is transformed into the unit of analysis," (Lederman & Lederman ibid, p. 228).

I have also noted that my practice, both in schools and in higher education, was premised upon my value of mutual respect. Prior to starting the research I believed I could best help develop the students' ecoliteracy through establishing specific 'mutualistic' educational relationships. I now understand that I had dichotomised my pedagogy (Simon 1981) by separating the; "act of teaching," (developing mutualistic relationships) (Alexander 2008, p. 3) from what I was teaching (developing ecoliteracy), I also appreciate that I had recognised the importance this value played in the manner in which I worked. I explained in Chapter 2 how this value manifested itself in a commitment to developing mutual respect between myself and the students, which I have likened to Buber's (1958) I-Thou relationships.

This clear intent to evidence the value of mutual respect in my practice consequently became part of the research process. There are obvious methodological implications concerning the role that values play in research. Phillips (2014) describes many educational researchers' desire to mimic the approaches of those in the natural sciences who claim for neutrality and objectivity. Phillips (ibid, p. 9) refers to these researchers as having 'physics envy' and questions whether there is a need for research to be value-free or indeed if it ever can be. Elliott (2007, p. 20) describes the methodological antithesis of this, and provides a justification for the manner in which I conducted this research, when he recounts that research is; "educational if its primary aim is the practical one of realising educational values in practice."

Brydon-Miller, Greenwood and Maguire (2003) argue that action research challenges the positivistic view that knowledge created in social science research is value free and objective. They suggest it should be acknowledged that any form of research (and in this I include research into the natural sciences) is an; "explicitly political, socially engaged, and democratic practice," (Brydon-Miller, Greenwood & Maguire ibid, p. 13) founded upon a system of nested values. If, as I have argued, it is not possible to divorce values and intent from practice then research and action will always have a purpose whether it is made explicit or not. Clough and Nutbrown (2012, p. 28) develop this further suggesting that; "the most persuasive critical accounts reveal the full range of values at work in the analysis." Throughout this process I have appreciated that my research could not be separated from my values or from what I value. As a consequence, I believe that much of the function of this thesis has been to articulate my values to the reader and describe how they have manifested themselves in my practice. In addition to this, and more importantly, I will demonstrate how I identified criteria by which to judge whether or not I realised my value of mutual respect (founded on Buber's 1947, 1958 theoretical frameworks) in the way that I worked with my students. These criteria were subsequently transformed into what Whitehead and McNiff (2006) refer to as living standards by which the quality of my work might be judged and the validity of my claims to knowledge tested. Section 4.6 will detail these standards of judgements and the validity checks I underwent to ensure my claims were accurate.

It is important to stress that, while I understood Elliott's (2007) claim that educational research's primary aim is to realise one's educational values in practice, I unquestioningly perceived the development of mutually respectful relationships as a positive act and never examined whether this aspect of my practice was ethical. However, as I have stated before, I was aware of the tensions I experienced about developing the students' ecoliteracy and whether what I was imposing on them was only of value to me. The following section will outline the methodological issues concerning the research in Cycle 1 and will highlight the impact of these tensions on how the research was conducted.

4.3 Cycle 1. October 2011 – February 2013

This section is specifically concerned with the methodological issues related to Cycle 1. Initially I will describe the aim for this Cycle of the research in order to frame the methodological choices I made; by this I mean the aims I had explicitly identified prior to starting the research and, as a consequence, the resulting research question. I do this as a way of demonstrating my thinking at that time and as a justification for the forms of data I collected and the manner in which I worked with the students. I will explain how these aims were premised on my nascent understanding of ecoliteracy and an ill-defined and abstract appreciation of how mutual respect might manifest itself in my practice.

As a consequence of my heightened awareness of planetary well-being, the focus for Cycle 1 was on whether I could help to develop the students' ecoliteracy. To ensure I was not imposing a curriculum that was only of value to me I concluded that this could best be achieved by contributing to the development of the students' criticality. I have argued that this was part of my mutualistic practice and considered that this would empower them to challenge any dictate from me. As a result, the initial research question for this cycle became; "Can a curriculum for ecoliteracy be developed through a mutualistic practice?"

4.3.1 Research participants for Cycle 1

I have expressed my desire to study my own practice in relation with the students that I taught. The following will outline who these participants were and give greater detail for their choice.

The research participants chosen for Cycle 1 of this research were drawn from a group of undergraduate students who were studying for a degree course in primary education (BA Initial Teacher Training Programme). Successful completion of this course resulted in their obtaining qualified teacher status (QTS). I taught on two modules within this course. The first was a mandatory core science module which had set pedagogical and subject-knowledge objectives; this was taken by all Initial Teacher Training students. The second was the specialist science module, which was elected from the range of National Curriculum subjects (DfES 1999) and was chosen by the students to develop further their understanding of teaching primary science. The students I invited to participate in the research were 18 students that had chosen this specialist science course. 15 students gave permission for their names to be used and as a consequence I have referred to them as such. I hope that this personalisation provides the reader with an insight into the relational manner in which I viewed them rather than adopting the objectifying practice of denoting them as ‘participants’ or ‘students’. However, where students did not consent to my using their names I have referred to them as ‘Student A’ for example.

	Cycle 1
Total Number of students	18
Females	15
Males	3
Start of Research	January 2012
End of Research	February 2013
Number of Sessions	12
Total hours of sessions	48 hours

Table 4.1: Participants – Cycle 1

The decision for inviting this specific group of students to be participants in the research was founded upon my aspiration to develop authentic educational relationships underpinned by my value of respect. The contact time with students on the mandatory science course was only 20 hours long and covered a period of 4 months. I had noted in the past that this brevity of contact time had meant it was not possible to cultivate the form of educational relationships which I believed were necessary for learning and teaching, akin to the ones that I was used to developing in school. The relationships I hoped to cultivate have been outlined in Chapter 2 and are modelled on the dialogical I-Thou relationships (Buber 1947, 1958) which Infed (no date) argues can only be developed if trust and respect is evident. I appreciated that trust and respect have to be earned and that this happens over time. I was in the company of those studying on the specialist course for 110 hours. The course ran for 19 months over two academic years between October 2011 and February 2013 (although Cycle 1 of the research only occurred between January 2012 – February 2013) and I believed that this extra time would provide an opportunity to earn this trust and respect. With previous science elective groups I had been keen to promote the idea of a community of practice (Wenger 1998) and a feeling of belonging and in doing so had ‘branded’ the group as the ‘Science Club’. This sense of belonging was evidenced by the following from a course tutor reporting back from a student tutorial who wrote that; “I just wanted to let you know that one of my academic tutees has commented that she loves the ‘science club’ community that you have in elective science,” (email correspondence; Bridge 2009).

In addition to this it is important to note that the science specialist course did not have fixed objectives and therefore stated learning requirements. Without this course feature I would not have been afforded the opportunity to introduce and negotiate the curriculum for ecoliteracy. This is of particular significance as many of the topics concerned with ecoliteracy were not reflected in the curriculum that the students would be teaching from (DfES 1999) in school. While I had not identified it at the time, I appreciate that the experimental and developmental curriculum I had established was similar in guise to Stenhouse’s (1975) idea of a process curriculum.

4.3.2 Articulated aims may not have been what they seemed

The following will provide evidence of my thinking prior and during Cycle 1 and therefore how I had interpreted the aims for this section of the research. It will briefly detail my, then, nascent and ill-informed understanding of ecoliteracy and a mutualistic practice. As a consequence, I will use this as evidence in the following sections to justify the actions I took with the students during this cycle.

4.3.2.1 My early understanding of ecoliteracy

Despite claiming that I wanted to develop the students’ ecoliteracy there is little evidence to suggest that I fully understood what this embodied. I highlighted in Chapter 1 how, in previous writing (Sinclair 2012a), I had found defining ecoliteracy problematic. Perhaps more telling is my use in this writing of Orr’s (Orr 2005, p. xi) definition that the goal of ecoliteracy; “is not just mastery of subject matter but making connections between head, hand, heart, and cultivation of the capacity to discern systems.” I had not been able to fully comprehend the relationship between ‘head, hand and heart’ and had primarily focused on the ‘head’. Subsequently I argued that; “the ‘head’ refers to specific areas of scientific ecological knowledge necessary to understand how the planet works,” (Sinclair 2012a). From this I suggest that the forms of epistemologies I wanted to develop were not the ecological types that I have believed are necessary for improving planetary well-being, but rather those which were predominantly focussed on the importance of learning content knowledge. I argue that this resulted in electing session content which focussed upon developing subject knowledge and planetary awareness and I did not identify strategies which would help the students to think in the relational manner I have detailed in Chapter 2 (Capra 2005). The course outline can be found in Appendix 9. For further detail of the course content I have provided a completed transcript of a students’ Learning Diary (the purpose of the Learning Diaries will be explained in further detail in Section 4.3.5.2) which details the learning that occurred in each session from the student’s perspective (See Appendix 8). This emerging understanding of ecoliteracy and relational epistemologies provides a justification for the forms of data I collected and further evidence of the way in which I was thinking. Section 4.3.5 attends to the specific data collection methods utilised during Cycle 1. I will demonstrate that these were selected to judge the success of the action I had taken to improve the students’ knowledge about planetary well-being, which I had equated to developing ecoliteracy. These methods, therefore, did not provide opportunities to generate evidence for whether my actions helped them to think in a relational manner.

4.3.2.2 My early understanding of a mutualistic practice

I have provided detail in Chapter 2 of the relationships I wished to promote with the students and have highlighted throughout this writing that these were premised on developing mutual respect. I have stated that one of the founding principles of this practice was the emergence of a community where the students considered that they had a sense of belonging, purpose and the freedom to convey their opinions. In particular I have stressed that a mutualistic practice needed to involve the development of critical thinking. However, an analysis of the strategies I used (which will be outlined in detail in Chapter 5) makes it apparent that it was not yet helping the students to critique their own thinking fully which I was interested in but in their ability to be critical of the teaching they were receiving from me. The following statement from my learning log provides evidence that it was this interrogation of my teaching that I was hoping to promote. The learning log entry read; “having read students’ learning diaries – not many are being critical about the teaching – 2 maybe. How do I help develop this form of reflection?" (Learning Log, Session 1). To place this in context, and explain these actions, it is crucial to understand the tensions I felt about imposing a curriculum. An entry in my Learning Log affords an insight into this. It describes how I felt about a headteacher asking the students to provide lessons for the children in his school on the theme of sustainability for a science week that they would be planning and teaching;

> I was a little worried that the group would think that I had chosen the topic for the science week – even though it had been requested by the headteacher ie ramming it down their throats, but there didn't seem to be an issue. I was even hoping that it wouldn't be around sustainability so that we could cover some other areas of science.
> (Learning Log, Session 9)

This short section has outlined my under developed appreciation of a mutualistic practice in relation to my concerns about imposing what was of value to me and has provided the context for many of the activities I undertook with the students while developing the curriculum for ecoliteracy in Cycle 1. I propose that by providing the students with a platform to be critical of their learning experiences they had the opportunity to advise me whether the imposed curriculum had little relevance or much value to them. The activities I provided which I hoped would promote this form of criticality will be specifically detailed in the following section. This section attends to issues regarding research positionality and the ethical implications of undertaking a first-person action enquiry.

4.3.3 Researcher positionality for Cycle 1

This section considers issues concerning researcher positionality. It justifies the adoption of a methodology which shuns what McAteer (2013, p. 48) states is; "research ON practice," and celebrates; "research AS practice and practice AS research." It will briefly justify the choice of methodology in relation to my ontic stance and then explicate how this positioning influenced the aims for the research during Cycle 1. This section will then attend to issues concerning power which are related to the dual role I adopted as the students' teacher and as researcher of my practice whose explicit intent was to have an educational influence.

A first-person action research methodology allowed me to be part of the research process and to study the forms of relationships which developed with the students from Cycle 1; this was congruent with my relational ontic stance. McNiff (2016, p. 45) refers to ontology as; "the study of the nature of being and reality, about how you see yourself in the world and how you create your identity in relation to others." I add that identity is not only created in relation to others, but also in relation to all aspects of the planet; both abiotic and biotic. I have previously drawn upon the work of Abrams (2010) and Lovelock (2006) in order to theorise my ontological position and to explicate that it is underpinned by ecological principles which guide my actions towards the planet. Lovelock (ibid) explains that the connection between humans and the planet should be premised upon a lasting relationship of mutual benefit. While Lovelock (ibid) makes specific reference to the natural world I believe this ontological positioning also reflects my educational situation and how I hoped to carry out the research.

I maintain that a first-person research methodology is grounded in the framework for ecological thinking which I have adapted for educative purposes from Capra’s (2005) systems thinking and which was outlined in Chapter 2. I will demonstrate below that my research into developing a curriculum for ecoliteracy did not have fixed objectives, or a hypothesis to work from, and that the tentative and transformative nature of what might materialise was encouraged. I remind the reader of the ecological approach to science that I proposed in Chapter 2 and suggest that a first-person methodology mirrors many of the processes which I outlined. In particular this research recognises that knowledge is premised upon degrees of uncertainty which Feynman (1998) highlights is how scientific enquiry proceeds. As a consequence, emphasis was placed on the process of developing an understanding of how the curriculum had evolved and not from any rigid research approach. The research celebrated the contextual knowledge gained from working with the students and the judgements related to the success of the practice were related to the quality of the educational relationships formed and how they influenced the students’ and my learning. The research process advanced my learning which augmented further work and knowledge generation with future students.

In order to explain the relevance of knowledge generated in context it is important to return to how I thought a curriculum for ecoliteracy could be developed. I was aware that such a curriculum would need to be relevant to the particular group of students from Cycle 1 and that there was no; “homogenised one size fits all curriculum,” (Barlow & Stone 2005, p. 6). Prior to working with the students I wrote that;

> it will be crucial to work with my students to develop a curriculum that is relevant to them and the children they will subsequently teach. This will require a flexible and creative approach as it will entail having no pre-planned sessions and working from the students’ ideas, reflections and needs.
>
> (Sinclair 2013, pp. 140-141)

Further evidence of this comes from a video of the session when I first negotiated with the students whether developing such a curriculum would be appropriate. The following comment highlights the tentative nature of my understanding and the transformational process I believed this could entail;

> I don’t call myself an expert in anyway in any of this, and I think that’s what is reasonably exciting, about what is someone who is ecoliterate, what do they look like? What do they do? And what kind of values, that sort of thing. I want to develop my understanding of that.
>
> (Video Footage, Initial presentation. Full transcript Appendix 2)

Stenhouse’s (1975) ideas about curriculum are useful to help explain the researcher positionality I adopted. He proposed that, as part of enhancing teachers’ professionalism, they should research their own practices. Stenhouse (ibid) appreciated the procedural and developmental nature of teaching within a specified context. In particular, he referred to the testing of curricula ideas which he suggests can only be established in contextual action and through a continuous cycle of reflection and adaptation. He also suggested that this can only occur if thought has been given to the personal and professional contexts of the students and the teachers involved. By doing this I argue that it located me at the ‘centre’ of both the curriculum and the research, thus emphasising the interdependent and embodied nature of both processes. From this perspective, curriculum (and therefore teacher) development and research are artificial boundaries and perhaps can be conceived as equivalent.

However, the common view within the field of social sciences is that research is something usually ‘done’ by researchers (who are usually academics) and who position themselves ‘outside’ the research. McAteer (2013) suggests there is a general assumption that abstract theories produced in this way, and out of context, should then be applied to a teacher’s practice. It has never been my intention to be seen as a distant expert (an ‘outsider’) from Schön’s (1995) ‘high ground’, that of the higher education academy, where research can be perceived as having little relevance or influence. In particular, this non-ecological and non-relational research methodology positions those being studied as objects (as “Its”) and elevates the status and power of the researcher. As I have stressed throughout this report, this power imbalance was not congruent with the value of mutual respect that guided my practice or the forms of relationships I hoped to engender. I now discuss issues relating to power and how this methodology, founded upon an intent to influence, could be considered coercive if not handled in an ethical manner.

4.3.4 Ethical considerations

I have highlighted issues concerning the positionality of the researcher and have identified that in an action enquiry, which has intent to exercise educational influence, there is the potential to be; “power-coercive,” (Elliott 2007, p. 114). The following section will attend to this and other ethical issues about my research. I will demonstrate the ethical considerations I made and the strategies that I put in place to ensure that I was working in an ethical manner. In doing so I will refer to two different sets of ethical guidelines. The first are professional and institutional codes of practices. The second is the emergent personal ethical standards I adopted. These developed from my practice as a consequence of my value of mutual respect and were also borne from the tensions I felt about imposing the curriculum for ecoliteracy.

4.3.4.1 Professional ethical guidelines

Before undertaking my research, I made applications for ethical approval to the ethics committees of St Mary's University (my own university) and York St John University (the institution through which this doctoral thesis was undertaken). Written ethical consent was provided by all of the participants (See Appendix 3) and ethical clearance granted by both institutions (See Appendix 4.1 and 4.2).

These applications identified three key areas for ethical consideration which asked me to:

1. Specify how the consent of subjects will be obtained (*please note the ontic stance the term 'subjects' implies – author's note*);
2. Indicate any potential risks to subjects and how you propose to minimise these;
3. Describe the procedures you intend to follow in order to maintain the anonymity and confidentiality of the subjects.

(York St John University, Ethics Application Approval Form, 2011)

While I understood the need for anonymity and confidentiality (ethical consideration 3) I believed that this was a procedural matter and wrote the following in my ethics application regarding the processes I would implement to ensure this aspect was respected:

- When completing questionnaires or Learning Diaries, participants would not include their name and would remain anonymous;
- Data would be stored on secure, password protected computers and would only be accessed by myself and my supervisors. Participants may view this information if desired;
- Information from/about them would not be published without their permission;
- Participants would have the right to withdraw from the research at any time;
- Participants would be informed that they can seek advice through their programme director should they feel the need.

Of most importance were ethical considerations 1 and 2 which I believed were more closely related to the aforementioned potential to abuse my position of power both as a lecturer and researcher. Yassour-Borochowitz (2004) highlights my concern about informed consent that it may not, in-fact, be consensual as participants may feel coerced into complying because they have been asked to participate by someone in authority. I have previously outlined how the assessment process in higher education places me in a dual role; that of teacher and also judge of the students' work. In the latter, the power of assessor establishes me as arbiter of the final degree classification and subsequently the student's potential employability. This was made apparent to me by a student responding to whether they felt developing the curriculum for ecoliteracy during the science teaching sessions was an appropriate strategy. She commented that she was happy to be a participant as long as; "it didn't get in the way of passing the module," (Sarah, Pre Course Questionnaire, 10.1.12). The two ethics committees mentioned above raised questions about the potential abuse of my power. They highlighted their concern that the students might feel compelled to be participants of the research. One of the committees questioned;

> you are the students' lecturer so it would be useful to outline how you would ensure that participants do feel comfortable in consenting to participate / withdrawing from the study and do not feel coerced in anyway.
>
> (email correspondence; Rouse 2011)

My second ethical concern was to do with the potential risks to the 'subjects' (See terminology used in the York St John University, Ethics Application Approval Form) which for this research I identified as the imposition of a curriculum premised upon my values and not necessarily those of the students.. It is important to note that the strategies adopted to address these ethical concerns were put in place not only to comply with institutional guidelines but also because of the deep-rooted tensions I felt about the effect of my educational influence. The following addresses the approaches I employed which performed a dual role in assuaging the discomfort I felt about developing the curriculum for ecoliteracy while also providing evidence of compliance for the two academic institutions' ethics committees.

4.3.4.2 Living ethical guidelines

Elliott (2007) highlights that action research is, in itself, a form of accountability as one's practice is opened up for scrutiny by others and is therefore an ethical act. McNiff (2016) argues that achieving ethical principles is equivalent to demonstrating how one is realising their values in practice which provides a further example of the indistinct boundaries between practice and research. Previously I introduced the idea that the validity of my claim to knowledge could be tested and judged by reference to living standards of judgement

(Whitehead & McNiff 2006) and therefore how successful I have been in living out the value of mutual respect in my practice. If, as McNiff (2016), suggests this validation is synonymous to achieving ethical principles then the process of undertaking this research also becomes a form of living ethical check and the entire thesis could be seen as a report of my ethical considerations. Public scrutiny of this research by critical friends, supervisors and external examiners will provide further grounds for ethical accountability (Elliot 2007).

The following will outline the strategies I put in place which acted to ensure that I was not abusing my position of power and that I was operating in an ethical fashion. Yassour-Borochowitz (2004, p. 179) argues that ethical issues can be resolved through the process of; "reciprocal dialogue," between the researcher and the participants. I believe that the strategies I employed, and which are detailed below, are examples of this and are premised on developing the forms of respectful relationships Buber suggests (1947, 1958), while using the mediatory principles of Alexander's (2008) dialogue.

At this point it is relevant to refer back to my interpretation of the aims of the research. I have highlighted that one aspect of the mutualistic relationship was in developing the students' critical thinking yet practically this manifested itself as providing opportunities for the students to be critical of my teaching to assuage any potential feelings of guilt. I only now appreciate that these emotions were evoked due to my determination to live out my values in practice. The strategies I afforded the students to be critical of my practice were as follows. The success and outcome of these approaches will be discussed in Chapter 5;

1. I gained permission from the students to ensure that they felt that it was appropriate for me to develop the curriculum for ecoliteracy with them prior to starting the research;
2. Students were asked to reflect on the learning and teaching they received from me during the science sessions through entries into personal student Learning Diaries;
3. Students were asked at the start of their course to guide their learning by making suggestions for what they felt should be included in sessions;
4. Students critiqued a chapter about my research that I had written for a book;
5. Students were asked to produce images and metaphors for how they viewed my teaching (idea drawn from James 2013).

I concur with Elliott (2007) that the nature of an action enquiry often makes it difficult to distinguish between the research and the researcher's practice. As a consequence of this, these strategies, which I propose were embedded in my practice, also acted as data collection methods to which the following section now attends.

4.3.5 Data collection methods for Cycle 1

McNiff (2013) highlights that some of the data collected in an action research enquiry is about monitoring one's practice systematically. It entails recording the actions and noting any changes to practice and learning. By recording such information it affords the researcher the opportunity to identify significant episodes that may occur in practice and which can be subsequently used to generate evidence for knowledge claims. She notes that the types of data collected must be appropriate to justify the nature and the purpose of the research, demonstrating the relationship between methodology and the research tools employed to gather data.

Again, it is of significance to refer back to the difference between the articulated aims and the tacit purpose of this research in order to provide a context for the choice of data collection techniques and the forms of data recorded. I have detailed how the initial research question; "Can a curriculum for ecoliteracy be developed through a mutualistic practice?" was premised upon an understanding that ecoliteracy was about raising awareness and developing subject knowledge about planetary issues. I have also articulated that my mutualistic practice was concerned with providing opportunities for the students to be critical of the teaching they were receiving from me. Consequently, the data collection methods employed provide evidence for the success of these approaches, but they also help to determine the manner in which I was thinking.

I acknowledge that the generation of evidence from data sets is an essential part of demonstrating the validity of my claim to knowledge (which will be detailed throughout Chapters 5, 6 & 7). The range of research tools used are detailed below. While I appreciate that these were ultimately used to show my changed understanding, for the purpose of comprehensibility I have separated them into how I collected data to show the students' actions and learning and also my own.

The data collection methods used to monitor how the students were thinking included:

- Student Learning Diaries;
- Semi-Structured Interviews;
- Questionnaires;
- Critique of my writing about the research process;
- Pictorial Metaphors of my Teaching.

The data collection methods used to record my actions and learning were:

- A personal reflective journal which I refer to as my Learning Log;
- Videos of my teaching;

- Emails with colleagues;
- Meetings with colleagues;
- Writing at different stages of this thesis.

The following table provides detail of the data collection tools from Cycle 1, the numbers of students involved and when in the research timeline they were utilised.

Data Collection Tool	**Date which data collection tool was used**	**Numbers of students involved in data collection**
Student Learning Diaries	10.1.12-18.2.13: completed after science sessions	18
Pre Course Questionnaire	10.1.12	18
Critique of my writing	8.10.12	16 (2 students absent)
Pictorial metaphors of my teaching	11.2.13	15 (3 students absent)
Post Course Questionnaire	18.2.13	18
Post Course Interview	18.2.13	6 in total: 3 interviews of 2 students

Table 4.2: Data collection tools – Cycle 1

As can be observed, a range of data collection tools have been utilised throughout this research as I was aware that no one method could provide a comprehensive account of the interrelated phenomena I was studying. This varied approach to studying one's practice embraces the intricate nature of human interactions and their manifestations and acknowledges that these cannot be demonstrated through a single data collection method or standpoint. This approach eschews the Newtonian model of research which can be characterised by the reduction of complexity and the isolation of single variables. The use of multiple data collection tools also acts as methodological triangulation. Triangulation is the process of using different data sources to generate evidence and cross-check findings (Bell & Waters 2014) which Cohen, Manion and Morrison (2017) argue is an authoritative way of demonstrating validity. The following will now provide greater detail of the data collection tools and provide a justification for their employment.

4.3.5.1 Questionnaires

All students were asked to complete a questionnaire at the start of the course (Initial Session, 10.1.12; Pre Course Questionnaire; see Appendix 5) and then the same at the end (Session 13; Post Course questionnaire; see Appendix 5). The questions were aimed at assessing their understanding of sustainability, the level of appropriateness of this being part of their course and the suitability of the issues for their age range of children. I was aware that as part of the research process you need to "explain what the situation was like when you began your research, and produce data to show it," (McNiff & Whitehead 2006, p. 61) and I believed that these questions would provide this baseline data. However, it is prudent to mention briefly that, although these questionnaires provided me with limited evidence regarding whether I had helped the students to develop relational epistemologies they do demonstrate the way I was thinking at the time. These ideas will be developed further in Chapter 6 when I suggest that I was demonstrating a non-ecological epistemology during Cycle 1 and attempted to undertake a Newtonian model of research which objectified sustainability and delivered a quantitative measure of the students' thinking. I also refer to questions I was asking in the questionnaire which I propose acted as another check to ensure that the curriculum for ecoliteracy was relevant to the students' needs. In particular are the following questions taken from the questionnaire which query the importance of learning about sustainability and whether it was the role of the science curriculum to develop this;

> How important do you believe it is that trainee teachers should be taught about sustainability as part of their course?
>
> If issues about sustainability were taught as part of this degree whose role should it be to deliver these modules?
>
> (Pre Course Questionnaire / Post Course questionnaire; Appendix 5)

The questionnaires provided evidence of the influence of the course on the students' attitudes towards planetary issues and their perception of teaching such material in schools. Of the 15 students who completed both the initial and post course questionnaires, 8 had increased how they rated the importance of trainee teachers learning about sustainability. While the other 7 remained the same they had initially ranked it of high importance. Significantly all of the students except two had lowered the age range which they felt children should learn about planetary issues. I am confident this was as a result of planning and teaching young children in school a lesson on the theme of sustainability. This concurs with the United Nations Educational, Scientific and Cultural Organisation (UNESCO 2008) who stress that young children are not only capable of understanding issues to do with sustainability but that such an education is their right.

4.3.5.2 Student Learning Diaries

The students were provided with individual Learning Diaries at the start of the research (Initial presentation, 10.1.12). At the end of each science session they were requested to complete these diaries as a form of reflection about their learning experiences. I have previously identified that this was one of the key strategies I had deliberately adopted to assist in redressing the teacher/student power relationship and in doing so provide the students with a voice to critique my teaching; which I equated with developing their critical thinking.

I provided them with questions to guide the reflective process which were formulated from the work of Boud, Keogh and Walker who note that; "reflection is an important human activity in which people recapture their experience, think about it, mull it over and evaluate it," (1985, p. 19). They highlight three main areas regarding the process of reflection:

- Returning to experience – that is to say recalling or detailing salient events;
- Attending to (or connecting with) feelings – this has two aspects: using helpful feelings and removing or containing obstructive ones;
- Evaluating experience – this involves re-examining experience in the light of one's intent and existing knowledge. It also involves integrating this new knowledge into one's conceptual framework (1985, pp. 26-31).

The questions that arose from Boud, Keogh and Walker's (1985) reflective framework were:

1. What did I learn?
2. How did I learn it?
3. How did I feel?
4. In what ways did it challenge my thinking?
5. What was the relevance of my learning?
6. What further questions do I have about my learning?

In addition to this I added a further question which provides extra evidence for my preoccupation in ensuring that students had the opportunity to critique my teaching.

7. What changes could be made to improve the session and my learning?

Ideas surrounding how successful this approach was in engendering critique of my teaching will be dealt with in Chapter 5. However, it is worthwhile noting that at this stage I had not only conflated the development of critical thinking with a critique of my teaching but also with a superficial form of reflection (evidence of which I was finding within the Learning Diaries). Much of my understanding of the importance of reflection was underpinned by Schön's (1983) legitimation of practitioner's theory generation through reflection in-and-on practice. Similar to how I had viewed pedagogy I had viewed reflection as an 'act of' teaching (Alexander 2008) rather than advocating that students addressed concerns about the underlying discourses of what and how they had learnt. Therefore, the learning diaries did not aid them in; "focussing on the power dimensions of assumptive thinking," (Fook 2015, p. 441).

Students were asked in the post course interview what they felt was the purpose of the Learning Diaries. Many students, like Francesca, identified my hopes for them which gives evidence that I had made explicit the intention for my practice to be critiqued. However, Jessica provided an explanation for the superficial reflection I had recognised in many of the students' comments that; "I think the automatic approach is just to scribble down something quickly and briefly in order to leave the lecture." Similar to Mann, Gordon and MacLeod (2009), I appreciate that for effective reflection which moves beyond description, sufficient time and space needs to be given. I question whether the obligation to me, to complete their Learning Diaries, at the end of a three-hour teaching session was a mutually respectful act and whether it allowed for effective reflection to take place. Holden and Griggs (2011) identify through their literature review, (entitled; "not another learning log") that this form of superficial approach is common as students often question the relevance of completing them. In addition to time, they suggested that many trainees either felt overwhelmed or ill-prepared to carry out this form of reflection successfully. This is pertinent as, while I had provided a framework of questions, there had been no discussion regarding what truly reflective comments should entail.

Nevertheless, the Learning Dairies did provide an insight into the substantive issues which the students felt were important from each session. Probably due to time constraints they gave most detail to what they had learnt and how they had learnt (which were their responses to questions 1 and 2). This gave me an indication of the groups' subject knowledge and the strategies they felt were appropriate for their learning. While I now appreciate Sterling's (2001) caution that merely learning 'about' planetary issues is unlikely to assist in developing an ecological epistemology I am also aware that many of the students' understanding in these areas was not strong. This is in keeping with Hart and Nolan's research (1999) which identified several studies which have reported the lack of basic planetary knowledge of most teachers.

4.3.5.3 Student critique of my writing about the research

In addition to the critique of their experiences in their Learning Diaries I gave the students the opportunity to review some draft writing of mine during Session 7 (later published as Sinclair

2013). The title of the writing was; ‘Cultivating an ethos of Eco-literacy’ which relayed some of the research that I had carried out with the group of students from Cycle 1. Each student was provided with a copy of the writing and asked to annotate their thoughts throughout and then provide an overall summary at the end.

The original purpose of this was to provide the students with a further strategy by which to critique their experiences. The writing focussed, as has much of this thesis, on my pervasive concerns about coercion with the introductory section of the chapter outlining;

> I believe that this science curriculum is one of the vehicles that could be used to cultivate an ethos of eco-literacy. This chapter will focus on the tensions I have experienced in using this module for these ends and whether or not I am abusing my role in attempting to influence my students to adopt attitudes and values concerning issues that are important to me.
>
> (Sinclair 2013, p. 133)

However, I also came to see this technique as an example of dialogue-in-action (Bohm 1996) where the construction of meaning through a collective conversation generated a theory of my practice as the students’ responses provided validation for the action I was taking. Three themes emerged from analysing the students’ comments. They suggested that they valued my honesty, that they did not feel they had been coerced and that working with them in the manner I did had engendered a community of mutual respect. One student commented that; “I admire your dedication and have learnt a lot from your teaching style – especially the bonds + respect you gain with your students,” (Student X, Chapter Critique - Session 7). However, it is important to note a concern I had about all the strategies I had adopted regarding the honesty of student feedback. This was vocalised by one student in their post course interview who stated how the process; “should have made us feel empowered but I think we were all slightly worried that if we said something awful then…we are only poor students,” (Samantha, End of Course Interview 2). I am aware that the entrenched positionality between teacher and student may have left this student and others feeling either uncomfortable or unavailable to make critical feedback. However, I was buoyed by Susannah who felt unable to critique the article, but identified that others in the group felt confident to.

I also suggest that critiquing writing about my perception of the manner that I had negotiated the curriculum also acts a validation check, that of member checking, which strengthens the claims that I am making about my practice. I also propose that this specific strategy helped the students reconceptualise the power relationship in positioning me as a learner. One student remembered this activity and, sometime later in the post-course interview, commented;

> I quite liked reading his academic work because it’s nice to know that he, because obviously we are doing assignments all of the time and bits and pieces it’s nice to sort

> of, you almost share in that, I think you can very quickly think of lecturers as, you know, having gone through that and not doing it anymore.
>
> (Anthony, End of Course Interview 3)

4.3.5.4 Pictorial metaphors of my teaching

Towards the end of the course (during Session 8) I asked students to produce a pictorial metaphor with a textual explanation to describe and explain how they viewed me as a teacher and my teaching. Lakoff and Johnson (2003) and Bateson (2000) have argued that metaphors are a fundamental mechanism for the way we think because of the way they structure our sensory experiences. Combs and Freedman (1990) conclude that as a result that effective communication is premised on the ability to work with metaphor. Previously I had engaged with work by James (2013) who had used this strategy to help her students articulate their teacher identity. James' (ibid) work was founded upon Price and McGee's (2009) suggestion that the recognition of identity is one of the key aspects of teacher education programmes and that the use of visual metaphors can act as a cognitive device which encourages reflective and creative thinking. Avraamidou (2014, p.146) recognises that;

> the construct of identity is particularly important within the field of teacher education because it offers a comprehensive construct for studying teacher learning and development, which goes beyond knowledge and skills.

In this instance I felt that this activity would act as a useful tool in helping the students to articulate their perception of me as a teacher. In addition to this I believed that this format added variety to the data collection methods because it differed from the customary questions that they were asked to answer when completing their Learning Diaries.

As I was cognisant of the number of times I had asked them to reflect on their experiences I asked them to complete their metaphors during one of their breaks within the session and did not make it a compulsory task. Subsequently the quality of the metaphors varied and not all students chose to perform this. While I have already argued that in a first-person enquiry research and practice should be viewed as virtually synonymous I suggest that data collection, where participants monitor their own thinking (McNiff 2013), can infringe upon this. I have questioned whether this imposition on their time reflected the development of respectful educational relationships. Because the images and explanations produced were concise and lacked detail they have been difficult to analyse. This will be revisited in Chapter 5.

I am aware that it would have been beneficial to have asked the students to have produced metaphors at an earlier stage of the course as well as towards the end. This may have provided evidence of their expectations of me as their science lecturer at the beginning of the course and any transformation in their opinions following their teaching experiences. I also suggest that I should have used this strategy in a similar fashion to James (2013) which may have provided a greater depth of data to show how the students' thinking had changed. She used 'Pictorial Transition Metaphors' to gain an insight into her students' learning and, therefore, her influence. Her students provided images and explanations of how they felt about teaching Religious Education both before and after working with her. Price and McGee (2009) suggest that revisiting an initial metaphor is a vital element in assisting teachers to conceptualise their teacher identity.

4.3.5.5 Semi-structured interviews

I used semi-structured interviews with groups of participants at the end of the course during Session 11 (End of Course Interviews 1, 2 & 3; full transcripts can be found in Appendix 6.1, 6.2 & 6.3) to gather further data. I was guided by some of the principles of grounded theory which suggest that data collection is an emergent process. Theoretical sampling is used to identify gaps in understanding in order to determine what further data should be collected (Birks & Mills 2011). The transformative theory generated from this additional data collection exemplifies the ecological nature of this method. The justification for undertaking these interviews will be used to demonstrate my previous argument about how I had separated my pedagogy (Simon 1981); the manner in which I had separated my mutualistic practice from the curriculum for ecoliteracy. The need for these semi-structured interviews was premised upon my belief that I had not demonstrated the link between the relational nature of my teaching and encouraging the students to develop their ecoliteracy.

Lichtman (2006) outlines that it is necessary to set up an environment where the interviewee feels confident they can reveal their intentions and feelings. While I appreciate that DiCicco-Bloom and Crabtree (2006) suggest participants feel more at ease when they have a strong rapport with the interviewer I deemed it necessary, because of the personal nature of the questions, that it could not be me. Atkins and Wallace (2012) highlight that one of the key drawbacks of the interview is the trustworthiness of the replies. For this reason, and to avoid potential bias, another colleague from the school of education conducted the interviews in a neutral setting. This colleague was known to the participants as they had also been taught by her.

The following questions were given as guidance to the interviewer with the interviews being recorded in an mp3 format so that they could be transcribed at a later stage:

- How do you feel about learning about sustainability?

- How has Alex's teaching helped you to learn about sustainability?
- Have you ever felt coerced to learn about sustainability?
- Did you feel able to critique his teaching?

Questions were specified to ensure the aforementioned priorities of the interview were addressed. Atkins and Wallace (2012) highlight that the interview allows for face to face engagement and an opportunity for dialogue which the questionnaire does not provide (Silverman 2017). Interviews underpin an ecological approach in that they can be viewed as a social encounter (James 2013) which value the participant as more than their responses. I hoped that the interviews would; "provide a site for interplay between two [or more] people that leads to data that is negotiated and contextual," (Birks & Mills 2011, p. 56) which I believe is the form of dialogue and relationship that both Buber (1947, 1958) and Bohm (1996) call for.

Much of the analysis of these interviews will be discussed in Chapter 5. However, the students spoke overwhelmingly around a few interrelated themes with the main focus being the respectful environment created within the classroom. Despite not articulating the relationships I hoped to develop with the students, I argue that my value of mutual respect was manifested in practice and subsequently identified clearly by those being interviewed. Regardless of the number of strategies I implemented these were not mentioned explicitly and it was my long-established teaching style that I adopted which was deemed of most importance. Many students commented that they felt their ideas were valued and that they could speak without fear of judgement from me or the rest of the class. Regarding whether introducing issues to do with sustainability throughout the course was appropriate, the general consensus was that it had been a positive and worthwhile experience. Pleasingly, most interviewees commented that the curriculum had not been imposed upon them.

However, I recognise Jessica's sole voice who mentioned on two occasions during the End of Course Interview that she questioned whether what she was learning was of benefit to her or whether it was to help me with my research. While not a consensual perception of the whole group, I am placated slightly by my awareness that no curriculum is neutral and that subsequently the curriculum is mediated through the teacher's values (Kelly 2009) and that with this group, many students appreciated the candid approach I took with them.

4.3.5.6 Recording my learning

I understood that there was a need to monitor systematically my actions and learning throughout the research process (McNiff 2013). At this point I was not really aware of the multi-faceted aspect of data collection, or the forms of data which could be used in an action enquiry to generate evidence. I felt that the systematic monitoring of my emergent learning could best be achieved by completing a reflective Learning Log at the end of each teaching session (a full transcript of the Learning Log can be found in Appendix 7). Unlike the students I did not provide myself with set criteria as a guide for writing my Learning Log entries. I will argue in Chapter 5 that much of the focus of my reflections was around the aforementioned tensions about the curriculum for ecoliteracy and whether or not I was providing the students with the opportunities to critique the imposition of this. However, it acted as a reflective tool for pedagogical issues; not in the sense which Alexander (2008) argues for, but with a focus mainly on the 'act of my teaching'. I faced similar time-related issues to students when they completed their Learning Diaries; finding space to articulate these reflections during a demanding teaching day was problematic.

In addition to my Learning Log I will also draw upon data in the form of: videos of my teaching; conference presentations; emails; meetings with colleagues and supervisors. However, I propose that the most valuable data source I possess is my previous writing. I suggest that writing this thesis has afforded me the space, time and opportunity to develop my critical reflections in a way that the Learning Log did not. I argue that Alexander's (2008) call to evaluate critically the 'attendant discourses' which underpin teaching is a time-consuming process and cannot be achieved through reflective journals as I had first envisaged. I am also aware that the many iterations of this thesis and my writing prior to undertaking it can be used to demonstrate how my learning has transformed as my thinking and writing have developed.

4.4 Insights from Cycle 1

The following section consists of a concise summary of the development in my thinking between Cycle 1 and Cycle 2. This evolution most importantly involved an uncomfortable critical evaluation of my understanding of the nature of science and resulted in my transformed perception of science, science education and also ecoliteracy. These aspects of my learning will be developed in far greater detail in Chapter 7 where I will provide evidence of my change in thinking. However, it is important to describe this epistemological transformation to explain why there were redefined aims for Cycle 2 which may initially appear radically different from those of Cycle 1. These new aims will therefore provide the context for the action I took during Cycle 2 of the research. The focus for my practice was no longer on planetary well-being but on developing ecological epistemologies through a reconceptualisation of science.

Engagement with the ideas of Bateson (2000), Orr (1992), and Capra (2005) and other scientists such as Feynman (1998) and Bohm (1996) revealed that these authors promoted a worldview which sees value in seeking out interrelating patterns and where emphasis is placed on understanding the patterns of relationships rather than the objects involved. This is in contrast to the objectification of knowledge endorsed by most western ways of thinking and, which I argue now, was primarily how I perceived the curriculum for ecoliteracy. As I have articulated in Chapter 2 these authors suggest that this way of thinking resulted from the glorification of a particularly scientific viewpoint which was founded upon Newtonian science; one which generally ignores an ecological way of perceiving the world and functions by isolating and studying the properties of constituent components to explain complex systems. Through this matured understanding of the nature of science I came to identify that my initial focus on planetary well-being and the development of a curriculum for ecoliteracy, in Cycle 1, was in reality a study into my perception of science and scientific enquiry. Consequently, I started to appreciate that both ecoliteracy and science are bound together and are ultimately underpinned by an ecological way of thinking. This demonstrates how the research changed to focus on how I could help others reconceptualise science as an ecological act and therefore to develop relational epistemologies. This helped me to start redefining the purpose of science education and science teacher education.

4.5 Cycle 2. November 2016 – March 2017

The initial remit for this thesis was confined only to one cycle of research. However, the articulation of my thinking which accompanied analysing the data from Cycle 1, and my developed understanding of ecoliteracy and ecological epistemologies, started to inform my practice in a way that I felt needed to be documented. Without data from Cycle 2 there would be no way to demonstrate how the transformation in my thinking had subsequently influenced my practice and, therefore, how I had reconceptualised my view of science. While I would have been able to articulate a theory of my practice (McNiff 2013) this would have been impoverished and partial and would only have provided evidence of my disconnected appreciation of pedagogy. The data collected from Cycle 2 has helped to show how I made connections between a particular worldview of science and the need to develop ecological epistemologies.

In this respect Cycle 1 should be perceived as research, which McNiff (2014) refers to, as having social and environmental intent. This intentional aspect of the research resulted in the prescribed and systematic data collection methods that I have detailed previously and an articulated commitment to developing the curriculum for ecoliteracy. Cycle 2 in contrast was research to demonstrate how the learning I gained from undertaking Cycle 1 manifested itself in my practice. I suggest the data collection process during Cycle 2 is less contrived and the research account of this cycle provides a more natural reflection of my practice.

4.5.1 Cycle 2. The aims of my practice and therefore the aims of the research.

This section focusses predominantly on the change in my practice as a consequence of my reconceptualisation of science and therefore science education. My practice during Cycle 2 was premised on my belief that relational epistemologies, necessary for ecoliteracy, could be developed by helping others to perceive science as an ecological act.

I will demonstrate the deep-rooted tensions, ubiquitous throughout Cycle 1, were still influencing my practice. I will show that I thought I could develop ecological epistemologies by reference to the science taught in schools and this afforded me the opportunity to eschew introducing the ideas about planetary issues which had caused such tensions during the previous cycle.

I believed these epistemologies could be developed by learning about the nature of science. Taber (2012) places my misinformed understanding about this process of science in context stating that secondary school science teachers' understanding of the nature of science is often poor. In particular, I propose I had not given consideration to how scientific discoveries were historically and culturally related and influenced by what was happening in the scientist's own time and space. While I understand that the nature of science attends to issues regarding philosophy, history and sociology (Taber ibid) from an ecological perspective the aspect which most resonated with me, was in developing ways to help my students to understand that scientific ideas have changed over time and thus demonstrate the dynamic, evolving nature of knowledge. I have previously detailed how this revelatory aspect of my learning became the predominant motivation for the way I acted. Therefore the aim for this cycle was to answer the question; 'can the science curriculum be used to develop an understanding of the transformational and generative nature of knowledge?' This preoccupation with a particular aspect of science provided a justification for omitting to attend to other issues relating to ecological thinking (premised on Capra's 2005 systems thinking) detailed in Chapter 2.

4.5.2 Research 'participants' for Cycle 2

The 'participants' for Cycle 2 were not restricted only to the students I was teaching. They were also drawn from the primary science education community I had interactions with and who had engaged with my new way of thinking. My developed understanding gained from theorising my practice provided me with the confidence to engage in debates around science education. This resulted in writing for a primary science teaching journal, presenting at conferences and providing continuing professional development training. As a consequence, the participants for Cycle 2 comprised a group of students studying on another science elective module (which I will detail below in Section 4.5.1.1) but also included a range of colleagues working in the primary science education community.

Ethical clearance was obtained via email from the participants who provided data for this cycle of the research. Copies of these emails can be found in Appendix 4.3 (Ethical Consent: Cycle 2).

The student participants were studying on a similar course to those from Cycle 1and had chosen to study science as a specialist subject. I noted earlier, these specialist courses allow for greater flexibility in content choice. This meant I was able to introduce the students to new resources I had produced in the hope that I was developing an ecological view of science.

Although the course aims were similar to those from Cycle 1 these students were on a newly validated programme in order to reflect the current educational issues and the newly updated National Curriculum (DfE 2013). This programme format only gave the students the opportunity to choose science as an elective subject for one year. The cohort comprised 7 students, who I worked with between November 2016 and May 2017. The course duration was only 20 hours, which was in addition to their mandatory core science course. The limited number of students and contact time and the potential effect this had on developing the mutualistic relationships mentioned previously will be addressed at a later stage.

The following summarises the participants from Cycle 2 and the time period they were involved in the research:

	Cycle 2
Total Number of students	7
Females	6
Males	1
Start of Research	November 2016
End of Research	May 2017
Number of Sessions	5
Total hours of sessions	20 hours

Table 4.3: Participants – Cycle 2

4.5.3 Data collection methods for Cycle 2

McNiff (2017) suggests that in order to monitor one's practice that there is a need to find episodes to show that:

1. You have influenced your own learning;
2. Your new learning has influenced new actions;
3. Your actions have influenced other's learning.

(adapted from McNiff ibid, pp. 169-172)

In order to show how my learning has been influenced I have used two main data sets. The first has been the different iterations of draft writing composed throughout the research process. The second are the presentations I gave at my end of year PhD review meetings to my doctoral supervisors. While not providing a demonstration of the complex and messy nature of my learning they conveniently distil it into blocks which show radical changes from one year to the next. Both sets of data have provided me with evidence to demonstrate how my thinking has transformed as my ideas about the nature of science and epistemologies have developed.

To generate evidence to show how this new way of thinking has influenced my actions I have drawn upon the following; new resources that I produced to develop an understanding of the nature of science (detailed in Sinclair & Strachan 2016 and in Appendix 1) and strategies and a way of working I adopted during sessions with the science specialists during Cycle 2 (see Appendix 11).

So as to demonstrate how these new ways of working have influenced others' learning I have used data from two different sources. The first is an article written by the students from Cycle 2 (Cain et al. 2017). This is a reflective piece that details their experiences from studying on the science course and reveals how, in part, they have been influenced by my teaching. In addition I have utilised feedback from members of the primary science education community who have either attended conference sessions or used the resources I have produced.

The previous part of this chapter has addressed matters related to the practicalities of undertaking the research and therefore has detailed aspects of the rigour in which the research was conducted. McNiff (2016) suggests that the first steps in legitimising research work is through demonstrating the validity of claims to knowledge. The following section will outline the validity checks I undertook to ensure that the claims I have made about my practice are authentic, credible and related to what I have written.

4.6 Testing the validity of claims made through an ecological methodology

Cohen, Manion and Morrison (2017) claim that one of the fundamental aspects of any research is the validity of any claims to knowledge which are made. This section provides details of the methods used to ensure I can demonstrate and, therefore claim, that I have developed an ecological approach to my practice. I will draw upon validity checks which are appropriate for an ecological methodology and suggest reasons why there was no requirement to rely upon those assumed from Newtonian social science research.

I outlined in Section 2.5 that the personal theories (Polanyi 1958) I developed in the unique context of my practice, and with a unique set of students, has led to my personal claim to knowledge; that I have developed an ecological approach to science teacher education. I also detailed that because of this, my claim to knowledge is neither generalisable nor can be replicated. This is unlike the forms of educational research which attempt to replicate the natural sciences which can rely upon an absolutist, external form of validity. Maxwell (1992) claims there are differing models for demonstrating validity depending on the research undertaken. He argues that researchers should not feel compelled to comply with the dominant method of demonstrating validity when this is not appropriate. In a similar manner to the interpretation of findings from quantum theory (Colbeck & Renner, 2011), Hammersley (1993) suggests that the validity of qualitative research, such as this, should eschew the notion of certainty and that it should be replaced with a focus on confidence; this is similar to the claims that Feynman (1998) has made about scientific theories.

Whitehead and McNiff (2006) claim that demonstrating the validity of a claim to knowledge requires two checks; the first concerned with personal validity and the second with social validity. They state that personal validity refers to the ability; “to test the validity of your claim to knowledge against personal criteria and standards of judgement,” (Whitehead & McNiff ibid, p. 25). They both declare that determining personal validity requires an ontological and epistemological perspective which values personal knowledge (Polanyi 1958). They assert that a demonstration of personal validity is initiated through an articulation of one’s personal values and that these are subsequently used as criteria for judgement. I have professed that much of my work has been underpinned by the desire to develop educational relationships founded upon mutual respect. The validity of my claim to knowledge that I have developed an ecological approach to my practice, therefore, will be judged by how successful I have been in living out this value of mutual respect in my practice; as a consequence this value became a living critical standard of judgement (Whitehead & McNiff 2006). While I appreciate the unified nature of pedagogy I also appreciate that, alongside developing mutualistic relationship, my educational intent has been to help those I work with to develop ecological epistemologies. Therefore, for the sake of clarity I have separated the standards by which I would like my research and practice to be judged into two separate (but related) pedagogical facets; pedagogical facet A deals with whether the forms of relationships I developed were premised on mutual respect, while pedagogical facet B attends to the success of the approaches I adopted in helping the students to develop ecological epistemologies. The following sections will address these two personal validity checks. This will be developed in Chapters 5, 6 and 7 when I will aim to show how I have interrogated the data for evidence which justifies the validity of my claims. Matters concerning social validity will be addressed in Section 4.6.2.

4.6.1 Personal validity – pedagogical facet A: identifying standards to judge whether I had developed a mutualistic practice during Cycle 1

As part of developing an ecological practice I have argued for certain forms of relationships which are ecological in nature. I have explained that that these mutual relationships are premised on my value of mutual respect. I have used Buber's (1947, 1958) theoretical frameworks about human relationships to articulate how this value could be identified in my practice. In particular I have drawn upon his suggestions for mutually respectful relationships within an educational setting. Buber (1947) advises that it is incumbent upon a teacher to set a curriculum which provides a value-platform for the students. He counsels that to ensure the curriculum is not an imposition of the teachers' values that it should be founded upon the students' needs, interests and freedom. In this instance I have interpreted a curriculum premised on freedom as one that provides students with opportunities to develop their criticality. This criticality should have allowed the students to articulate whether their needs and interests are being met. Section 4.3.4.2 has already detailed the strategies I used throughout my time teaching the students from Cycle 1 which I hoped would help the students develop this criticality. I propose that the students' needs were related to preparing them for teaching science in schools and ensuring that they passed their assignments for the specialist science module. In Chapter 5 I will suggest that I catered for these needs. However, I will argue that, at this point, I only had a tacit awareness of how I worked mutualistically. I have only been able to make this explicit through analysing my actions and the students' reactions during Cycle 1. I was also aided in theorising my mutualistic practice through engagement with Buber's theoretical frameworks work regarding dialogue. I am aware that dialogue is related to the teacher/student power relationship and the development of non-objectifying relationships. Throughout this research process I claim to have identified strategies and a way of working which are relational in nature but which maintain a position of authority and expertise. While Buber (1958) denotes dialogue as any human interaction, Alexander (2008) provides specific guidance with reference to talk about empowering the student and giving them a voice. This relies on the teacher allowing the students' ideas to flourish without closing or shutting down thought. I identify in more detail later that this was a key aspect of how I worked, with one student commenting on my practice that;

> I certainly have never felt like anything that I've had thought was worth saying in front of people wasn't welcomed, so I think there's a sort of environment which everybody contributes to whatever extent they wish to.
>
> (Suzanne, End of Course Interview 3)

In order to assess whether I had developed mutually respectful relationships (pedagogical facet A) I utilised Buber's (1947, 1958) and Alexander's (2008) educational frameworks in asking the following interrelated research questions about my practice.

- Q1. Did I outline my value system to my students in order to make the reasons for introducing a curriculum for ecoliteracy transparent?
- Q2. Did the curriculum for ecoliteracy allow for the students to develop their interests, needs and critical thinking?
- Q3. Did I create a dialogic learning community while working with this group of students?

These questions were transformed into standards of judgement and I looked for evidence in the data where I believed that I had:

- S1. Demonstrated that I had articulated my values to the students clearly;
- S2. Demonstrated that I had provided opportunities for the students to identify and then develop their interests, creativity and critical thinking;
- S3. Demonstrated that I had created relationships which did not objectify the students and encouraged the flourishing of student thought.

I used these criteria to judge whether I had developed a mutualistic practice only during Cycle 1. I have previously specified that the development of this facet of my practice was primarily introduced to ensure that I was not imposing my views about planetary well-being. In Section 4.5.1 I detailed how the research focus transformed during Cycle 2 and why I no longer felt the need to introduce the students to the planetary issues I felt were so contentious during Cycle 1. For this reason I did not employ data collection techniques that would capture this pedagogical facet. I provide this as further evidence that I was still dichotomising my pedagogy and had not yet appreciated that 'what' and 'how' I taught were related.

4.6.2 Personal validity - pedagogical facet B: identifying standards to judge whether I had helped to develop ecological epistemologies through a reconceptualisation of science during Cycle 1 and 2

I hope the reader will appreciate that this thesis charts the development of my ideas around ecological thinking. I have already briefly described how they were ill-formed during Cycle 1 and, still underdeveloped in Cycle 2. My current understanding has been outlined in Chapter 2 where I explained how I had adopted Capra's (2005) conceptual framework about systems thinking to articulate my understanding of how to develop ecological epistemologies in an educational setting. I expressed that there was a need to focus on; process over structure, quality over quantity, relationships over objects, and studying the whole and not the parts. I then applied this to learning science. As this was my most recent thinking I utilised this theoretical framework to provide research questions by which to judge the validity of my claim that I have developed ecological epistemologies (pedagogical facet B). The research questions were as follows:

- Q4. Did I help the students to develop an understanding of the relational nature of scientific ideas?
- Q5. Did I help the students to develop an understanding of the temporal and transformational nature of relationships in science?
- Q6. Did I help the students to develop an understanding of the symbiotic relationships they have with the planet and those that share it?

These questions were transformed into standards of judgement and I looked for evidence in the data to identify whether I had:

- S4. Encouraged the students to understand the related nature of science and because of this whether they were able to make links between different scientific ideas;
- S5. Encouraged the students to understand that some scientific ideas change over time when new evidence appears and because of this whether they viewed knowledge as both tentative and potentially transformational;
- S6. Encouraged the students to perceive themselves as part of the natural world and not as separate from it.

It is important to note that I used these criteria to judge my practice in both Cycles 1 and 2 despite my under-developed understanding at both points. The evidence of the students developing an ecological way of thinking about science, in Cycle 1, is limited due to my nascent appreciation of this aspect. Because my actions during Cycle 2 were predominantly focussed upon encouraging students to appreciate that scientific ideas change over time (S5) there is only partial evidence of the other ecological aspects (S4 & S7). This at first may appear a negative way of conducting research. However, I believe this form of analysis has offered me the opportunity to chart my learning through the whole research process and therefore demonstrate how I have arrived at my claim that I have developed an ecological approach to science teacher education.

Further specific detail for how these six standards of judgement were used to analyse the data, and generate evidence for my claims, will be provided in Section 4.7.

4.6.3 Social validity

McNiff (2013) highlights that it is important to recognise personal bias and factual errors when making claims to knowledge. McNiff and Whitehead (2009) emphasise that, because of this, it is not enough solely to demonstrate personal validity and that any claim to knowledge should also be subjected to the critical analysis of others. I view this process like Anderson and Herr's (1999) dialogic validity check which is evidenced through the reflective process of conversation followed by the negotiation of shared meanings with peers. I propose that this process is not merely one of validation but also provides further evidence of how I embraced the idea that knowledge is transformative and continually in a state of regeneration and is often socially constructed.

I have tested the validity of my claims through the feedback of colleagues who have acted as critical friends and my doctoral supervisors. I will hope to do so with the external examiners during the defence of this PhD thesis. Any action taken on suggested amendments as a consequence of this defence will demonstrate a dialogical validity check in action (Anderson and Herr 1999). I also involved the students in the validation process when they were given the opportunity to critique writing which detailed how I had negotiated the curriculum for ecoliteracy with them. In addition to this were the many opportunities I have offered my work and articulated practice for public scrutiny. The following will outline these social validation checks in more detail.

4.6.3.1 Critical friends

Throughout the research process I have worked with three colleagues who have acted as my critical friends. While Stenhouse (1975) first coined the term 'critical friend' it is important to stress that his principle was premised upon full-time researchers supporting teachers through their research. The relationships that were formed with my critical friends were not premised upon such a hierarchical system but on the same mutually respectful relationships I endeavored to develop with the students I worked with. These critical friends were colleagues from my place of work with whom I have been working since completing my Masters and starting this doctoral thesis. This provided the necessary familiarity with my work which McNiff (2013) suggests is needed for such a role. Feedback was either given face to face in validation meetings or via comments attached to written work. At times, the meetings were recorded and subsequently transcribed. Importantly, my critical friends were also undertaking doctoral work and therefore the practice of critiquing each other's work was reciprocated. Wennergren (2016, p. 264) suggests that the characteristics of critical friends are comprised of two roles and that these are premised upon; "on the one hand, friendship built on trust, support and affirmation and, on the other, criticism based on analysis, assessment, evaluation and quality." I argue that this dual role is a necessity as receiving feedback on my work was often an uncomfortable and emotional experience. However, I was grateful for the supportive, meaningful and honest manner in which it was given. The process of offering my work to the scrutiny of my peers has provided me with another validation check for the claims I have made throughout the research.

4.6.3.2 Member checking

A further strategy to strengthen my claim to knowledge was when I invited the students to critique and therefore validate what I was saying about them. This strategy has been outlined in Section 4.3.5.3 but involved providing the students with the opportunity to critique writing I had composed about the research process undertaken with them up until that point. They were asked to provide feedback on how honest and fair they felt the claims I had made about them were. This participant validation technique was first introduced by Lincoln and Guba (1985) who referred to it as member checking and highlighted that it; "is the most crucial technique for establishing credibility." There is, however, debate in the literature regarding member checking and whether it improves the trustworthiness of research. Thomas (2017) posits, in his review of this area, that there is limited evidence to suggest that this process improves the quality of findings. However, I argue that from an ecological methodological perspective, the participation of the students in the validation process provides a further opportunity to empower their voices. While I will suggest in Chapter 5 that some students' critique remained at the level of correcting written structure I will also provide evidence that some engaged critically with the arguments I had put forward. I advocate that this strategy, in combination with the others outlined in Section 4.3.4.2, assisted in re-positioning the normative teacher/student relationship.

4.6.3.3 Offering my research and work for public examination and validation

In addition to this, and to provide further support for my claims to validity, I have offered my research and work for public examination and scrutiny. By placing my practice and research into a range of public fora I have provided others with the opportunity to challenge whether my claims to knowledge are genuine, fair and accurate (O' Neill 2007). As a process of gaining social validation I have presented my research and tentative findings at national and international conferences (Sinclair 2011a; Sinclair 2011b; Sinclair 2012b). As with the validation meetings some of the presentations were filmed. At CARN 2011 (Sinclair 2011b) I can be seen offering my work to public critique and saying to the audience; "I am hoping you can tell me whether what I am saying to you makes sense. Can you give me feedback on this please?"

Similarly, I have also published my work in written form (which McNiff 2013 refers to as a form of professional validation). Two of these publications (Sinclair 2010; Sinclair 2013) were subjected to peer review. The process of publication for one of these involved engaging in an open reviewing process between the reviewers and myself (the transcripts of these can be found at http://ejolts.org/mod/forum/discuss.php?d=25). A third involved the publication of teaching resources (outlined in Sinclair & Strachan 2016) about the nature of science which have been subject to critical feedback from teachers at a range of conferences and training days (Strachan & Sinclair 2016; Sinclair & Strachan 2017)

McNiff (2013) also suggests that Habermas' (1987) criteria for judging quality in communicative action can also be used for the purpose of social validation. I have therefore asked the following four questions based on Habermas' (ibid) criteria both of myself and those that read this thesis:

- Is my claim comprehensible? Have I written in a manner that the reader understands what is being communicated?
- Is the claim truthful? Have I provided enough evidence that the reader believes that I am providing an honest account of my practice?
- Is my claim authentic? Have I articulated what my practice entailed and provided evidence to demonstrate that this occurred in reality?
- Is my claim appropriate? Have I understood, and communicated to the reader, the normative assumptions of the contexts in which the research took place?

(adapted from McNiff 2013, pp. 141-142)

The following section will now attend to issues relating to data analysis. It will explain the process I undertook in selecting specific examples from my data archive to produce evidence against which the validity of my claim to knowledge will be tested.

4.7 Data analysis

Cohen, Manion and Morrison state that data analysis; "involves organising, accounting for, and explaining the data; in short, making sense of data in terms of participants' definitions of the situation, noting patterns, themes, categories and regularities," (2017, p. 184). Robson (2002) suggests that the analytical process is necessary because the messages within the raw data will otherwise remain hidden. McNiff (2016) refers to this as giving meaning to the data. In this section I will explain the process I undertook in using the standards of judgement I specified previously (Sections 4.6.1 & 4.6.2) to generate evidence to test the validity of my claim to knowledge that I have developed an ecological approach to science teacher education.

Silverman (2014) suggests that there are no fixed methods for the analysis of qualitative data only guiding principles. Sandström, Willman, Svensson and Borglin (2015) state that researchers dealing with qualitative data often have contradictory foci. They suggest that the analysis of quantitative data can be premised on a priori themes formulated through experience and engagement with literature. They also recognise that this in contrast to an inductive approach (which I liken to grounded theory; see Charmaz 2014) where theory emerges from the data during the process of analysis. Wilson (2013), however, concludes that despite this dichotomy in methods it is likely that most qualitative researchers adopt both approaches. I will outline below how the predominant focus for this analysis was premised on a deductive approach yet also explain how themes that were not predetermined emerged from this process.

While Sandström, Willman, Svensson and Borglin (2015) indicate that the deductive process of analysing data is premised on notional predetermined themes I argue that, for this, research, these themes were far more focussed and for this reason so was the data analysis. Bazeley (2013) suggests that themes often emerge after an initial analysis of the data. However, I have identified previously that the aim of this action research project was to exercise my educational influence; there was intent and a purpose to my actions and therefore, I argue, my themes were explicit from the start of the analysis process. In Sections 4.6.1 and 4.6.2 I proposed that my claim to knowledge could be judged by reference to how successful I had been in developing an ecological approach to my practice. I identified 6 criteria (which are analogous to the 'themes' outlined previously) and explained how these were subsequently transformed into standards of judgement (McNiff 2013) to determine whether or not my claims were valid. I remind the reader of these criteria and standards of judgement in the table on the following page:

Developing an ecological approach to my practice	
Developing a mutualistic practice **Pedagogical facet A**	Developing ecological epistemologies through a reconceptualisation of science **Pedagogical facet B**
Q1. Did I outline my value system to my students in order to make the reasons for introducing a curriculum for ecoliteracy transparent? S1. Demonstrated that I had articulated my values to the students clearly.	Q4. Did I help the students to develop an understanding of the relational nature of scientific ideas? S4. Encouraged the students to understand the related nature of science and because of this whether they were able to make links between different scientific ideas.
Q2. Did the curriculum for ecoliteracy allow for the students to develop their interests, needs and critical thinking? S2. Demonstrated that I had provided opportunities for the students to identify and then develop their interests, creativity and critical thinking.	Q5. Did I help the students to develop an understanding of the temporal and transformational nature of relationships in science? S5. Encouraged the students to understand that some scientific ideas change over time when new evidence appears and because of this whether they viewed knowledge as both tentative and potentially transformational.
Q3. Did I create a dialogic learning community while working with this group of students? S3. Demonstrated that I had created relationships which did not objectify the students and encouraged the flourishing of student thought.	Q6. Did I help the students to develop an understanding of the symbiotic relationships they have with the planet and those that share it? S6. Encouraged the students to perceive themselves as part of the natural world and not as separate from it.

Table 4.4: Developing an ecological approach – criteria and standards of judgement

Saldaña (2013) indicates a contrary position, that the development of a theme is the result of coding, categorisation and the subsequent identification of relationships between these codes. Bazeley (2013) states that the general consensus is the development of themes comes after the identification of codes and categories. However, I argue that in identifying the criteria by which I wished my practice to be judged, that they acted as deliberately identified themes to analyse the data and did not emerge from the process of analysis. This form of predetermined thematic analysis allowed me to analyse the wide range of data I collected to assess how successful I was in meeting my aims across the whole of my practice. In order to establish my claim that my values had been realised in the way I worked with the students, it was necessary to take into account the whole of my practice and not its constituent parts (Capra 1996). I have outlined and have aimed to justify in Chapter 4 the data collection methods I adopted during Cycle 1. These ranged from methods taken in natural settings such as video and audio recordings of my practice and more contrived data collection techniques, such as questionnaires and interviews. In addition to providing a more ecological representation of my practice, the analysis of data generated from a range of data collection tools, in this thematic manner, acted as methodological triangulation. Cohen, Manion and Morrison (2017) indicate that this is a credible technique to demonstrate validity to any knowledge claims. The following section will detail the practical steps I undertook to generate evidence from the data.

4.7.1 The process of generating evidence

Step 1

The first step in this process was transcribing the data sets which were recorded as Microsoft Word documents. This was completed personally and not by a professional transcriber. This provided me with an opportunity to familiarise myself and immerse myself in the data. Hoath (2015) argues that being familiar with the data is an essential part of the interpretation phase of research. The transcribed data were then collated in folders and each folder attributed a title which reflected the data collection method from which it was derived. When the transcribed data had been collected from students, the student's name was assigned to the title of the Word document. For those students who had not given their permission for their names to be recorded a unique student identification code was applied. Consequently, a single folder containing all the data was produced and is what Cousin (2009, p. 194) terms a single text which can subsequently be analysed.

Step 2

Silverman (2014) suggests that a word, sentence, or paragraph can be highlighted and then given a label. Using the standards of judgement outlined in Table 3.4 I methodically went through each Word document labelling the sections of data which I believed provided evidence for each criterion. These were labelled accordingly from S1 through to S6 (see above) and additional annotations and reflections were added where appropriate. Importantly I was also aware of Silverman's (ibid) advice that good qualitative analysis involves paying attention to disconfirming cases which might provide alternative explanations. Cohen, Manion and Morrison (2017) suggest that theory generated as a consequence of this is more robust. Therefore, in addition to examining the data to provide evidence which I believed demonstrated that I had lived out these actions in practice, there was also a deliberate attempt to search for occasions when I had not (these were labelled within the text as XS1-XS6).

Step 3

Cousin (2009) proposes that researchers should read through their data four or five times which allows the researcher to refine and alter the labels that have been applied. Saldaña (2013, p. 11) notes that sometimes this refinement can result in labels becoming more; "conceptual and abstract." However, I suggest that when I undertook this iterative process I established there was a need to provide greater specificity for how each standard could be articulated and therefore evidenced. Multiple readings of the data assisted in producing a new set of key terms with the effect of subdividing each of my lived standards. These new terms were subsequently ascribed the labels S1-S6. In some instances, the data were ascribed multiple labels as they provided evidence for more than one standard. I argue that this form of data analysis is similar to Sandström, Willman, Svensson and Borglin's (2015) suggested way of working, that some of the key terms emerged inductively from the data.

Step 4

The data that had been ascribed labels were then copied and pasted into separate Word documents. These documents were then saved using the key words as the file names. These files were then stored in folders related to each of the six criteria outlined above.

I appreciate that analysing data in this manner can be problematic because once the data has been used as evidence it can become decontextualised. I also recognise that the interpretation which follows has been mediated through my subjective lens as a researcher. As has been stated earlier there has been no attempt to disguise these biases and I concur with Cousin (2009) who states that ultimately it is the articulated integrity and honesty of the researcher which manifests itself in the validity of the analytical process. I hope the reader appreciates that, while I have identified that subjective bias exists, I have explicated what these are in a clear and comprehensible manner so that it is evident how and why I made the interpretive decisions I did. Silverman (2014) and Winter (1989) both argue that sometimes, because of the decontextualised nature of this form of evidence, it does not offer the reader an opportunity to contest the data and formulate a contrary opinion. For this reason, and for issues of honesty and transparency, I have provided full transcripts of the end of course interviews (Appendix 6.1, 6.2, 6.3), my personal Learning Log (Appendix 7) and an example of a completed Learning Diary (Appendix 8).

4.8 Chapter summary

This chapter has aimed to justify the use of action research as a research methodology for this thesis. I have referred to it as an ecological methodology because my research was conducted amongst those I worked with and with whom I had built positive educational relationships. As a consequence, I have argued that it has been difficult to distinguish between my research and practice because of the educational intent that this research was premised upon. I have discussed that this approach allowed me to generate the forms of data which recognised the qualities, and not quantities, of an ecological way of thinking and acting. As a result of this way of acting I detailed how my value of mutual respect was transformed into a living standard of judgement in order to show how successful I was in developing the forms of educational relationships I believed most benefitted learning. In addition to this I outlined the data gathering techniques I used to collect data to provide evidence for my claims and the participants who were invited to be part of the research. I explained how the foci for the research shifted between Cycle 1 and 2 due to the change in my thinking. I detailed the process I undertook in generating evidence using the standards of judgement outlined above.

The following two chapters will present the findings from analysing the data collected during Cycle 1. Chapter 5 will explore the evidence generated to test the validity of my claim to knowledge that I developed a mutualistic practice (pedagogical facet A) while Chapter 6 will determine whether I developed ecological epistemologies through a reconceptualisation of science (pedagogical facet B).

Chapter 5. Evidence for Developing a Mutualistic Practice

5.1 Introduction

In Chapter 4 I proposed that my claim to knowledge could be judged by reference to how successful I had been in developing an ecological approach to my practice. I recognised that this approach was premised on two interrelated aspects of my pedagogy which I termed i) pedagogical facet A and ii) pedagogical facet B. Pedagogical facet A was concerned with developing a mutualistic practice while pedagogical facet B was related to whether I helped to develop ecological epistemologies through a reconceptualisation of science. In Sections 4.6.1 and 4.6.2 I outlined how the research questions related to these facets were identified and how they were subsequently transformed into standards of judgement.

5.2 Generating evidence from data - pedagogical facet A: developing a mutualistic practice

This chapter will demonstrate how I generated evidence from the data to check whether I developed a mutualistic practice during Cycle 1. It will attend separately to the three standards of judgement (S1-3) I identified in Chapter 4 as necessary for demonstrating that I was working in a mutualistic manner. For reference these are outlined below:

Developing a mutualistic practice **Pedagogical facet A**
Q1. Did I outline my value system to my students in order to make the reasons for introducing a curriculum for ecoliteracy transparent? S1. Demonstrated that I had articulated my values to the students clearly
Q2. Did the curriculum for ecoliteracy allow for the students to develop their interests, needs and critical thinking? S2. Demonstrated that I had provided opportunities for the students to identify and then develop their interests, creativity and critical thinking.
Q3. Did I create a dialogic learning community while working with this group of students? S3. Demonstrated that I had created relationships which did not objectify the students and encouraged the flourishing of student thought.

Table 5.1: Developing a mutualistic practice: pedagogical facet A – research questions and standards of judgement

5.3 Pedagogical facet A - standard of judgement 1

Q1. Did I outline my value system to my students in order to make the reasons for introducing a curriculum for ecoliteracy transparent?
S1. Demonstrated that I had articulated my values to the students clearly.

The evidence for this will come in two interrelated forms. I will first provide evidence for whether I made explicit my intentions for developing the curriculum for ecoliteracy. I will draw upon data from two specific occasions which I propose demonstrate that I had made this intention clear. Secondly, I will analyse whether I shared my value of mutual respect, and therefore whether I had articulated the way I wanted to work, with the students. Subsequent evidence will be generated from data provided by the students to corroborate whether they agreed that these examples from my practice demonstrated that I had articulated my value system.

5.3.1 Standard 1- making my intentions for developing the curriculum for ecoliteracy explicit

The first data I examined to provide evidence that I articulated my intentions and understanding of ecoliteracy to the students was the video clip taken when I first introduced the students to my research (Initial Presentation, 10.1.2012). The seven-minute presentation outlined my values towards the planet (See Appendix 2 for transcript). It briefly showed that I had concerns about planetary well-being and that I felt the schooling system that I, and the students, had been through was producing ecologically illiterate students. The video clip then shows me highlighting the focus of my research at that time which was to:

1. Develop my understanding of ecoliteracy and how it might influence my pedagogy;
2. Help my students to develop their understanding of ecoliteracy;
3. And how this, in turn, might influence their future teaching practice.

(Initial Presentation, 10.1.2012)

As I have suggested throughout this thesis my ideas around ecoliteracy were initially under developed. Previous writing, Sinclair (2014), demonstrated that I found it easier to define what ecoliteracy was not and I believe that I established that this was also the case in this presentation. I made reference to Orr's (1992) simple definition that; "someone who is ecoliterate and understands these things, is someone who can say well 'what then?' If I do this action, what will be the consequences of that action?" (Initial Presentation, 10.1.2012) which I believe reinforces this difficulty in articulating ecoliteracy. Further evidence of this ill-formed understanding can be seen later when I explained in the same presentation that the focus of the research was to ask; “what is someone who is ecoliterate, what do they look like? What do they do? And what kind of values, that sort of thing. I want to develop my understanding of that.” While I argue that this demonstrates that I had understood the developmental process of this research I also suggest it confirms how I had objectified the term ecoliteracy. This is strengthened later by my reference to creating a fixed curriculum; “that could be taken into schools.”

The second occasion for articulating my intentions came during Session 7 when the students were asked to critique the writing I had produced (this writing can now be found in Sinclair 2013). The writing was premised on data collected from the initial presentation referred to above and how I had negotiated with this group of students whether the development of a curriculum for ecoliteracy was an appropriate action for them. Further credence to my claim that my understanding of ecoliteracy was still in development can be seen in my definition which explained the meaning in this way;

> This term, eco-literacy, in its most fundamental form, denotes the ability to ask; ‘what then?’ with regard to a person’s actions and an understanding of the subsequent consequences on planetary and human well-being. In addition to this an overly simplified description of eco-literacy is; ‘that quality of mind that seeks out connections. It is the opposite of specialisation and narrowness characteristic of most education. The ecologically literate person has the knowledge necessary to comprehend interrelatedness and an attitude of care and stewardship (Orr, 1992: 39).
>
> (Sinclair 2013, pp. 132-133)

Both the presentation (Initial Presentation, 10.1.2012) and the book chapter make explicit the tensions I had been feeling about introducing the students to the research and the prospect of using the science sessions to create a curriculum for ecoliteracy. The tensions shared at this point were the same that have been identified throughout this thesis. This included highlighting the lack of issues to do with planetary well-being within their teaching curriculum. I made it explicit that I understood that, because of this, they justifiably might not be interested in engaging with these ideas and that I was concerned I would be imposing my value system upon them.

The following section will attend to issues regarding whether I had explicitly shared my value of mutual respect with the students. As a result of this it will also analyse the students’ feelings of my sharing my convictions about wanting to develop the curriculum for ecoliteracy.

5.3.2 Standard 1 - sharing my values and the manner in which I wanted to work

It is important to stress that while I had attempted to define ecoliteracy to the students (Initial Presentation, 10.1.2012) I had not explicitly highlighted the manner in which I hoped to help them to develop their ecoliteracy. I had also not articulated to myself, nor my students, how my value of mutual respect might manifest itself in the way I worked with the students. In the initial presentation there was only one statement which gave an insight into the collaborative nature of the science group I hoped to develop. I stated that; “with 20 odd people in here, you know, the kind of knowledge we could create could be amazing,” (Initial Presentation, 10.1.2012). Excerpts from the article the students’ critiqued, which was written following the initial presentation, suggest my ideas had developed sparingly in the interim and provide evidence of my developing understanding of an ecological approach to science education. Writing about how I perceived working with the students I commented that;

> Buoyed by this positive outcome I now look forward to the future. Barlow and Stone highlight that it is important to remember that there is no; ‘homogenised one size fits all curriculum.’ (2006: 6) and with this is mind it will be crucial to work with my students to develop a curriculum that is relevant to them and the children they will subsequently teach. This will require a flexible and creative approach as it will entail having no pre-planned sessions and working from the students’ ideas, reflections and needs.
>
> (Sinclair 2013, pp. 140-141)

However, I now appreciate that my need to be honest with the students and negotiate with them whether developing the curriculum for ecoliteracy during the initial presentation was rooted in a tacit desire to share my values with them. Students were asked at the end of the presentation to; “write down your thoughts about what I’ve just, what I’ve just said. Have I been preaching to you? Do you think I’ve been fair? How do you feel about what I’ve just said?” I recognise mentioning these points, and in this manner, could be considered a form of coercion as the style of questions were directed and may not have given the students free-will in compiling their responses. Understandably the comments made reflected these remarks with the students using the terms ‘fair’ and ‘preaching’ in their responses. This is evidenced in the following two students’ statements;

> I feel what you have said is fair…I am glad that you have approached us about this first.
>
> (Viki – comment following Initial Presentation)

> It's not preachy.
>
> (Anthony – comment following Initial Presentation)

Despite the use of the same language, I was encouraged that most students justified their reasons for wanting to be involved in developing the curriculum for ecoliteracy and provided evidence that they did not feel it be an imposition. Further corroboration for this came in the End of Course Interviews. When explicitly asked; "did you ever feel that you could really say actually that's enough about sustainability let's, let's go back to something else? Over to you," (Interviewer, End of Course Interview 3), Anthony and Suzanne replied that it had been a decision negotiated by the group. This reinforced my perception of how it had occurred.

> Anthony: I think, well when it was first sort of thrown at us as an idea, right at the beginning of the course, it was, would you be interested in particip... it was like the group coming together making a decision rather than Alex saying, you know, I want to teach this or to talk about this.
>
> Suzanne: We had a decision in it.
>
> Anthony: Yeah, we and everybody had, a say which was important.
>
> (End of Course Interview 3)

Most students commented after the initial presentation that sustainability was an important issue to them and they wanted to learn about it to gain confidence in their teaching. Many were shocked that it had been actively removed from the primary National Curriculum (DfE 2013). Rohinni's comment expresses these feelings when she stated; "it would be good and beneficial to the children as well as the teachers to understand the concepts throughout the curriculum, even if we were to slightly touch up on it in lessons," (Rohinni, Pre Course questionnaire)

Reinforcement that this was a genuine area of interest, and therefore not an imposition, also came from students' comments they had made following reading my chapter. Jessica explained that;

> I certainly will be trying to include these issues in my future practice, but, not because I feel you have pressed your views upon us a group, but because I personally feel it is important that children's awareness is raised," also adding that; "involvement in this research has opened my eyes and educated me.
>
> (Chapter Critique – Session 7)

Others noted that they were grateful for the transparent approach I had adopted. Student R wrote that it was; "nice to see how our views and opinions are taken into consideration," with Student Q commenting similarly that; "I also value your honesty about how you feel on the particular subject and when you spoke about 'not being honest' in your writing," (Chapter

Critique – Session 7). Francesca provided an example of member checking when she suggested that the writing was a truthful account of my practice with them. She noted that; "I have no issue with the section on us as students. I think it is a clear and honest reflection of our experiences," (Chapter Critique – Session 7). Further corroboration of this aspect of my practice came in the end of course interview. When asked to sum up my teaching style one student remarked that I was;

> Approachable and transparent, as well, and not, and not in a kind of in emotions, you know, this, this is it, this is everything that we are gonna do, it can work, it might work, it might go off in a different way, but let's see how we do with this, you know, we are all in this together, so, that, that's what I mean by transparent.
>
> (Suzanne, End of Course Interview 3)

In addition to this I am cognisant that despite the students acknowledging I had articulated my intentions and gained their permission to develop the curriculum for ecoliteracy, in reality, because of the developmental nature of the process they, nor I, really perceived what this might entail. This is echoed in Jessica's thinking when she reflected on the course. Jessica first commented that; "I agree with what you have said and would love to take part, and further develop my knowledge," (Jessica, comment following Initial Presentation) yet in the end of course interview she stated that;

> I know that he is very keen to make sure that this didn't happen, but sometimes his research may have taken over our classes and something like that. I know that sometimes he was worried that it may take over the lesson, I don't think it did to a huge expense, but a lot of the time I felt rather than learning about sustainability we were helping him to complete something.
>
> (End of Course Interview 1)

However, Jessica's view is unique. Despite the initial lack of clarity regarding what the course might demand, the remainder of the group commented positively about the focus of the year in their post course review questionnaire. When asked about the influence of the course Jemma stated that; "you have opened my eyes, an awakening to the importance of teaching children about sustainability and ensuring the planet is resourceful enough for future generations – them + their children," (Jemma, Post Course Questionnaire). Hayley also counteracted Jessica in the same interview responding that;

> I think at the beginning I felt a bit like that, but then as I was going on and when we were on enhanced placement I think I realised how much it did effect [sic] the way I taught and it was really positive, like it affected me like in a positive way and I think, I've become a lot more aware of things like, for example sustainability but I think I've also become a little bit more passionate about it and when I'm teaching about it I think I'm a bit more like, really excited. (End of Course Interview 1)

In addition to this, both Samantha and Katherine, on reading the tensions I felt about introducing the curriculum for ecoliteracy within the book chapter, suggested that my concerns were unfounded. Their comments include the following;

> I think that occasionally you have been too harsh on yourself about the 'deceiving' element. There is an underlying sense of guilt, you should respect your decision and the ecoliteracy impact on this group.
>
> (Katherine, Chapter Critique - Session 7)

> My gut feeling is that you have over-worried your responsibility regarding what you teach us. The NC tells us what to teach, but not how, and it is our responsibility to "fill the gaps" – beyond top ten tips.
>
> (Samantha, Chapter Critique - Session 7)

When asked in the end of course interview what forms of relationships I had formed within the group Anthony answered; "I think what's happened with Alex, and I'd like to think that I'd take something from his style of teaching is he earned our respect, that's what's happened," (End of Course Interview 3). I was reminded by a critical friend that it should not be considered an issue that I had not shared my values as many individuals and institutions articulate their beliefs which only remain as rhetoric. Referencing; "you've heard of action speaks louder than words," (email correspondence; James 2018) she highlighted the importance of living out one's values in practice whether they have been openly stated or not.

5.3.3 Standard 1 - summary

This section has considered whether I shared my intentions for the curriculum for ecoliteracy and the manner in which I hoped to work with the students. I argue that despite my, then, unarticulated understanding of a mutualistic practice that, on different occasions throughout the course, I explicitly highlighted my concerns about introducing what was of value to me and questioned whether I was being coercive. I have suggested this played a role in helping the students to identify that my practice was premised on transparency and honesty. I have also provided brief evidence that most students felt that the course had benefitted them and was an appropriate course of action. Issues regarding how the students felt this contributed to their learning will be dealt with in further detail in the following section when I address whether the course met their needs. I have also proposed that the students did not feel coerced into studying issues which had no relevance to them. Additional issues regarding coercion will be revisited in Section 5.5.3 which analyses whether I provided a dialogic community whereby the students felt comfortable to express their opinions without fear of judgement.

5.4 Pedagogical facet A - standard of judgement 2

> **Did the curriculum for ecoliteracy allow for the students to develop their interests, needs and critical thinking?**
> **S2. Demonstrated that I had provided opportunities for the students to identify and then develop their needs, interests, and critical thinking.**

I identified that the students' needs were predominantly two-fold. The first need was related to assessment. As I have mentioned previously many students are understandably driven by a desire to receive good grades in their course work. I highlighted how their grades from this module would affect their degree classification and potentially their employability, especially if not passed. Sandra noted at the start of the course that she was happy to be part of the research process; "as long as it doesn't interfere with me passing," (Sandra, comments following Initial Presentation). I had already classified helping students to achieve their potential in their coursework a need of this course, but not that it should become the main focus. The second need was related to the course's module aim which was, obviously, to prepare the students for teaching (and possibly leading) science in the primary classroom. This aim is specified by the module handbook which outlines that the course should;

> consolidate students' understanding of the pedagogical issues related to the teaching and learning of science in the primary classroom and subject knowledge and understanding to a standard appropriate to a subject leader / learning manager.
>
> (QP344 Module Handbook, p1)

5.4.1 Standard 2 -meeting the students' needs: assignments

The outline of the course's sessions (Appendix 8 and 9) shows that session 1 and session 6 had time dedicated to explaining the approaching assignment. Feedback from the students' Learning Diaries suggests they were satisfied with the assignment input and felt confident with what was required of them. The following remarks are indicative of the rest of the group's. Suzanne wrote that; "today we discussed as a group how we would tackle the assignment. This was very good as was able to take lots of different ideas to comprehend how to develop the writing," (Learning Diary – Session 6). Jemma commented that there had been; "very good input on assignment, much more detailed and informative clear too." (Learning Diary – Session 6). Although Hayley still had concerns following the second input, she felt confident her needs regarding the assignment could be met responding that; "I'm slightly nervous about the layout, however any problem I'm going to bring to a tutorial," (Learning

Diary – Session 6). Rohinni's entry in her Learning Diary also provides evidence for this preparation and the manner in which it was achieved;

> Today's session was based around our assignment and what we need to include in it. It involved a lot of discussion, which was helpful as we were able to share our ideas with one another. It was also good to get better understanding of what it is that is expected of us. Looking at sample essays was also a helpful way to get a better idea of what to and not to include.
>
> (Learning Diary – Session 6)

This attitude reinforced my initial belief that for many, passing assignments was the highest priority to them. The assignment input during session 6 only lasted a short while. Most of the remainder of the time had been spent planning a resource pack for working at the local river which, Rohinni had not mentioned in her Learning Diary. This focus on the assignment was not, however, displayed by all students as I initially thought it would be. Several students, such as Natasha, did not reference the assignment in their Learning Diary. Her entry only focussed on the planning undertaken for the educational visit to the river; "I learnt how to incorporate learning into field trips and how activities can promote learning. Also then how follow up activities can confirm learning. Feel confident in planning activities," (Learning Diary – Session 6). This was a pertinent reminder for me that the needs and priorities for the students differ.

5.4.2 Standard 2 - meeting the students' needs: preparation for teaching primary science

While I have suggested before that the curriculum for ecoliteracy, in its form during Cycle 1, did not overtly develop the ecological epistemologies I have recommended previously, I believe that preparing the students for teaching science in primary schools was one of the biggest strengths of the course. While analysing the data to generate evidence for this, three recurring and interrelated categories emerged. These were related to students articulating that the sessions had improved their knowledge about issues concerning sustainability, provided them with concrete examples to teach with and enhanced their confidence of teaching science. Evidence for this will be drawn from three main data sets; the students Learning Diaries, their reflections on teaching about sustainability in school and the End of Course Questionnaire.

Studying the students' Learning Diaries showed that they felt in each session that the activities were appropriate for preparing them to teach science. Many students wrote about their personal learning in sessions. Anthony and Hayley provide examples of this. Anthony commented after an investigation that; "my thinking was challenged by the experiment and how ice displaces water. I feel more knowledgeable as a result," (Learning Diary – Session 2). Hayley wrote after Session 10 that; "I've learnt loads about global warming; climate change and energy," (Learning Diary – Session 10). Some students also proposed that the sessions had amounted to a metacognitive process identifying areas of subject knowledge which they needed to develop. Monica noted that; "I learnt that I need to learn more – a lot of questions asked I did not know the answer," (Monica, Learning Diary – Session 2).

Additionally, the students perceived that the activities they carried out within sessions were appropriate for the children they would teach. An example of this came from Katherine who stated; "today I learned a lot about snails and the use of videos in classrooms, the snail hunting was active and fun, I could see the benefits it would have for children's learning," (Learning Diary - Session 4). Vikki demonstrated how her learning might influence her future practice stating that; "I would now like to experiment and test the concept cartoons in class," (Learning Diary – Session 2).

Pleasingly many students felt their confidence to teach science in primary schools, particularly concerning issues related to sustainability, had improved. When asked about the influence of the course on her learning Lucy answered;

> I am now more confident and passionate about integrating sustainability in my lessons. By engaging in the lectures I feel as if I now know a wide range of activities that could influence children's ideas about sustainability.
>
> (Learning Diary – Session 11)

This was echoed by Hayley who responded to a question asking her how she had felt about the focus of the course; "now I think I'm a little bit more passionate about it and I can think about how to do it in really exciting ways and how I can make it exciting for the children," (End of Course Interview 1). In addition to this she was asked whether she felt she could engage with the ideas around sustainability in lessons and lectures and replied that; "yeah, I feel quite empowered sometimes when we talk about it."

Further evidence of their developed confidence of teaching science came from the students' reflections on a day's teaching they had undertaken in school. The lessons were based around water wastage and were taught to children whose ages ranged from 4 to 7. In particular, it was the learning gained from those that had not taught such young children before which were most pertinent. Remarks that these students made demonstrated that not only had they gained in confidence but also that they now understood the capabilities of young children. Many commented, similarly to Anthony, how they had originally underestimated young children's capacity to learn.

> I really enjoyed teaching in year one. I had no experience of teaching science to year one before so it helped my professional development. I was surprised by how capable the children were to think and discuss ideas in a specific way and enjoyed discussing the children's ideas as a group. (Learning Diary – Session 11)

I suggest that one of the reasons that this teaching experience was so positive is because of the nature of the planning sessions. Many students commented that they appreciated the support they were given through the collaborative process of planning in a group. Both Vikki and Student T recognised this, writing in their Learning Diaries that;

> I also like the chance to be able to work with others in the classroom. You do not feel alone and scared as you have others in the class to help you if you get stuck. It helps builds confidence working with people that you know.
>
> (Student T, Learning Diary - Session 9)

> I feel science week was really beneficial both for myself and the children. For me I feel like we were given a huge amount of support in planning the session.
>
> (Vikki, Learning Diary - Session 11)

I also suggest that despite my belief that the predominant focus for the course was concerned with sustainability this was not perceived by some students to be the case. When asked in the end of course interview how she felt about covering sustainability throughout the year, Samantha identified that this was not the sole purpose. She stated that; "I think it has been a very good focus for the two years, it has been something that we have gone away from and come back to." (End of Course interview 2). Student Q, in the last entry of her Learning Diary also recognised that we covered other aspects of the science curriculum. She wrote in response to being asked what she had learned during the year;

> I have learnt: how to teach science creatively; the issues that surround the teaching and learning of science, for example the implications of hatching chicks; and the need to look outside of the national curriculum to teach concepts that are not explicitly written there but can be embedded into it, such as sustainability.
>
> (Learning Diary - Session 11)

5.4.3 Standard 2 - a curriculum which developed their own identified interests

I have written before that I professed that there was no one fixed curriculum for ecoliteracy (Barlow & Stone 2005) and as a consequence it would be imperative to develop a curriculum which was relevant and appropriate to the students from this specific science elective group and the children they would subsequently teach. I proposed there would be no fixed session plans and that I would be guided by the students' reflections and needs. For this reason, I asked the students in session 1 to work in groups and identify areas of potential interest to them. They were asked the following three questions:

- What do you feel are the environmental concerns that the children we teach will be faced with?
- How do you feel the science curriculum can help children to develop an understanding about these issues?
- What areas would you like to learn more about?

(Questions asked in Session 1 to groups)

I argue that these questions show my initial appreciation of the personal and professional needs of the students with regards to sustainability and the start of a flexible curriculum which was tailored to this group (responses can be found in the students' learning diaries – Session 1; an example of this can be found in Appendix 8). I also concede that a major omission at this point was any question to elicit the students' needs and interests in areas other than sustainability. I have argued earlier that the students felt confident they were prepared for their assignments and for teaching science in the primary classroom. However, I recognise that this was probably due to an anticipation of their needs based on my previous experiences. The exclusion of an open-ended question which asked them to identify their needs is further evidence of my pre-occupation on helping them to develop their ecoliteracy.

Despite this preliminary questioning of the students there is limited evidence from either the session outline (See Appendix 9) or the reflections in my Learning Log (Appendix 7) which can demonstrate that I used this information to guide my planning. Some topics highlighted by the student groups as areas of interest, such as water and global warming, were covered at some point during the year but this was not through a deliberate attempt by me to do so. Students learned about these issues when given the opportunity to undertake personal research into an area of their choosing. I cannot at this stage give a full explanation why I asked them to identify these areas and then proceeded to ignore this information.

In spite of this I did offer the students the opportunities, on two occasions, to research issues regarding sustainability that were of potential interest to each group. This first occurred in Session 2 when students chose an issue concerning planetary well-being to act as a stimulus to develop their understanding of the use of puppets to teach primary science. The second personalised choice took place in Session 3 when they practised drawing Mind Maps and related this to an issue of interest to them. A number of students noted the positive benefits from identifying their learning needs. Hayley's Learning Diary entry for Session 2 shows this. She wrote; "I enjoyed learning about current issues that are relevant to me," (Learning Diary - Session 2). In addition to this, some students expressed their attentiveness to the topics that the other groups had discussed which also provides initial evidence of the collaborative and sharing nature of the group which will be discussed in Section 5.5.3. Grace noted; "It really interested me to know what other people were interested in sustainability wise," (Learning Diary - Session 2).

Regardless of the lack of personalisation within sessions, founded upon the students' articulated interests, I argue I have provided evidence in the previous section to suggest that my tacit awareness, based on experience and prior knowledge, ensured they felt that these needs and interests had been catered for throughout the course.

5.4.4 Standard 2 - developing critical thinking

I have identified that one of the central themes running throughout this thesis is a felt tension about imposing my own views on the students by introducing a curriculum for ecoliteracy. I have also outlined that in order to counteract this I provided many occasions for them to be critical about my teaching (these methods were detailed in Chapter 4 and included; Learning Diaries, Critique of Writing, Metaphor of Teaching). While I am aware that this critique was a genuine attempt at reconceptualising the student/teacher relationship, in retrospect, I came to appreciate that this process was primarily undertaken in order to justify and legitimise my actions. However, this was to the detriment of an explicit intention to develop the students' critical thinking. Commentary from my Learning Log provides evidence for this. I wrote that; "not many are being critical about the teaching – 2 maybe. How do I help develop this form of reflection?" (Learning Log, Session 3). The following section will analyse the data to evaluate the students' impressions of the purpose of these methods. It will also subsequently identify whether they, or any other aspect of the course, provided them with an opportunity to challenge their thinking.

Most Learning Diary entries showed reflection at a practical and descriptive level and communicated what the students had carried out in the session and the potential influence their learning might have on their teaching practice. The following two excerpts exemplify many of these entries. They both come from Session 3 and are the full excerpts for that session's entry;

> From doing the memory learning root [sic], it was interesting what things you can remember from using a brain storm of that type. It was nice to look at strawberries as I learnt that the bud comes from the middle of the flower. I am interested to see if the wheat grows as the D+T garden did not have much luck really, this I think may have been due to the weather conditions.
>
> (Zainab, Learning Diary – Session 3)

> I enjoyed today's lecture. I learnt how to plant wheat grains and the way in which strawberries grow. I also learnt about the best way to create a mind map to ensure effective learning of a topic. Also thought about factors which may affect how a raft floats. I came away with some practical ideas to use in school.
>
> (Amy, Learning Diary – Session 3)

There was only one solitary comment within all of the students' Learning Diary entries that made any suggestion about improvements or challenged what they had been presented. It came from Student J who wrote;

> Learnt about strawberries and the rock cycle.
> Mind maps were helpful for this
> Memory route was good and would use it for lessons
> Sinking boat was enjoyable but more science behind it would have been good
>
> (Learning Diary – Session 3)

The lack of critique in the students' entries can be explained by reference to the comments made during the End of Course Interviews. When asked for the students' perceptions of the purpose of the Learning Diaries most commented that, while they understood it was a reflective tool, they often felt they were repeating themselves. As a consequence, at the end of the session many were in a hurry to leave and completed them superficially. The following excerpt from Hayley and Jessica's conversation exemplifies this;

> Hayley: I think, what were the questions again? What have you learnt from the lesson? I felt like I was just writing out the learning objectives. They did like, I think I found it quite hard writing about how I like feel sometimes and it's better just to speak it, so I think writing it down, like, I was looking through my book when I filled it in last time and it is quite repetitive what I have written (Hayley)
>
> Jessica: I mean I know that obviously it is a reflective piece of work and you know we are reflecting on the lesson and what we've learnt but I think doing it at the end of the lesson when you've said right that's it for this week can you just full out your books I think the automatic, erm, you know, approach to it is just to scribble down something quickly and briefly in order to leave the lecture.
>
> (End of Course Interview 1)

During the interview the students made it clear that they understood that the Learning Diaries were also provided as a tool to critique the teaching that they had experienced. However most relayed feelings that they either did not feel able to do this or questioned whether the Learning Diaries were the most appropriate method to achieve this. Jessica commented that;

> I mean I know that it would possibly help Alex's research as well, to get an idea to see how his teaching has affected his pupils, but from our point of view, I would definitely say that it's a method of analysing your knowledge and reflecting on what you've learnt so far.
>
> (End of Course Interview 1)

In response to being asked whether she felt she could have critiqued the sessions, Hayley responded; “I think I could have, I, we didn’t have to write our name on it so if I had wanted to I think I would have been, but it would have felt quite mean, still,” (End of Course Interview 1).

Similar views were expressed by a couple of students in the End of Course Interviews when they were asked how they felt critiquing my writing. Their responses identified their lack of confidence in their abilities which were related to comparisons between their experiences and mine. Samantha stated that; “it should have made us feel empowered but I think we were all slightly worried that if we said something awful then… we are poor students,” (End of Course Interview 2). She also commented in her chapter critique that she had felt uncomfortable undertaking the process despite finding the writing interesting. Suzanne appreciated the opportunity but felt she did not have the skill set to participate in the discussion following this critique, but recognised that those with more confidence appeared able to do so;

> because I was sitting next to Francesca and Francesca, who’s very clever, started to critique it and I was uncomfortable critiquing it but, then again, maybe I don’t have the skill to critique it, but she critiqued it, and she spoke to him about it and it was quite interesting to kind of watch this dynamic happening because I think he has a great deal of respect, well he has a great deal of respect for all of us, but I think that Francesca writes very academically and he took it all and it was like yes that’s interesting I hadn’t really considered that, so that was quite nice to watch that going on but personally I’m like, do you really want me to give you feedback when I’m not as good as you?

(End of Course Interview 3)

Most of the comments made about my chapter, including Francesca’s, were related to improvements in academic conventions and structure of the writing. I suggest this provides evidence that when the students felt self-assured in their ability they were able to make appropriate recommendations. For example, Francesca annotated the article with the following;

> Could this be reduced to a sentence or two?
> Interesting and important point to highlight.
> Is there a way of reducing length of the introduction – as in sandwiching the part about ‘us’ in the middle.

(Chapter Critique - Session 7)

However, there was limited evidence that the students challenged the content of what I was writing. Many, like Rohinni, agreed with the sentiments outlined in the draft chapter. Rohinni wrote; “I think that this chapter really flows and makes sense and I agree with everything that you’ve mentioned” (Chapter Critique - Session 7). However, Katherine felt confident to suggest that; “maybe you could look at the emotional impact that having a lecturer that shares their beliefs and uses engaging strategies to show them,” (Chapter Critique - Session 7)

The following will provide further evidence of the occasions when I believe I challenged their thinking which I argue is the first step in developing critical thinking.

While I have argued that the Learning Diaries produced mainly descriptive accounts of the sessions, there were a couple of occasions when the students identified how their views and thinking had changed. These statements came in only three sessions which all contained activities which discussed matters to do with sustainability (Session 2, Session 7 and Session 10). I tentatively propose that this occurred because of my portrayal of these issues as being uncertain, compared to advice I may have given about teaching which may have been more deterministic. I previously provided evidence of this in the initial presentation when I professed that I was not an expert in these matters. My Learning Log from Session 2 (which gave the students the opportunity to research areas of interest to them) shows this. I stated; “from this I knew that I needed to develop my understanding of how melting ice caps sometimes don’t make the sea levels rise.” While I do not have data to suggest how I behaved, Anthony’s entry for this session mirrors how I was thinking. He wrote that; “my thinking was challenged by the experiment and how ice displaces water,” (Learning Diary - Session 2). This session challenged the views of some students who identified that their knowledge was insecure. Samantha commented about this session noting that she; “felt very interested in the topics raised, certainly enough to go away and investigate more myself. It showed some gaps in my knowledge, particularly recycling,” (Learning Diary - Session 2) Student J also wrote that she; “became aware that my knowledge of climate change is insufficient. This therefore challenged my thinking,” (Learning Diary - Session 2). Perhaps the strongest evidence for challenging the students’ thinking came in Session 7. This followed a discussion about actions made by those in charge at Heathrow Airport. Due to a broken valve, a decision had to be made whether to divert harmful chemicals onto the Heathrow runways or into the river we had visited the previous week. They chose the river killing most of the life in it. Jessica wrote in detail that;

> I have come away from this lecture with questions about how much we know about sustainability. Are we being given information as members of the public? How do we know we are doing good? Is there info that we are not being given that may change our views of the world
>
> (Learning Diary – Session 7)

5.4.5 Standard 2 - summary

This section has addressed whether imposing the curriculum of ecoliteracy, which was of value to me, allowed the students to develop their needs, interests and critical thinking. I have suggested that I identified the students' needs as the requirement to pass their assignment and in feeling prepared to teach science in primary schools. I provided evidence that advocates that these needs were met and that the students felt that this was a positive aspect of the course. While I have detailed that the students had limited occasions to identify and develop their own interests I suggest that my tacit understanding, developed from experience of working with students for some time, helped me to anticipate what their needs and interests may have been. I also argue that issues regarding planetary well-being were of interest to them as well. In addition to this I have argued that I provided few opportunities to develop the students' critical thinking. However, I identified that on the occasions when they were presented with contentious and uncertain issues about planetary well-being this challenged their views and thinking the most. I will propose that while many of the activities did not intentionally help develop the students' explicit ability to critique or be critical, they assisted in establishing an atmosphere which was conducive to sharing ideas without fear of judgement and which allowed independent thought to flourish. The next section will develop these matters further.

5.5 Pedagogical facet A - standard of judgement 3

> **Did I create a dialogic learning community while working with this group of students?**
> **S3. Demonstrated that I had created relationships which did not objectify the students and encouraged the flourishing of student thought.**

Undertaking analysis for this criterion provided me with the opportunity to specify the pedagogical strategies I used with this group of students. Unlike the conscious strategies I adopted to ensure I was not imposing the curriculum for ecoliteracy, this section addresses my well-established, but as yet not specified, teaching style and how this was perceived by the students. I will identify that my value system premised on mutual respect evinced itself instinctively through the promotion of discussion and group work which was conducted in a collaborative atmosphere where others felt they would not be judged by me or the rest of the group. Most evidence for this criterion has been generated from the data provided by the students' Learning Diaries and the End of Course Interviews. Similar comments made in the Learning Diaries and all three of the End of Course Interviews support my suggestion that this was the way I usually worked.

Through analysis of the Learning Diaries it became apparent that the pedagogical strategy I utilised most frequently was the use of discussion. This was commented upon by nearly all students throughout their Learning Diaries. Representative examples come from Natasha who noted in Session 2 that she; “enjoyed use of frequent discussion,” and Jessica who wrote; “today I learned more about constructivism and how it relates to LOC [Learning Outside of the Classroom]. I learnt it through group discussion,” (Jessica, Learning Diary – Session 6).

I suggest that most students valued the discursive nature of the sessions and that their learning was greatest when they shared ideas within the group. Students commented that; “today’s session involved a lot of discussion, which was helpful as we were able to share our ideas with one another,” (Rohinni, Learning Diary - Session 6) and; “group discussion to share knowledge is always useful,” (Samantha, Learning Diary - Session 1). In particular, students valued the opportunity to work in groups to plan lessons and identified the benefits that collaborative action can bring. Student T’s diary entry for Session 9, reflecting on the planning they undertook in Session 8, demonstrates this;

> I really enjoyed having the opportunity to plan with others in my class.
> Teaching is all about sharing ideas, what worked well and even better if.
> As there were others in the group, you could not be dominant and say only your idea will work as you need to consider other ideas.
> I also like the chance to be able to work with others in the classroom. You do not feel alone and scared as you have others in the class to help you if you get stuck. It helps builds confidence working with people that you know.
>
> (Learning Diary - Session 9)

Surprisingly there were also a number of comments about the collaborative nature of planning for the assignment which I would have proposed, prior to the analysis, would have been far more dictated by me. Suzanne wrote that; “today we discussed as a group how we would tackle the assignment. This was very good as was able to take lots of different ideas to comprehend how to develop the writing,” (Suzanne, Learning Diary - Session 6) with Jessica corroborating this stating that; “I felt pooling the class’ ideas really helped me gain a wider understanding of the assignment,” (Learning Diary - Session 6).

It is important to recognise that this strategy was not favoured by all students. Katherine’s thoughts about group work were in relation to particular members dominating the conversation. She noted on two separate occasions that; “I did feel a little self-conscious about giving my opinion quite a few times in the class discussion, but then I struggle to get my views across the table,” (Learning Diary, Session 1) and; “in the group I was in I couldn’t get too much said, lots of dominant personalities.” (Learning Diary - Session 2). She noted in Session 3’s Learning Diary entry that on this occasion, however, working in a smaller group had really helped her learning. This brings into question the nuanced balance of using whole-class and small group discussions. It also provides a justification for my concerns, which I noted in my Learning Log, that not all contributed to whole class discussions. I noted that;

> Discussion was limited to about a third of the group. Should I be concerned?
>
> (Learning Log, Session 7)
>
> A shame but only about 6 were involved in the conversation at the end.
>
> (Learning Log, Session 10)

I have argued that the students felt a positive aspect of the course was the sharing of ideas and that this benefitted their learning. I propose that an element of this was due to the students' genuine interest in each other's work. It was pleasing to read this in the Learning Diaries. Grace commented on this aspect after Session 2 writing that; "it really interested me to know what other people were interested in sustainability wise and how they made this child friendly to be brought into the classroom," and Amy noted; "I enjoyed hearing everyone's views on the trip to the River and having the opportunity to think about how else you can use the trip to help the children's learning," (Learning Diary - Session 6). This respect and interest was further corroborated in the End of Course Interviews when Suzanne was asked to express how she felt the science group had worked;

> It's the feedback that we give each other. It's not, it's not just from us to Alex and Alex to us. It's feedback within the group as well. In fact, the class would go, would also notice each group's work as well and say I liked that.
>
> (End of Course Interview 3)

The following part of this section will suggest that it was the non-judgemental attitude I adopted with the students which allowed this open and free form discussion to flourish. Much of the evidence generated has been drawn from the End of course Interviews. The primary foci of these interviews were to gather data about the manner in which I worked with the students and whether I had imposed my beliefs and values upon them.

When the students were asked about the atmosphere within the group, students from Interview 1 mentioned that it was relaxed, those from Interview 2 perceived that it was a safe environment and those from Interview 3 felt it was informal. Students qualified the reason for this justifying that they were able to express their opinions without fear of judgement. I have provided evidence of this from each of the three interviews to corroborate this pivotal perception of the group's ethos.

> I think it has been quite relaxed which has been good. For example I didn't know anything about sustainability and I can imagine that there are people in the class that knew loads about it, but it's sort of, everyone's been able to say what they believe and no one has really been like embarrassed to say, oh, I don't know anything about it,

> because I didn't know anything before I started whereas now I feel like I know quite a bit.
>
> (Hayley, End of Course Interview 1)

> It's a very safe environment, there's never a fear of being put down or laughed at unless you have been particularly, humorous. I think that everybody does feel that they can say anything.
>
> (Samantha, End of Course Interview 2)

> I think that the way that lectures and things are structured and things, its very sort of, informal is the wrong word but very, sort of, I certainly have never felt like anything that I've had thought was worth saying in front of people wasn't welcomed, so I think there's a sort of environment which everybody contributes to whatever extent they wish to.
>
> (Anthony, End of Course Interview 3)

While the students outlined the group ethos they also made particular reference to the way in which I was non-judgemental about their remarks. Jessica categorically outlines that I did not impose my views;

> Yeah, I wouldn't say that he sits there and just tells you, you know, what's right or wrong. I mean, speaking for myself, I know that I'm quite stubborn, so I know that if somebody was standing there, you know, spouting off about their own personal views, and they feel that I should take upon those views that I immediately would put up a defence and say, no, well hang on a minute, that's not what I think, but, I think suggesting something and considering that suggestion is completely different, a way, a way of teaching the topic rather than just telling what's right and wrong.
>
> (End of Course Interview 1)

Anthony made similar remarks in a different interview;

> When we are discussing things, sort of the way that he phrases his own opinions and things, he is very clear that it is his opinion and it's not just because I'm the lecturer what I say goes kind of thing and it's very much about discussion a lot of the time, so when he sort of throws ideas out and things he's welcoming of what people have to say and other people's views and opinions and things so it's not like he pours knowledge in your head he is very much getting you involved and the whole group I think.
>
> (End of Course Interview 3)

When asked to identify how I had encouraged the group to develop their own opinions Hayley provided a verbal metaphor suggesting; "I suppose he like plants a seed and then, here, you kind of think of that in your own way. He'll just give you a little bit of an idea and then everybody goes off and thinks about it differently," (Hayley, End of Course Interview 1). This reference of providing nurture for growth was also expressed by Suzanne through a pictorial metaphor of my teaching;

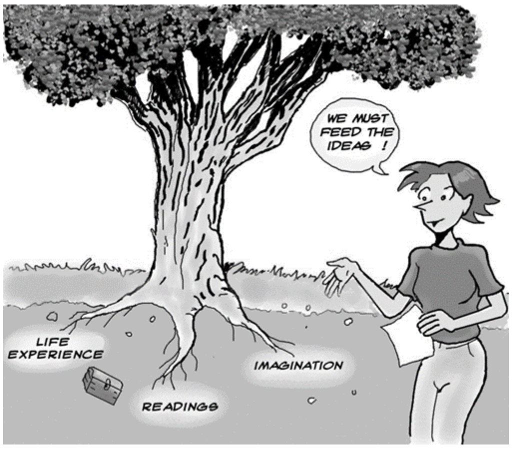
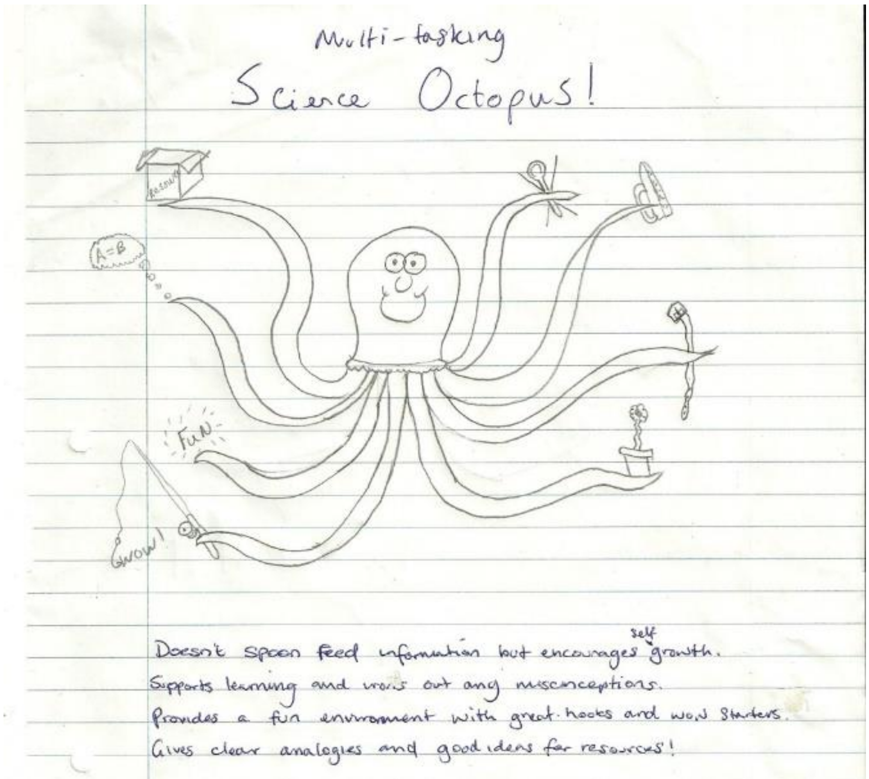


Figure 5.1: Pictorial metaphor A – nurture for growth

"This shows that your lessons inspire me and give me confidence to teach science in class."

A similar metaphor was drawn by Daniel and Anthony who identified that; "[he] doesn't spoon feed information but encourages self-growth." This can be found on the following page.



"Doesn't spoon feed information but encourages self-growth.
Supports learning and irons out any misconceptions.
Provides a fun environment with great hooks and wow starters.
Gives clear analogies and good ideas for resources!"

Figure 5.2: Pictorial metaphor B – science octopus

While I have provided evidence which suggests that many of the activities were related to group work and student-led activities, I also determined from the data that this did not result in a lack of appropriate guidance from me. Due to the nature of the data collection methods and the questions asked in the End of Course Interviews it was difficult to identify this aspect of my practice. However, I suggest that the references made about this aspect of my pedagogy, although limited, are natural and uncontrived examples. For instance, Vikki wrote on two separate occasions about the balance between the students' input and mine;

> There was a really good balance between teacher led discussion and students talking and sharing experience.
>
> (Learning Diary - Session 1)
>
> I thoroughly enjoyed the balance between teacher and student led learning.
>
> (Learning Diary - Session 2)

Suzanne further validated this claim stating that; "during this session we discussed as a class the experience we had on our school placement. Alex led this discussion and through this, we all had a voice," (Learning Diary - Session 1).

5.5.1 Standard 3 - summary

Analysing the data for evidence of the achievement of the final criterion has had the effect of articulating my inherent practice. Prior to completing this I had a vague appreciation of my teaching style but the research process has demonstrated how my value of mutual respect was naturally evinced whilst working with the students. The data has consistently shown the use of class and group discussions as a teaching tool. I have demonstrated that the students appreciated learning from each other and suggested that they were genuinely interested in what other members of the group had to say. I have also proposed that this dialogical way of working was successful because of the respect the members of the group had for each other. I tentatively submit that this community ethos, in part, was developed from the students' appreciation of the non-judgemental and non-objectifying manner in which their ideas were negotiated, coupled with a clear understanding that I did not wish to impose my views upon them. Finally, I suggest that this environment encouraged the students to perceive themselves as free-thinking agents capable of making independent decisions.

5.6 Pedagogical facet A – developing a mutualistic practice: summary

I offer the following summary as an analysis of my learning from working with the students. For much of the time prior to writing this thesis I have professed that I wanted to develop the curriculum for ecoliteracy through a mutualistic practice. I have mentioned previously that the mutualistic manner in which I wanted to work was premised on my value of mutual respect yet I had not fully addressed what this might look like in reality. This analytical process has helped me to identify and articulate what my mutualistic practice comprised.

Initially much of this practice was premised on the tensions of imposing the curriculum on the students and I introduced specific strategies which afforded the students the opportunity to critique their learning experience which I believed was a mutually respectful way of working. The Learning Diaries and the opportunity to critique my writing were examples of this. I believe I have established that these explicit methods were not particularly successful in developing the students' critique of my practice nor in engendering mutual respect. However, I have confidence that I have shown that my well-established and tacit pedagogical interactions and choice of teaching and learning tools provided far greater evidence of developing respectful relationships and, because of this, I can tentatively claim that I worked in a mutualistic manner. Previous experience, gained from working with similar students, ensured that the students' needs were met so that they could achieve their potential in the course assignment and develop their confidence for teaching science in primary schools. The focus of sustainability was of interest to the students and provided a consistent and valuable theme to their learning.

While I have recognised that my prime focus may not have explicitly supported the students to develop their critical thinking, I do acknowledge that the dialogical community that emerged across the course allowed for independence of thought which I suggest is the first requirement of critical thinking. The atmosphere that was unconsciously generated was not coercive and the students felt comfortable in expressing their own thoughts. As a result, the students acknowledged that my ideas concerning planetary well-being were not foisted upon then.

The following chapter will now attend to issues relating to pedagogical facet B and will generate evidence to attest to whether I helped the students to develop ecological epistemologies during Cycle 1.

Chapter 6. Evidence for Developing Ecological Epistemologies through a Reconceptualisation of Science – Cycle 1

6.1 Introduction

The previous analysis chapter attended to a facet of my pedagogy (pedagogical facet A) which I have termed a mutualistic practice. I explored three interrelated aspects of this practice, premised on the relational nature of working which I determined by reference to Buber's (1947, 1958) ideas around I-Thou relations and Alexander's (2008) thinking about dialogic teaching and learning. I proposed that analysis of this facet of my practice uncovered tacit assumptions about my views around education and now suggest that these are ecological in nature. I believe that while I demonstrated that my implicit teaching practice helped to create a community which valued individuals and their opinions, it was the collaborative and relational aspect of the manner in which we worked as a group which were the key elements in developing the mutual respect I have identified.

This analysis chapter will produce evidence for the effectiveness of another aspect of my practice, pedagogical facet B. This facet was concerned with whether the science curriculum could be used to develop the ecological epistemologies that I have suggested throughout this writing are necessary if improvements to the planet's well-being are to be made. I detailed in Chapter 2 that a reconceptualization of science and science education might help to develop these relational epistemologies which I highlighted were premised on Capra's (2005) conceptual framework of systems thinking (which I have previously detailed and which focus on: process over structure; quality over quantity; developed relationships over objectification and studying the whole and not the parts). I detailed in Chapter 2 how this might manifest itself in the practical nature of learning science. This chapter will demonstrate how I generated evidence from the data to determine the effectiveness of this approach with the students from Cycle 1. I will attend separately to the three standards of judgement (S4-6) which I identified in Chapter 4 as necessary for demonstrating that I was developing ecological epistemologies through a reconceptualisation of science. For reference these are outlined again below:

Developing ecological epistemologies through a reconceptualisation of science **Pedagogical facet B**
Q4. Did I help the students to develop an understanding of the relational nature of scientific ideas? S4. Encouraged the students to understand the related nature of science and because of this whether they were able to make links between different scientific ideas.

Q5. Did I help the students to develop an understanding of the temporal and transformational nature of relationships in science? S5. Encouraged the students to understand that some scientific ideas change over time when new evidence appears and because of this whether they viewed knowledge as both tentative and potentially transformational.
Q6. Did I help the students to develop an understanding of the symbiotic relationships they have with the planet and those that share it? S6. Encouraged the students to perceive themselves as part of the natural world and not as separate from it.

Table 6.1: Developing ecological epistemologies through a reconceptualisation of science: pedagogical facet B - research questions and standards of judgement

I have previously written about my initial ill-formed and vague ideas about ecoliteracy during Cycle 1. I also suggested that during this Cycle I was thinking in a non-ecological manner and deemed science, and the curriculum, as a set of abstract objects. As a consequence, this influenced the teaching and learning activities I provided for the students. I have identified that it was not until after Cycle 1 had occurred that I appreciated the need to develop ecological epistemologies or that the science curriculum could, in part, be used to establish these. I recommend that the emphasis of this chapter for the reader is the important evidence it provides for the way I was thinking during Cycle 1. Chapter 7 will then develop this to show the transformation in my thinking from this point.

6.2 Generating evidence from data - pedagogical facet B: developing ecological epistemologies through a reconceptualisation of science

6.2.1 Pedagogical facet B - standard of judgement 4

> **Did I help the students to develop an understanding of the relational nature of scientific ideas?**
>
> **S4. Encouraged the students to appreciate that science can best be understood in terms of relationships and because of this whether they were able to make links between different scientific ideas**

Despite Samantha stating in her End of Course Interview that the theme of sustainability; "…has been a very good focus for the two years it has been something that we have gone away from and come back to," (End of Course Interview 2) I will argue in this section that the course was disjointed and demonstrated a lack of explicit promotion of the relational nature of scientific ideas and how these related to planetary well-being

Appendix 9 outlines the session titles and the associated teaching and learning activities that were undertaken during them (additional detail of what was included can be found by reference to Appendix 8; an example of a student's Learning Diary). I offer this as evidence to show the lack of progression and links made between sessions and within them. Having analysed the content of the course's sessions I argue that I chose the subject matter and activities mainly in terms of issues of interest to me and which had clear links to National Curriculum objectives (DfE 2013). I provided a justification for this in the previous chapter and suggested that the success of the course was, in part, because of the relatable classroom strategies offered. This fixation on not deviating from anything other than the science objectives prescribed in the National Curriculum was first demonstrated, I suggest, in the initial session when I was discussing the curriculum for ecoliteracy and proposed that; "I would love to sort of spend most of the science curriculum developing these kinds of ideas," (Initial Presentation, 10.1.2012). I propose that my primary focus of providing science teaching activities which could be utilised in schools obfuscated the important relation between undertaking them and their relevance to planetary well-being.

In addition to this is my assertion that I selected activities of significance to me. For example, before commencing the course I already had tentatively planned a theme and suggested that;

> as a starting point, in helping children to reconnect with nature, a project on growing food may be prudent. There is evidence that many children believe that their food originates from the supermarket with no association being made to its origin or the processes that are undertaken for it to arrive in their home.
>
> (Sinclair 2013, p. 141)

This choice of the theme of 'growing' provided a vague connection between lectures which I now recognise stemmed, not from the students' interest, but from my own experience of having an allotment and my desire for being in an outdoor environment. Evidence of this can be found when I commented on my personal awareness of the pleasure I gained from being outside; "initially it was so much fun to get outside, even in the rain with another group. I was certainly well aware of my awe and wonder for nature, which I believe the others had as well," (Learning Log, Session 7).

I was cognisant that gaining an experience of planting seeds and growing food might play a small role in reconnecting the students with the natural world (which will be attended to below in Section 6.2.3). However, I was also aware that without highlighting the relationship between food and issues concerning planetary well-being these experiences would remain at the level of learning about plant life cycles. Evidence of this understanding came from my Learning Log from Session 1 which covered the germination of bean seeds. I noted in my Learning Log that I had briefly introduced the ideas of air miles and seasonality in the hope that connections between where food is grown and its environmental impact could be made. Analysis of the Learning Diaries for this session shows that no student commented upon this aspect of their learning. I appreciate that it is difficult to infer what importance the students placed on any activity only by studying their Learning Diaries, however I believe that they do highlight what the individual perceived was the most significant and memorable aspect of each session. While it is difficult to draw conclusions from these Learning Diary entries, I tentatively suggest that the lack of comments may be because planting was a novel and engaging process for many of the students and this became their sole focus. I also suggest that I may not have given enough time nor stressed the importance of these learning links.

Further emphasis on the relationship between growing and planetary issues was also placed in later sessions. Planting out the germinated seeds in the University's allotment, during Session 4, evoked three broad reactions from the students. Rohinni's response exemplifies those that purely listed the activities undertaken (including learning about strawberries);

> I thought that this was a very practical session and, once again, I really enjoyed it.
> I liked that we were able to go out and plant our germinating seeds. It's great that we will be able to see the progress that it will make.
> The snail hunt was fun. It was frustrating when we couldn't find any but towards the end we had more success.
>
> (Learning Diary - Session 4)

Clarissa's entry typifies those students who had related the activity to its potential use in school. She commented that; "I enjoyed the session. The planting was fun and can see the benefits of doing it with children," (Learning Diary - Session 4). There were a few students who I suggest were articulating links between the growing activities and learning about issues concerning planetary well-being. Natasha was one of these and she wrote that she; "really enjoyed planting the plants we had grown in the classroom – this would be good for children to participate in as they can watch the flower grow and be aware of where flowers/vegetables come from," (Learning Diary - Session 4).

Despite limited evidence to suggest that I promoted and developed links either between issues regarding planetary well-being or other science related matters I can provide embryonic evidence that I was thinking in an ecological manner and that there were other constraints which meant this was not evidenced in my practice. This initially came from an email with a potential guest speaker from a company called Sunny Schools whose aims are to educate children about climate change and solar power. Email correspondence before the session demonstrates that I was aware of the need for students to make associations surrounding the areas to do with climate change when I requested that;

> It might be nice to focus on renewables, but I am very keen for the students to see the 'big' picture. Maybe you/we could make the links between needing to 'energy save' (due to climate change) through the use of renewables due to climate change.
>
> (email correspondence with speaker; Sinclair 2012c)

This argument is further strengthened by reference to my Learning Log entry following this session which details how I believed it unified ideas from many of the students' preceding experiences.

> This was the session I would have liked to have done with the students as it really got to the nitty gritty about the 'problems' in the world although it did not focus too much on 'people' until the end of the session. It provided a background and links for all of the work that we have done, or its justification.
>
> (Learning Log, Session 10)

I am also aware that my understanding of the relational aspect of planetary well-being did not really take into account the impact that planetary degradation is having on the human population. Analysing the course outline (Appendix 9) shows I only considered this aspect in Session 3. I provided a human context to a raft building activity by introducing the students to flooding in Bangladesh and ways in which some communities were building floating growing spaces. However, I argue similarly to the growing activities that this was tokenistic and referred to the practical aspect of constructing the raft rather than to how this related to planetary well-being. Rohinni's Learning Diary entry is typical of the other students' comments reflecting my lack of commitment, and their paucity of appreciation, to this facet of their learning; "the floats we made was [sic] a really random but fun activity to do. It was all disjointed but I felt it was a really practical lesson and I really enjoyed it! YAY!" (Learning Diary - Session 3).

Despite the limited evidence to suggest that I promoted an understanding that issues concerning planetary well-being were not confined solely to the science curriculum there is some evidence to suggest that this was implied throughout the sessions. When asked in their End of Course Interviews to respond to the question; "what do you think you will do in your classroom to make a difference or get the children to think about sustainability?" the students within all three interviews responded that the course had made them view the topic of sustainability in a more relational manner. They felt that it was not the sole domain of science and it should be taught as a cross-curricular topic and suggested that its influence should appear across many curriculum areas. Clarissa noted that; "it covers quite a broad range of subjects and you can see how it impacts everything in the curriculum. You don't really see that in specific curriculum subjects which I think is quite good," (End of Course Interview 1), with Jessica further outlining that;

> It's quite a cross-curricular subject so I don't think it can be, you know taught singularly, it's very, you could include it in all of your practice and I know Hayley and I in our enhanced placement managed to combine it with art quite easily and as a result it was all linked to the theme within the school too, so , I think it's effecting [sic] my practice, it's just going to make me consider it more as a cross curricular link when I'm, when I'm planning so.
>
> (End of Course Interview 1)

Student Q makes a similar reference to Clarissa and Jessica. When asked what effect the course would have on her practice, Student Q wrote in her Post Course Questionnaire of the need to be creative and not stick rigidly to the National Curriculum objectives (DfE 2013);

> I have learnt: how to teach science creatively; the issues that surround the teaching and learning of science, for example the implications of hatching chicks; and the need to look outside of the national curriculum to teach concepts that are not explicitly written there but can be embedded into it, such as sustainability.
>
> (Post Course Questionnaire - Session 11)

6.2.2 Pedagogical facet B - standard of judgement 5

> **Did I help the students to develop an understanding of the temporal and transformational nature of relationships in science?**
>
> **S5. Encouraged the students to understand that some scientific theories change over time when new evidence appears and because of this whether they viewed theory as both tentative and potentially transformational**

I have previously detailed that during Cycle 1 I had not interrogated my beliefs about science and science education and had not questioned the uncertain nature of knowledge produced by scientific methods. I have argued that this whole thesis relates to my reconceptualisation of science and that gaining an appreciation of the evolving and transformational nature of knowledge probably had the largest influence on my learning and therefore practice. For this reason there is no data to suggest that I challenged my students' thinking in this regard.

There is evidence to suggest that I understood the uncertain nature of matters relating to sustainability but that I had not made explicit cognitive links that these were, in fact, also related to a particular perception of science and the generation of knowledge. Despite this I wrote the following;

> In addition to the students' view of my role, science, in schools, is packaged so that there is the belief that there are either correct or incorrect answers often glossing over the reality that some scientific knowledge is incomplete and often uncertain. Nowhere is this uncertainty more obvious than within the science of climate change where Hulme (2009) notes that there will never be a consensus about the effects of global warming nor what should be done about it. Poignantly he asks; "what is the ultimate performance metric for the human species? Is it to restabilise climate? Stabilise population or to minimise our ecological footprint? Is it to increase life expectancy, to maximise gross domestic product, to make poverty history or to increase the sum of global happiness? Or just simply survival?" (2009: 336).
>
> (Sinclair 2012a)

The presentation from the following end of year review meeting strengthens the argument that I was starting to understand the uncertain nature of issues relating to planetary well-being yet had not made the conceptual link that this applied also to all scientific ideas. Slides 2 and 3 from the presentation that I gave for this meeting provides provisional evidence of this standpoint; no reference was made to uncertainty related to other aspects of science other than planetary well-being.

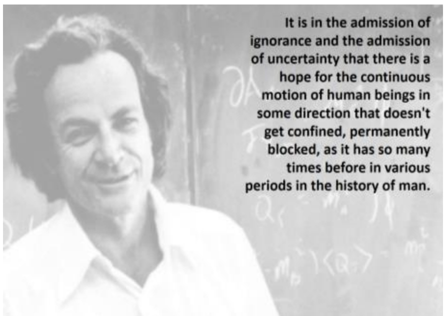


Figure 6.1: Slide 2, Presentation for End Year Review Meeting, June 2013

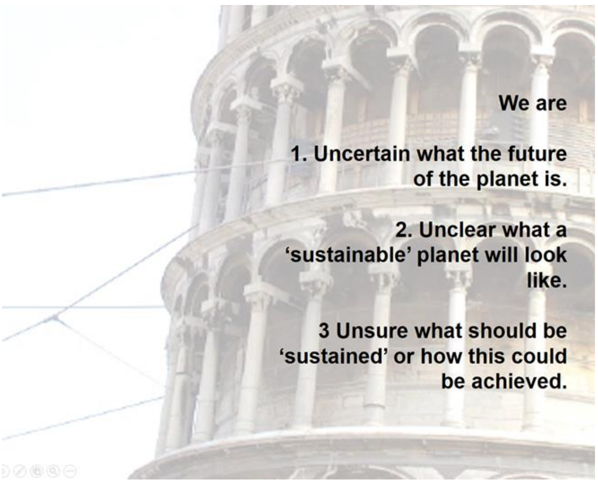


Figure 2.2: Slide 3, Presentation for End Year Review Meeting, June 2013

I had concurred with Hicks' (2006) suggestions that education needed to encourage students to discuss possible, probable and preferable futures to develop this understanding of uncertainty. Reference to the course outline (Appendix 9) demonstrated that these ideas never manifested themselves in strategies which I used with the students. Similarly I did not give the students an opportunity to explore what the term might mean to them, believing that there was a shared understanding within the group. Instead, I provided them with the teaching strategies I detailed in Chapter 5 which meant that I did not have to spend time dealing with the contentious issues of sustainability which did not appear in the science curriculum. My Learning Log entry for the session with an outside speaker whose general focus was on sustainability (but not focussed within schools) demonstrates this. I wrote that; "this was somewhat off the science curriculum and I would have felt conscious of delivering this. However, it provided a background for all of the work that we have done, or its justification," (Learning Log, Session 10).

Students were asked to define the term 'sustainability' both at the beginning and end of the course. The data shows that their initial definitions often were vague. Many mentioned the temporal aspect of planning for future generations yet the students' definitions often lacked clarity. Vikki wrote; "my understanding is that it is a geographical term to do with how we treat our environment. How to ensure it is okay for future generations + not waste things. I'm not sure really!" (Pre Course Questionnaire - Session 1). Despite Vikki's assertion at the start of the course that she was unsure, I have argued that I did little to address this. Understandably many students wrote similar definitions at the end of course demonstrating limited, if any, progression of their understanding. I have used Francesca's pre and post course questionnaire responses, which are comparable to many others in the group, to provide evidence for this;

> Sustainability is trying to sustain/ keep things the same for future generations, mainly to do with the environment,
>
> (Pre Course Questionnaire - Session 1)
>
> Sustainability is ensuring the resources we have on the earth today are maintained for future generations. Living sustainably by replacing the things we use – not destroying finite resources.
>
> (Post Course Questionnaire - Session 12)

This argument is further strengthened by evidence from one of the End of Course Interviews. I have included a large part of the transcript here. I suggest that it shows that, while they initially perceived they were clear about defining the term sustainability, they actually found it problematic. I propose that there was a tacit belief, on my behalf, that the students had a shared knowledge and as a consequence the term became over-familiarised without any critical evaluation of what it really meant. This is exemplified in the following interview:

> Interviewer: So a difficult question, a really difficult question, do you have a better idea of what we are talking about when we are talking about sustainability now?
>
> Jessica: Yeah definitely.
>
> Interviewer: So if you were to give a definition of it, that's a really difficult question. What would you say sustainability is?
>
> Hayley: To ensure a better future for future generations or to...keep…
>
> Jessica: Strategies to ensure a better, a better, you know, a healthier planet
>
> Hayley: Without, future generations, without impacting our own. I know exactly I just can't think of it.
>
> (End of Course Interview 1)

These excerpts have not been used to demonstrate the students' inadequacies but as evidence to show that I had avoided confronting these contentious issues which resulted in missed opportunities for the students to engage with the uncertain nature of the planet's well-being.

6.2.3 Pedagogical facet B - standard of judgement 6

> **Did I help the students to develop an understanding of the symbiotic relationship they have with the planet and those that share it?**
> **S6. Encourage the students to perceive themselves as part of the natural world and not as separate from it**

Much of this section will draw upon the previous suggestion that the loose theme for this module was premised on growing plants and therefore taking learning experiences outside of the classroom. I explained that this strategy was founded upon my personal interest of owning an allotment and therefore was not explicitly related to helping students make a reconnection with the natural world.

Many students appreciated the process of planting their germinated seeds in the University's allotment and despite my apprehension that rain may have affected their attitude to going outside I commented that; "I was really concerned that the students wouldn't want to come out in the drizzle, plant the wheat and get muddy. Really pleased with students' attitude, interest in the process," (Learning Log, Session 3). This was reflected in Rohinni's Learning diary entry for this session which stated; "we planted wheat, which is definitely something I have never done before. It was quite messy but still fun! Learnt something about strawberries that I never knew about! That was really interesting," (Learning Diary - Session 3).

It is difficult to infer much from the students' Learning Diary entries other than that they felt that planting seeds and checking on their progress was a worthwhile experience. Most, like Vikki and Rohinni, merely commented on their engagement. Vikki wrote that she; "enjoyed planting the variety of beans and looking for snails," (Learning Diary - Session 4). Despite the explicit lack of intention on my behalf that these activities should help the students reconnect with nature, I argue that Sandra's reaction demonstrates the potential power of these experiences for some, even if she was the only one that responded in this manner. She wrote that; "it made me appreciate the beauty that is found in nature – a simple bean. This is something that I feel we often overlook. Good to get your hands dirty and to feel the soil," (Learning Diary - Session 1).

In addition to the strategies I implemented for learning science outside of the classroom I provide the following as further evidence of my understanding of my connection with the planet and how this influenced the students. I have often drawn on the over-simplified term 'what then?' (Orr 1992) in order to clarify my understanding of ecoliteracy. In most cases I have explained how this basic view of ecoliteracy is unsatisfactory and lacks depth. However, I believe in this instance, that the ability to ask this question assists in a comprehension of the consequences of one's actions on planetary and human well-being. This, I argue, is part of perceiving oneself as part of the natural world and not separate from it. I have reproduced the following from my Learning Log following a trip to the local river to demonstrate that I was thinking in this manner and that I had provided the students with an opportunity to challenge their assumptions;

> A real eye opener today. Following our visit to the River Crane, I brought up the issue that Thames water had decided to flood the river with sewage rather than Heathrow runway. I gave them time to discuss their thoughts and to feedback what they felt about it. At the end we voted on whether Thames Water had made the correct decision. I was quite shocked and disappointed that only one student felt they shouldn't have flooded the river – 2/3s said it was the right thing to do and approx 1/3 were undecided. My worry is that money and inconvenience is given priority over the disruption of a living ecosystem with the students knowing that all life in the river (from the where the sewage was emptied down) was killed. The students seemed to justify this by stating that life had returned to the river within the year.
>
> (Learning Log, Session 6)

The emphasis given to this aspect of the session in my Learning Log highlights the importance and relevance I afforded it. Anthony's perception of this as a prominent part of the session concurred with mine. He wrote in his Learning Diary Entry that;

> I enjoyed the debate on the dumping of sewage into the river crane as it showed where sustainability is concerned there is never a clear cut answer. The debate was quite lively and some strong views were expressed. (Learning Diary - Session 6)

However, in reality the session's main focus was on planning resources that could be used to take children to the River Crane to learn science (see Appendix 9). Understandably, most students' Learning Diaries reflected the time given over to this planning and similar comments to Grace's were made. She wrote that; "we discussed our River Crane trip. This raised questions and discussion that involved what we could do as follow up activities and other activities that we could do if we were perhaps teaching or leading those activities," (Learning Diary - Session 6).

Although I was disappointed that most of the students approved of the decision to empty sewage into the River rather than the airport's runway there were a few students who commented how this discussion had challenged their thinking. Sandra and Jessica wrote;

> Pollution – I found myself arguing in favour of Thames water polluting the River Crane – this goes against everything I believe but I could see that rationally it was the right thing to do.
>
> (Sandra, Learning Diary - Session 6)

> I have come away from this lecture with questions about how much we know about sustainability. Are we being given information as members of the public? How do we know we are doing good? Is there info that we are not being given that may change our views of the world?
>
> (Jessica, Learning Diary - Session 6)

Even though there has been little evidence to suggest that I helped to develop this aspect of an ecological epistemology I will provide one further example to demonstrate the influence I had on how the students viewed themselves in relation to their environment; it is this of which I am most proud of. When asked how the course had affected her own life or practice, Hayley outlined how she had taken deliberate action at her place of employment. She commented that;

> I work in a supermarket and I'm on the fruit and veg department and before I was just like we get, can I say it, yeah its 'Shop B' so they are really like quality is a really big, so I have to chuck away loads of fruit and veg if it's just got a little bit of bruises on it and now when I'm doing it I'm a bit more, oh someone will buy that and I've got really like, they might get a bit annoyed but I leave loads of fruit and veg there because I know somebody is going to buy it, it's pointless me just throwing it away, and yeah I've become a little bit more mindful about that and chucking things away and wasting things when it will last.
>
> (End of Course Interview 1)

6.3 Chapter summary

This chapter has attended to the effectiveness of developing the three aspects of an ecological epistemology which I believe the science curriculum could help to address (to develop an understanding of the relational nature of scientific ideas; to develop an understanding of the temporal and transformational nature of relationships in science; to develop an understanding of the symbiotic relationships humans have with the planet and those that share it). I mentioned previously there was little evidence to demonstrate I had attended to this development and suggested that this was because of my embryonic understanding of the relational and transformational of science and as yet I had not questioned the purpose of a science education in relation to this reconceptualization. As a consequence, I have shown throughout this chapter that I provided limited opportunities to help the students to think in a relational manner. I have suggested that the theme of growing provided a loose framework to develop an ecological way of thinking but without explicit instruction it did not help to show the related nature of science. This theme did afford the opportunity to take the science learning outside.

The emphasis of this chapter has been to provide evidence for the way I was thinking, both about sustainability and science. I hope this information contextualises my learning and can be used to demonstrate how it subsequently transformed after Cycle 1 and how this influenced my practice during Cycle 2. The following chapter will provide evidence of how this way of thinking and a commitment to reconceptualising science was evidenced through my changed practice.

Chapter 7. Putting into practice what I learned from Cycle 1

7.1 Introduction

The previous analyses chapters have provided evidence of how I believe I have influenced the students' learning and the way I was thinking in Cycle 1 and consequently how this manifested itself in my practice. I detailed how the analytical process of my research provided me with the tools by which to articulate two facets of my pedagogy. I explained that the most successful aspect of my pedagogy was the relational manner in which I worked with the students. I highlighted that this was based on the development of mutually respectful relationships which were demonstrated, not through a set of explicit strategies, but as a result of long-established, but tacit, teaching interactions. As a consequence the students acknowledged that they were part of a learning community where their ideas were valued and independent thought allowed to flourish. I also established that my vision for a curriculum for ecoliteracy was primarily premised on non-ecological epistemologies which resulted mainly in the production of teaching activities that the students could use in school.

This chapter will provide evidence for how my thinking transformed between Cycle 1 and 2 and will focus specifically on my reconceptualisation of science. It will demonstrate my appreciation for the need to develop ecological epistemologies and my belief that this could be achieved by helping the students to view science as an ecological act. This new way of viewing science will provide the context for the actions I took within Cycle 2.

In particular this chapter will analyse one specific aspect of an ecological approach to science teacher education through asking whether I helped the students to understand the related nature of science knowledge (S4 Encouraged the students to understand the related nature of science and because of this whether they were able to make links between different scientific ideas.). This emphasis manifested itself as a result of my learning from Cycle 1 and the revelation that I had not considered this characteristic of the nature of science either as a student or as a teacher. As a result, it is important to note that during Cycle 2 I did not engage with the other elements of developing an ecological view of science which were related to whether I had:

> S5. Encouraged the students to understand that some scientific ideas change over time when new evidence appears and because of this whether they viewed knowledge as both tentative and potentially transformational.
>
> S6. Encouraged the students to perceive themselves as part of the natural world and not as separate from it.

7.2 Starting to reconceptualise science

This section will provide evidence to show how the focus of my research changed between Cycles 1 and 2. It will demonstrate how critically engaging with suggestions that the dominant, linear epistemologies, which have been perpetuated by a Newtonian model of science and have led to the planetary degradation we are now facing (Capra 1996; Orr 1992), helped me to view science in an ecological fashion. Through demonstrating my shift in understanding I will show why a new focus for Cycle 2 emerged that was premised on promoting a relational and ecological view of science in the hope this would develop the necessary ecological epistemologies which Capra (1996), amongst others, has suggested are necessary for improving planetary well-being. Evidence for this changed thinking will be drawn from draft writing and presentations given at yearly doctoral review meetings.

Draft thesis writing from January 2015 outlines what I perceived to be the stimulus, and therefore the focus for the research at this time and outlines my concerns about planetary well-being. There is no reference to the role science, and the forms of epistemologies I have suggested it promotes, have played in this process; I stated in the introduction that;

> The stimulus for conducting this research has come from my growing concerns for planetary well-being. In brief, my anxieties have developed from the fact that the global human population has recently reached 7 billion inhabitants and the negative effects this is having on our planet.
>
> (Sinclair 2015)

A single slide from the presentation that I gave at my doctoral review meeting at a similar time suggests that while I was engaging with ideas concerning the role of uncertainty in scientific enquiry and knowledge generation these were ill-formed and not the main focus of my studies or thought.

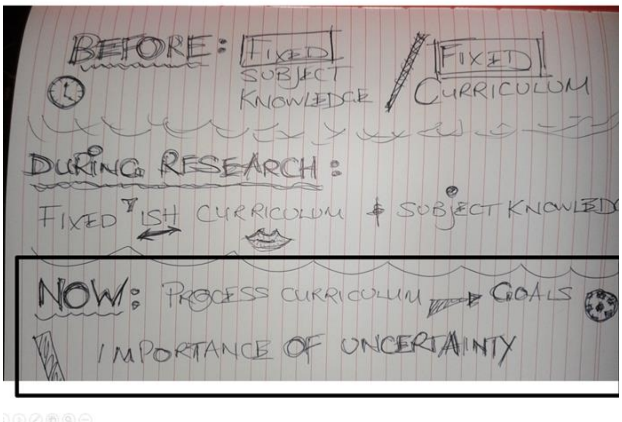


Figure 3.1: Slide 9, End of Year Review Meeting, July 2015

There was no evidence to suggest that I had questioned the assumptions I had about the knowledge generated from science or how this applied to ecoliteracy. The following slide demonstrates how my perception of ecoliteracy was still related to providing explicit experiences related to environmental issues and not related to developing ecological epistemologies:

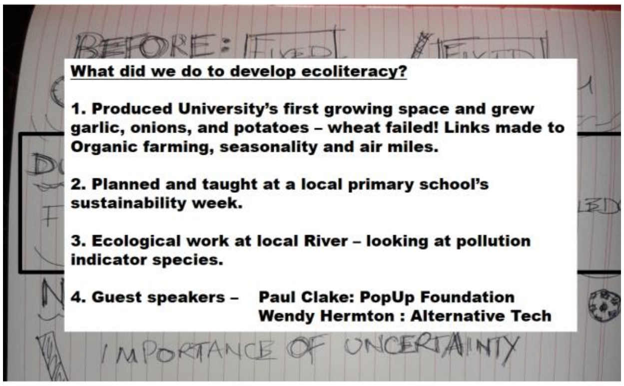


Figure 7.2: Slide 4, End of Year Review Meeting, July 2015

Initial evidence for my transformed thinking first comes in draft writing of the introduction to the thesis in June 2016. This is the first written reference which demonstrates my critique of the scientific epistemologies that I have argued have led to the planetary degradation we are currently facing. I wrote that;

> This chapter will bring to light a specific epistemological stance, which has been underpinned by traditional Western science methods and ways of thinking. It will show the effect this worldview has had on the education system I participated in.
>
> (Sinclair 2016)

This argument is strengthened by reference to the presentation I gave at the yearly review meeting at a similar time. I suggest that points 3 and 4 provide further evidence of my claim that I was starting to appreciate how the form of science education I had received and taught had formulated my epistemological stance.

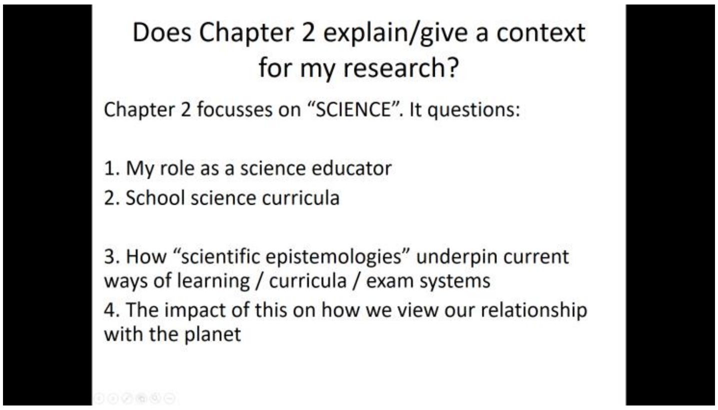


Figure 7.3: Slide 4, End of Year Review Meeting, February 2016

In addition to this, the slide's notes section contained the following reminder for the presentation, highlighting how I was starting to relate the uncertainty of knowledge to specific science content;

> Last year had ideas about this ie the uncertainty of scientific knowledge – will speak later about the historicity factor ie Galileo / helio and geo centric models. Also starting to get to grips with quantum mechanics.

The following slide from the same presentation also provides the first recorded evidence of how I had reconceptualised science and the influence I believed this had on my understanding about science education and therefore my practice:

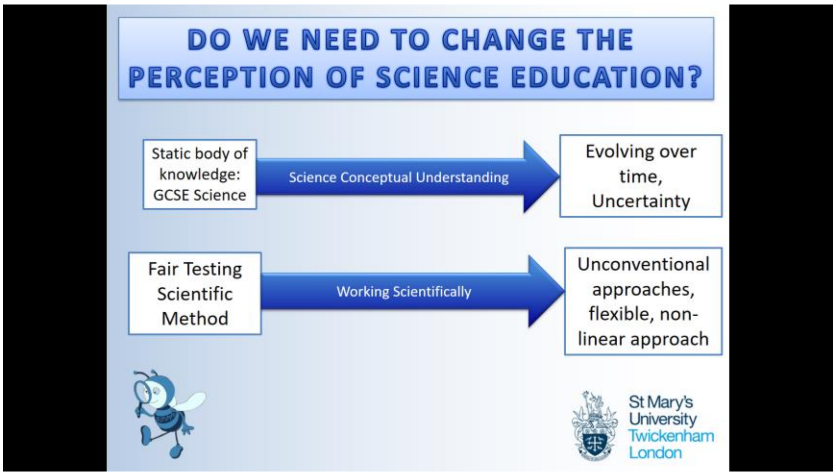


Figure 7.4: Slide 10, End of Year Review Meeting, February 2016

The notes section for this slide articulates this is in slightly greater detail;

> We think that science is often perceived as…something static with fixed answers. If the work and lives of scientists are studied it can give children the opportunity to understand the messy and changing nature of science.

A culmination of these ideas can be found in published writing from the same period. This writing briefly outlines my suggestions for the future of science education combined with practical activities for how the aspect of uncertainty in science can be developed with children (Sinclair & Strachan 2016). Much of what is to follow in this chapter will analyse the influence of sharing these practical ideas with students and others from the primary science community and whether or not they helped to develop the ecological epistemologies I had hoped they would.

This section has provided evidence of my changed view of science and therefore science education. In particular, it has shown my shift in understanding of a particular aspect of science; that science is premised upon degrees of uncertainty and, as a consequence, some scientific ideas transform and change over time. The following part of this chapter will analyse the data in relation to this and will suggest my practice and actions during Cycle 2 helped those I worked with to develop an understanding of the temporal and transformational nature of relationships in science.

It will draw on a wide range of data sources and participants. This varied analytical process best reflected the forms of data sources necessary to demonstrate the influence my ideas were having on those I worked with which, now, extended beyond the students studying to be teachers. These other research participants have been detailed in Chapter 4.

7.3 How the National Curriculum provided an opportunity for ecological thinking

Analysis of the data from Cycle 1, and therefore an impetus for my transforming perception of science, occurred alongside the publication of a new National Curriculum (DfE 2013) for schools. All maintained schools in England have a statutory requirement to follow the National Curriculum. Most students who attend teacher training courses will work in maintained schools and therefore will teach from this curriculum. For this reason, the courses I teach and write are premised on this and how I can best prepare the students to teach children science in primary schools. I have detailed in Chapter 5 that one of the key tacit drivers of my practice in Cycle 1 was ensuring this need was met by providing trainees with activities with clear links to the curriculum. I also detailed how this pedagogical aspect often overpowered my desire for them to engage with ideas related to planetary well-being. The following section will provide evidence of how I interpreted the National Curriculum to overcome this dilemma resulting in the production of resources which could play a dual role in providing explicit classroom activities while also developing an ecological view of science.

In particular I was drawn to a statement from the Upper Key Stage 2 section of the science school curriculum which noted that; “pupils…should also begin to recognise that scientific ideas change and develop over time,” (DfE 2013, p. 24). Its importance was strengthened by its inclusion in the Interim Teacher Assessment Framework which teachers were required to use to assess the children’s scientific abilities at the end of their primary schooling;

> The pupil can describe and evaluate their own and other people’s scientific ideas related to topics in the national curriculum (<u>including ideas that have changed over time</u>), using evidence from a range of sources.
>
> (emphasis authors; Standards and Testing Agency 2015, p. 8)

In addition to this, the National Curriculum (DfE 2013) also made suggestions in the non-statutory notes and guidance sections that children should study the works of famous scientists and inventors such as the following;

> Pupils might find out about people who have developed useful new materials, for example John Dunlop, Charles Macintosh or John McAdam.
>
> (DfE 2013, p. 12)

> Pupils might find out about the significance of the work of scientists such as Carl Linnaeus, a pioneer of classification.
>
> (DfE 2013, p. 31)

I believed my perception of the transformative nature of science aligned strongly with this area of science learning. I wanted to develop ways in which the inclusion of these suggestions could be used to help my students come to terms with the evolving nature of scientific ideas which subsequently they could pass on to the children they would teach. I have outlined in Chapter 2 how I understand that an ecological approach to science teacher education may require this strategy.

Although I believed this was a welcome addition to the science curriculum for children in England there was no justification for the inclusion for studying these famous scientists and inventors. This omission therefore left this section of the curriculum open for greater interpretation by teachers in schools. I felt that this was a missed opportunity and that these named scientists could be taught about in such a way so as to convey the messy process of scientific discovery in relation to recognising; “that scientific ideas change and develop over time,” (DfE 2013, p.24). In this way I believe I was perceiving science as a dynamic process of enquiry.

7.4 Finding out how teachers were using the famous scientists.

This section will address my concerns regarding how students and teachers viewed the purpose of teaching about the famous scientists. It will draw upon research which corroborated these worries and suggested that many teachers in schools were only using those scientists specifically named by the National Curriculum (DfE 2013) and were setting it as project work for children to find out about the life story of the scientist. It will highlight my belief that if taught in this manner it could perpetuate the image of science as a dormant, static discipline and maintain the current non-ecological way of thinking.

My initial concern was that many students studying to teach primary science do not have qualifications beyond GCSE (Heywood 2007). As has been discussed in Chapter 2 those in this position may not have had an opportunity to engage with the nature of science and, similar to myself, may perceive it to be of the Newtonian version and static in nature. I was concerned that those students confronted with these broad statements from the National Curriculum (DfE 2013) may have had difficulty in linking the potential purpose of studying these scientists in relation to promoting the transformational nature of the discipline. If this was true of the students then it may also be likely of those teachers already qualified and teaching in schools.

Anecdotal evidence and a reflection on my previous teaching practice in school suggested that when this area of the science curriculum was taught in schools it was usually set as a fact-finding project which highlighted the scientist's experience during their lifetime. In order to justify these assertions I carried out internet searches to ascertain the form of resources that were available for primary schools. This research highlighted that many of the resources provided did not place the scientist and their discovery or invention in a historical context. I suggest that this only assists in replicating the dominant epistemology which views values and practices as timeless. Consideration is not given to how these discoveries were historically and culturally related and influenced by what was happening in the scientist's own time. Other than reference the shift from the geocentric to the heliocentric model of the universe and the context in which the theory of evolution was proposed, the resources available to students and teachers on the internet made reference to irrelevant information such as when the scientist was married and how many children they had. An example of this type of resource came from the Linnaean Society who provided a fact sheet entitled; 'Who was Carl Linnaeus?' (Who was Carl Linneaus? no date).

To develop my understanding of how information about the scientists in the curriculum was being used I carried out further research with my colleague (Sinclair & Strachan 2015). Forty primary school science coordinators were surveyed and asked; 'What do you think the purpose of including these famous scientists is within the Primary Science Curriculum?' Analysis of the qualitative responses produced three broad (although overlapping) categories, as follows:

1. To change attitudes about learning science;
2. To inspire science as a future career;
3. To help children gain an understanding of the nature of science.

While some commented that it helped children develop their understanding of the nature of science only two specifically noted that this was to show how ideas evolve over time. Examples of this were as follows;

> Highlights science's role of finding out things we don't know – shows we don't have the answers to everything.
>
> ` (Participant 22, Sinclair and Strachan 2015)

> To help children to understand how ideas develop.
>
> (Participant 27, Sinclair and Strachan 2015)

All comments were positive and about enhancing the children's understanding and experience of science. Considering there was no overarching guidance from the National Curriculum (DfE 2013) to justify studying the scientists, it was therefore understandable that there was no consensus from differing schools about the purpose of their approach. However, the majority of schools surveyed did not identify the opportunity to use these named scientists as a way of demonstrating to children how scientific ideas can change. Nevertheless, I understand that the short survey format of this study may have precluded these teachers from mentioning this and their schools may encourage this way of thinking in a different manner by other means. I am also aware that the responses to this question were from science coordinators in primary schools who are more likely, although not all, to have a greater awareness of the nature of science. As mentioned before, Abd-El-Khalick (2002 in Taber 2012, p. 23) and Cian, Dsouza, Lyons, and Cook (2017) highlight that secondary school science teachers' understanding of the nature of science is often poor. They suggest that it may be as limited as the students' knowledge that they teach. Bearing in mind that most primary school teachers do not have science qualifications beyond GCSE (Heywood 2007) it is difficult to perceive that their understanding will be any more developed than those of their secondary colleagues highlighted above. The survey also did not determine the manner in which these teachers used the scientists and a further question of 'how?' they were being used was needed to ensure that the use of fact-finding strategies was not solely taking place. This will be something I will continue to research.

In addition to this research I also carried out a scrutiny of some of the common published schemes of work. There was limited evidence (other than reference to the change in understanding regarding the theory of evolution and the organisation of the solar system) to suggest they were promoting this aspect of science education in primary schools. There appeared to be no consistent approach throughout the school years or between topics.

While I understood that the nature of science attends to issues regarding philosophy, history and sociology (Taber 2012) from an ecological perspective the most important aspect of this, to me, was to develop ways to help my students to understand that scientific ideas have changed over time and thus demonstrate the dynamic, evolving nature of knowledge. I believed that locating the scientists named in the National Curriculum (DfE 2013) within a historical framework could help to achieve this. It was important to show that not only had these scientists' discoveries challenged and changed thinking at that time but subsequently their ideas had been built upon up to the modern day and there is the potential for further change. The next section will detail how I went about changing my practice to accommodate for this.

7.5 How did I use the famous scientists named in the National Curriculum to challenge the dominant worldview about science?

The following section outlines how wanting to develop an ecological approach to my pedagogy, and in particular, the desire to promote an understanding of the transformative nature of some science knowledge, manifested itself in my practice. It will highlight that the specific resources I developed to advocate this way of thinking (see fig. 7.5 below which shows a template to assist in viewing the process of scientific enquiry) and how they were employed. Initially I will provide evidence to suggest this has helped some of my students from Cycle 2 to reconceptualise their view of the nature of science and how this could be established in the schools where they teach. It will also draw upon data from a classroom teacher and other student teachers (studying at another teacher training institution) and propose that this was a useful strategy in helping them to start transforming their perceptions of science.

This desire to support teachers to reconceptualise science resulted in the production of the following template which could be used for studying a specific scientist or inventor and which, it was hoped, would challenge the perception of science and the form of knowledge produced through traditionalist forms of scientific enquiry.

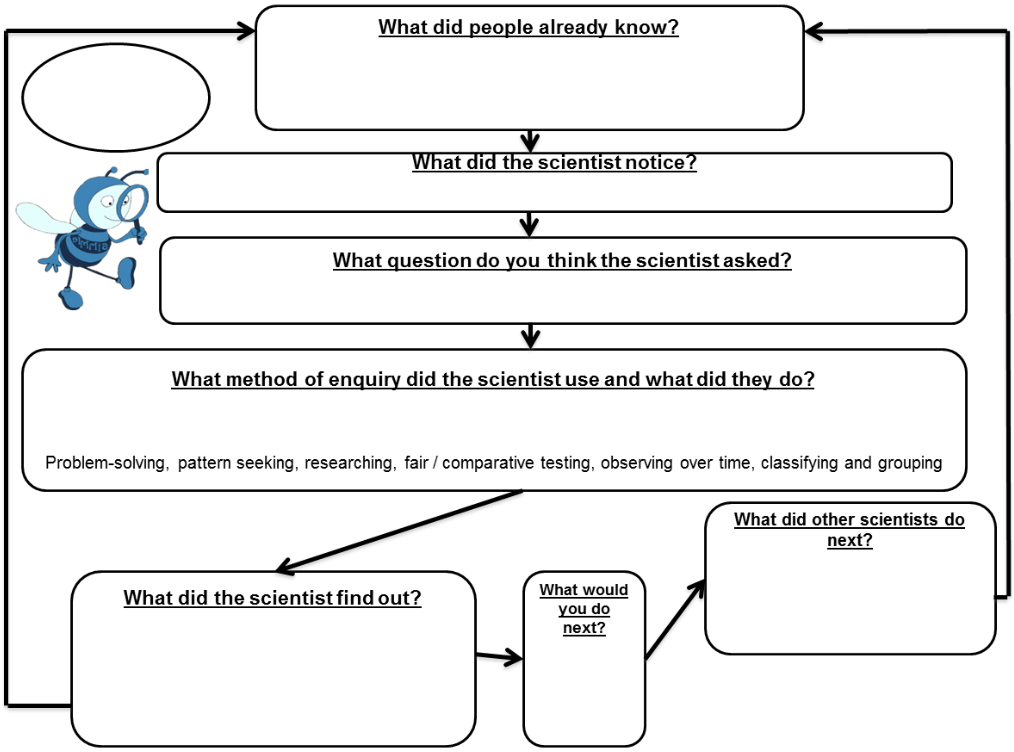


Figure 7.5: Famous scientist template

The template attempts to place the scientist's work in a historical context. The significance of understanding what the scientist found out, while important, is not the purpose of this resource and could be covered prior to this activity or at a later stage. The template starts with elucidating the knowledge that was current at the time the scientist was working (What did people already know?). This is followed by trying to replicate, in a simplified fashion, the process the scientist underwent in coming to their discovery. This includes i) the contrary evidence they identified (What did the scientist notice?), ii) which provoked them to ask a testable question (What question do you think the scientist asked?), iii) the method of scientific enquiry they used to answer their question (What method of scientific enquiry did the scientist use and what did they do?) and finally iv) what they learnt from their research (What did the scientist find out?). An example of a completed template for Charles Macintosh can be found in Appendix 10.

To demonstrate that knowledge is not static and the scientific discovery did not signify an end-point, the user of the template is challenged to consider what further questions they may want to ask and research (What would you do next?). They are then targeted with researching how the scientist's ideas have been developed subsequently (What did other scientists do next?). The arrows cycling to the top of the template have deliberately been included to show that scientific discoveries only lead to generating further questions. It is an attempt to demonstrate that 'what the scientist found out' becomes the current context for future rounds of scientific enquiry and therefore is the new ‘what people already knew’. The hope is that this will promote a study of current science and modern scientists. The justification for studying contemporary scientists, in addition to highlighting the science they may be carrying out, will be made below in Section 7.5.

In order to ascertain the effectiveness of this approach I used this template with the second group of students during Cycle 2. They were asked to complete it for two of the named scientists in the National Curriculum (DfE 2013); Charles Macintosh and Mary Anning. In particular I will draw upon data provided by one student concerning how the session had influenced her. She was exceptionally vocal regarding how her views about scientific knowledge had been challenged. In order to capture this I asked her via email (Sinclair 2017a) the following; ‘would you mind writing a couple of sentences/paragraph/book outlining your thoughts about the lecture?’ Her response was as follows;

> Science is an evolving subject, with new knowledge constantly being discovered and researched. This is true, but I only fully understood the meaning of this after a science lecture as part of my Primary Education degree. When discussing the impact of well known scientists and how we might use them to give context to our teaching, I realised that I had been thinking of science as ‘finished’ in a sense. When you asked the question “who thinks the science we teach now will be the same in 50 years?” I put my hand up, not really thinking about the gravity of this. I was always taught science as fact, and never asked to question it or be critical. This lecture made me see that the science we teach now is not the science we will be teaching in 10, 20 or 30 years’ time.
>
> (Davey 2017a)

I suggest that the whole session, not only the use of the template, had started to change her perception of the nature of science. The evidence for this shift in the student’s thinking was further reinforced when she asked me to observe her teaching science in her final teaching placement of the course. It should be noted that she was under no obligation to do this and that, understandably, students are often anxious to teach in front of others, especially their lecturers. This student wanted to use the template with her class to further the children’s understanding.

> I've planned a lesson looking into different scientists who contributed to our understanding of electricity and what happened next. It should be quite collaborative and interesting.
>
> (email correspondence; Davey 2017b)

Please note that for ethical reasons I am unable to comment on the lesson or the work the children produced.

In tandem with sharing this work with the students, an article summarising the premise behind this work was written and subsequently published in a practical journal for primary school teachers (Sinclair & Strachan 2016). Following this I received a number of emails from practising primary school teachers highlighting how this article had influenced them and which provided further evidence that this approach has the potential to promote a particular view of science. The following is from one of those teachers;

> I think the idea of looking at where a famous (or current but not necessarily famous) scientist's work fits with the work of others at the same time is a great idea and should help the children to begin to see how scientific ideas change over time. (It also raises the idea that what we think is true now might not be accepted as true in the future which I think is tricky but worth dropping in there.)
>
> (Chilvers 2017)

A colleague who works at two other teacher training institutions also used these resources with her starting teachers. Her initial feedback, with one set of students, was that it provided a format which helped them to focus on the science practices rather than the life story of the scientist. She used the same resources with another set of students and, again felt that they understood the same purpose. Four groups within this cohort of students undertook this activity and were asked to provide written feedback about their session. All groups felt that the structure was useful for them as teachers. One group also highlighted a concern mentioned previously in this chapter. This was a worry about the lack of science training some primary teachers may have had and the impact this could potentially have on their understanding of the nature of science. They suggested that this template provided a framework for those teachers in this position and commented;

> Good to have some structure to follow as NQT/teacher with limited scientific knowledge.
>
> (Group 3, PGCE Students feedback)

Perhaps the most gratifying feedback comes in relation to promoting the transformative nature of scientific enquiry which was the purpose for producing these materials;

> Good to look at what came before and after the scientist’s discovery/invention so that we can show children that science is constantly evolving, and they can be part of those future discoveries
>
> (Group 2, PGCE Students feedback)

I believe I have provided evidence from a range of sources regarding whether this specific resource had influenced others’ opinions about the nature of science. In addition to this I felt that it was important to establish whether working with the colleague who had helped to produce these resources had had any effect on how she viewed science. For this reason I asked the following question via email;

> Is there anything I have done, said, values I may have adopted etc, etc that has influenced (ie strengthened/changed) your view about science in general, science in school and science teacher education?
>
> (Sinclair 2017b)

Despite this chapter not focussing on the mutualistic aspect of my pedagogy, she highlighted aspects of my practice which were articulated in Chapter 5. She noted that; "firstly, he has demonstrated to me the importance of collaboration – the importance of talking ideas through and seeing things from different perspectives," (Email correspondence; Strachan 2017). I trust that the collaborative manner in which she noted how we worked suggests that I was not coercing her to adopt my ideas and values. I believe this demonstrates that this aspect of my pedagogy had remained unchanged through Cycles 1 and 2.

I also provide the following as evidence that I challenged the way she thought in some aspects of her practice, in particular how she interpreted a curriculum. She wrote that;

> Working with Alex has certainly been a steep (often uncomfortable) learning curve. Certainly from a curriculum perspective, Alex has enabled me to realise that every tiny statement in the curriculum may be interpreted slightly differently by different people….that the curriculum we deliver is neither black or white, or embraced in the same way by all. Frustratingly, being a person who likes to tick boxes and complete to do lists, this has made me stop in my tracks and question what the science curriculum's intentions are.
>
> (Strachan 2017)

While she proposed that I had not changed her understanding of uncertainty within science she did note that I had influenced her regarding how it could be located in her practice. She stated;

> In relation to uncertainty, I think my own understanding has been solidified, but I suppose what has changed is the awareness of how the science curriculum can be a potential vehicle to demonstrate the dynamic nature of science.
>
> (Strachan 2017)

7.6 Moving away from the stereotypical representation of a scientist

The following section returns to using the template in conjunction with the scientists named in the National Curriculum (DfE 2013). It highlights the potential problem concerned with this approach related to promoting the stereotypical view of a scientist. Research has suggested that some teachers and schools have felt limited solely to studying the scientists mentioned in the National Curriculum (Sinclair & Strachan 2015).

While I recognise that these scientists have been included because of the significance of their discoveries, the dominant characteristics of this group are that they are white, western males, most of whom are dead. If only these scientists are studied there is the implicit promotion of a certain set of characteristics required to be a scientist. Having produced this resource and modelled it with the students I presented it at conferences for teachers in schools. As a way of publicising this I tweeted an activity which was carried out during the presentation. This required attendees to name the scientists within the National Curriculum (DfE 2013) from photographs and drawings.

Figure 7.6: Tweet to publicise conference presentation

The purpose of this activity was to alert attendees to the scientists which are recommended to be studied and, as a consequence, highlighting the stereotyped composition of this group. Understandably, without this information, it appeared as if I was promoting a particular view of a scientist. This was observed by a female scientist on Twitter who responded in the following manner;

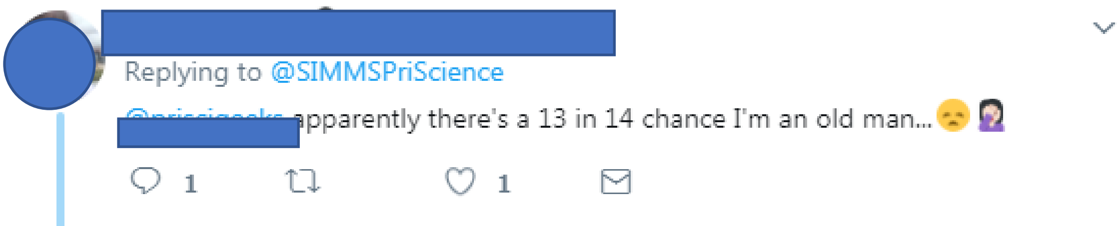


Figure 7.7: Tweet response

Research as far back as 1983 by Chambers demonstrated that children aged 11 held strongly stereotypical views when asked to draw a scientist. While Miller, Nolla, Eagly and Uttal (2018) have shown that, while there is now a greater tendency (at least in the United States) to draw female scientists than in the past, the language used to describe scientists is still negative or stereotyped (Plaister & Hamer 2016). Perceptions amongst students also demonstrate that little appears to have changed. One of the first session activities in which all my students partake also requires them to draw a scientist. The majority conform and replicate this stereotype. This is borne out by writing from the science specialist students from Cycle 2. This group were tasked with composing an article for a primary science teaching journal which outlined their science learning experiences on their three year degree programme. They reflected upon the activity from their first session and noted that; "without exception we drew an old man with wild hair, glasses, wearing a lab coat and holding a beaker with exploding chemicals," (Cain et al. 2017 p. 148).

While I do not argue about the inclusion of those scientists suggested for study within the National Curriculum (DfE 2013), it is worrying that there is no reference to more contemporary scientists. The study of a diverse array of scientists from differing cultures, with different ethnicities, ages and genders may go some way in challenging this stereotypical view of a scientist. Research suggests (Sinclair & Strachan 2015) that a large proportion of schools (50% of those surveyed) currently only study the scientists outlined in the National Curriculum (DfE ibid) who fall within the male, white and dead category. While it is encouraging that the others are not sticking rigidly to this list, it is also disappointing that few are including current scientists. Those schools that did, mainly limited their focus to a small number of particularly well-known scientists which included Brian Cox, Tim Peake and Stephen Hawking.

One of the additional purposes of the template (see fig. 7.5), therefore, is to help provide an association between a famous scientist (who may well conform to the scientist stereotype) with a contemporary one (who may display a range of diverse characteristics). Parker (2018) stresses that for a deepened understanding of the nature of science that the work of these contemporary scientists is studied. This was the reason for including the section in the template which poses the question 'what did other scientists do next?'

The following slide from a presentation given to the students about the process outlines this:

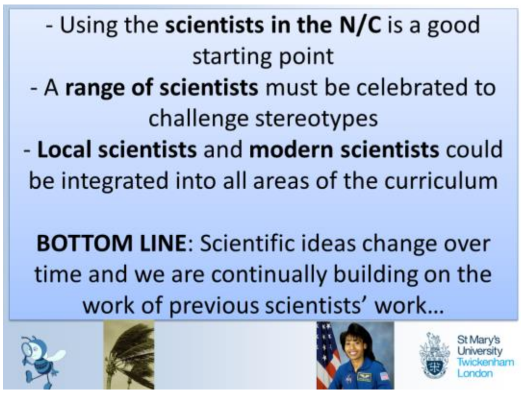


Figure 7.8: Slide 16, Famous scientist presentation to students in Cycle 2; Appendix 11

While no data was produced by the students to suggest that working with the template had influenced their thinking about how they felt using scientists, I provide the following email to suggest its usefulness for teachers. The e-mail correspondence comes from a teacher who read the article pertaining to this work. She highlighted that she would be using the template in future work with her children about scientists, noting,

> I am currently working on a lesson for year 5 on scientists and I really like the flowchart (template) in the article so I think something like that might have to feature in there somewhere. I think the idea of looking at where a famous (or current but not necessarily famous) scientist's work fits with the work of others at the same time is a great idea…I introduced the children to some of my favourite female scientists. Even though the children are very used to the idea that I used to be a scientist there was definitely an expectation that as I showed them each picture that it was a) going to be male and b) going to be Einstein. They were quite surprised when it was neither.
>
> (Chilvers 2017)

7.7 Not just a resource - how else did I promote an ecological perspective to my pedagogy?

The previous sections have focussed specifically on the resource I produced to help teach about the transformational nature of science knowledge. The following attends to how I have taught in a manner which promoted an understanding of the relational nature of science and the science curriculum. It will suggest that this currently manifests itself in a number of different ways, especially through the approach I advocate that starting teachers adopt when carrying out scientific enquiry with their children. This philosophy suggests in order to cultivate ecological epistemologies, which show an appreciation of the transformative nature of knowledge, that these enquiries should not signify an end point.

The first piece of evidence for this comes from the section of the template which asks; "what would you do next?" The slide from the same presentation details 4 questions of which the fourth is the most important to this approach:

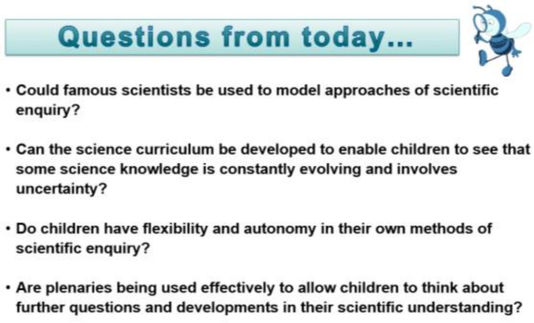


Figure 7.9: Slide 18, Famous scientist presentation to students in Cycle 2; Appendix 11

The statement which questions whether student teachers and teachers have given children the opportunity to ask further questions after they have carried out a scientific enquiry is at the heart of my ecological pedagogy. This overarching theme is raised in the first session I spend with the students. The final slide for this presentation displays a Tweet from David Attenborough. This Tweet was in response to asking why he was so fascinated with studying dinosaurs. He displays what I consider to be an ecological epistemology, in that he has expressed the need to keep on asking questions.

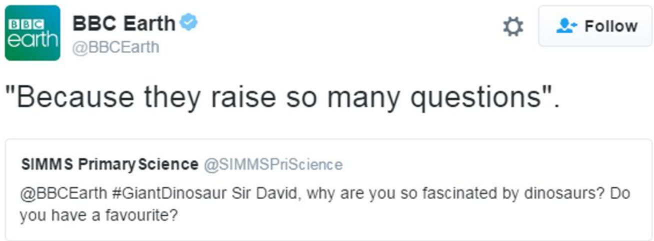


Figure 7.10: Tweet from David Attenborough

As has been mentioned previously, one of my roles is to help the students to interpret the statements outlined in the National Curriculum (DfE 2013) so they gain clarity around how they might appear in their practices in the primary classroom. One of the three aims of the National Curriculum is to; "develop understanding of the nature, processes and methods of science through different types of science enquiries that help them (children) to answer scientific questions about the world around them," (DfE ibid, p. 3). It states that the section; "'Working scientifically' specifies the understanding of the nature, processes and methods of science," (ibid, p. 4). This section outlines what children should be able to achieve through scientific enquiry at each age group. Perhaps most importantly it stipulates it; "must always be taught through and clearly related to substantive science content in the programme of study," (DfE ibid, p. 13).

I appreciate that there is currently debate surrounding the best methods through which children can be taught substantive content knowledge (Kirschner, Sweller & Clark 2006; Hmelo-Silver, Duncan & Chinn 2006), and whether this can be achieved through an enquiry-based approach, but engagement with this debate is not the remit of this thesis. However, my concern about using scientific enquiry to teach substantive content is how it is utilised to demonstrate a point and therefore will be directed by the teacher. It can limit the generation of further questions at the end of the enquiry signalling an end point to that knowledge.

Harlen and Qualter (2014) indicate that one of the benefits of learning science through enquiry is that it helps to support the general development of children's scientific literacy; specifically their understanding of the nature of science. Since Cycle 1 concentrated my attention on this aspect of science education I have subsequently considered how to use the sessions on scientific enquiry with students.

It has been important to produce sessions which help the students to teach substantive content through enquiry as this is a requirement documented by the National Curriculum (DfE 2013). However, Ofsted's (2013) wide-ranging survey into the quality of science across the country noted that this often results in children following a series of instructions devised by the teacher usually accompanied by a worksheet to scaffold the process. They commented that a common weakness in the teaching of enquiry in primary schools was that children were often given limited opportunity to test their own ideas. Teachers were often; "keener to cover the content than to develop pupils as independent, inquisitive young scientists," (Ofsted 2013, p. 14). It is important to note that the Ofsted (ibid) document was produced prior to the current National Curriculum (DfE 2013) which, as highlighted earlier, states that 'working scientifically' (much of which details scientific enquiry) can only be taught through the teaching of substantive science. Should this be strictly adhered to it is difficult to perceive how a scientific enquiry, whose purpose is to teach a specific scientific point, can afford children the opportunity to be inquisitive and ask questions which they can subsequently test. I also argue that this form of enquiry perpetuates the myth about science that it can always provide answers to questions and that these are not subject to change. The dichotomy lies behind the purpose of scientific enquiry in schools. I question whether it is being used to teach substantive content, the nature of science and whether these two are mutually exclusive.

My underlying philosophy of science education, grounded in my ecological approach, is that children or the students should not perceive that a scientific enquiry has an end point. As with science in the real world any discovery should stimulate further questions. To promote an understanding of the transformative nature of knowledge I concur with Firestein (2012, p. 175) who states that; "we must teach students how to think in questions, how to manage ignorance.” This is a shift from what the National Curriculum (DfE 2013) demands, and in my opinion, requires asking open-ended questions which probably will not lead to a developed understanding of substantive content. The following will provide evidence for how I have promoted this approach to enquiry with the students in the hope that they will adopt it in schools. Evidence of how this thinking has materialised in my practice can be seen in a session on ‘working scientifically’ which I have produced. The students were tasked with answering the question; “what makes the best bubble?” While I argue that this enquiry could be employed when teaching the Chemistry sections of the National Curriculum (DfE ibid), and in particular those about studying materials, I do not believe it teaches substantive content about bubbles. After the students had carried out this enquiry they were asked; a) what they found out and b) what further questions they would like to investigate. Following the practical work, a discussion was held about how open-ended questions, provided by the teacher, could promote further scientific enquiries. This is only one example from the many enquiries they undertook throughout their course.

The following excerpts have come from the article that the students from Cycle 2 composed (Cain et al. 2017). This text provides a group reflection of their learning on the primary science course. I use this as evidence to suggest that I have influenced how they perceive science and science education in particular in relation to science enquiry. While they discuss many issues in this article the recurring theme is about giving children the opportunity to ask questions. I hope that the experiences gained working in this open-ended manner gave the students confidence to adopt this approach in their practice which is often not seen in the primary classroom (Correia 2017).

They recalled the first lecture which explored their current views on science and science teaching. They stated that; “the general consensus was that science is about learning facts and in order to be good at the subject you need to be able to recall specific facts,” (Cain et al. 2017 p. 147). They noted that their time on the course had helped them to define their individual ethos in direct relation to their previous experiences. They charted this as a group in the following way;

> We all found that we shifted from our original focus of subject knowledge to one that promoted curiosity and autonomy within a framework of open investigations. We want children to ask and answer their own questions and feel it is important to encourage an approach where it is acceptable to make mistakes and be wrong.
>
> We feel much more comfortable admitting that we do not have the answers to all scientific questions. If we are encouraging children to be content that they can make mistakes we should be leading by example. In fact, we found that when we did not know an answer that this often maintained the curiosity of the children. We made a point of getting children to ask as many questions as possible, even though we knew that we may not have all the answers. (Cain et al. 2017 p. 148)

7.8 Chapter summary

This chapter has analysed a range of data produced between Cycle 1 and during Cycle 2 to show the transformation of my thinking in that time and, in particular, to demonstrate my recognition that science is a relational and therefore ecological process.

I generated evidence to suggest the influence that thinking in an ecological manner had on my practice. In particular it demonstrated my focus on a specific aspect of my pedagogy, the promotion of the transformative and generative nature of science, which I have explained became the primary emphasis of this cycle.

I detailed how this resulted in the production of certain materials which I have tentatively suggested have helped those using them to gain a greater appreciation of how some scientific ideas change over time. In addition to this I highlighted the types of open-ended enquiry-based activities that I provided for the students. I did this to demonstrate how these forms of enquiries could be used to promote transformational epistemologies.

The chapter has detailed a further development in establishing an ecological approach to science teacher education. I recognise that during this cycle I did not attend to issues relating to planetary well-being as I believed that I could develop the desired ecological epistemologies solely through the objectives from the science National Curriculum (DfE 2013). Nor did I promote the other aspects of an ecological view of science which I elaborated on in Chapter 2. The following chapter attempts to address these omissions. It will detail how my ideas have changed as a consequence of Cycle 2 and state my current understanding of what an ecological approach to my practice should entail.

Chapter 8. Moving Towards an Ecological Approach to my Practice

8.1 Introduction

The following chapter will outline the findings that have already been explicated in the preceding writing. It will detail the continual critical learning I have undertaken in coming to my claim that I have developed an ecological approach to science teacher education. I appreciate that, in providing a justification for my actions during Cycle 2, many of the findings have already been expressed throughout Chapters 5-7. For the purposes of clarity I will first provide a concise summary of these findings before I then go on to explore what I have learnt from Cycle 2. Following this I will summarise the findings from the whole research process and, in doing so, make tentative suggestions about what my future ecological practice might entail.

8.2 Summary of findings from Cycle 1

The summary is as follows:

1. The students had an interest in learning about issues relating to sustainability and most could express the actions that I had taken to develop my mutualistic practice which had ensured that they felt I had not imposed my views upon them;
2. The students interviewed could articulate that my teaching approach was premised upon developing mutual respect and expressed they felt confident to voice their own beliefs without fear of ridicule by me or other members of the group. Consequently they confirmed that this generated a community of learners who valued and learned from each other;
3. Many of the learning strategies undertaken by the students had been included to raise awareness about planetary issues or could be used by them as activities to teach about sustainability;
4. Personal critical evaluation identified the relative lack of success of this approach in improving planetary well-being. An interrogation into why this may have been the case helped me to question the epistemological foundations upon which my practice was established. It was at this point that I recognised that knowledge generated through Newtonian science was the dominant and primary epistemological discourse which had infiltrated every aspect of my life and practice including the forms of learning I had offered the students;

5. Consequently I understood that the ideas I had been engaging with about Newtonian and ecological approaches to science were epistemologically derived. I appreciated they were not confined solely to science but related to knowledge and knowledge generation in general;
6. My understanding that my perception of science was parallel with my view about knowledge led me to explore whether I could develop ecological epistemologies by developing an understanding of the relational, and therefore ecological, nature of science. As a result of this I identified three interrelated aims which I felt would help to demonstrate that science was an ecological process. By promoting science in this manner I hoped that it would develop the ecological epistemologies I now recognised as necessary for planetary well-being. These aims were to help students to:

    - develop an understanding of the relational nature of scientific ideas;
    - develop an understanding of the temporal and transformational nature of relationships in science;
    - develop an understanding of the symbiotic relationship humans have with the planet and those that share it.

8.3 Findings from Cycle 2

I now attend to the learning that took place after Cycle 2 and will therefore outline the findings in relation to my learning from this cycle. Understandably this learning has also helped to redefine my understanding of what occurred in Cycle 1.

8.3.1 My feelings of guilt were unfounded

I now appreciate that work with the students from Cycle 2 (and the others mentioned in Chapter 7) predominantly focussed on using a resource I had developed about famous scientists as a way to develop only one aspect of an ecological way of thinking; to develop an understanding of the temporal and transformational nature of relationships in science. I have already explained that this approach did not require me to attend to any contentious issues surrounding planetary well-being and articulate or test the validity of my beliefs about them. I have previously outlined that this was one of the reasons for the prevalent feeling of tension throughout the research process.

However, it is only now that I recognise that the disclosure of my beliefs during Cycle 1 was only partial and not particularly controversial. While I explained in the initial presentation that I had major concerns over planetary well-being I gave little detail regarding what these were.

I also did not offer opportunities for the students to discuss the complex and uncertain nature of those concerns. This uncertainty is exemplified by Hulme (2009). He specifically makes reference to climate change but I suggest that this is the same for most complex planetary issues. He proposes that there will never be consensus about what should be done to mitigate the effects of global warming.

Subsequently I identified that during Cycle 1 I only offered one opportunity for the students to engage in discussions about such uncertain issues. This occurred in Session 6 following a visit to the local river. The students had been informed of the decision to flood the river with sewage rather than the Heathrow runway, resulting in the destruction of most of the life it contained. I allowed for discussion about this topic and stated my belief that I thought the decision was incorrect (this was detailed in Chapter 5). It is engagement with topics areas where there is no correct answer, and the subsequent disclosure of my beliefs about such controversial issues, that I believe was predominantly missing throughout Cycle 1 (and therefore Cycle 2) and which should have been planned for. This approach, as Hess (2005, p. 48) states was the; "selection of controversial issues that [didn't] don't actually spark a lot of controversy." It is for this reason I now suggest that my feelings of guilt about introducing controversial ideas about planetary well-being were largely unfounded.

8.3.2 Meeting student expectations based on the premise that they were 'having' students.

I also recognise that the strategy of using famous scientists in a manner which was unequivocally related to one of the statements from the National Curriculum (DfE 2013) guaranteed that I matched, what I now understand to be, the dual aims of my practice. The first aim was to ensure that the students' expectations of the course were met by preparing the students to teach in schools. The second, which was reassuring to me, was that I was helping them to develop ecological epistemologies.

Perhaps the most important learning from this is the identification that the tacit desire to ensure the course matched the students' expectations. I appreciate now that meeting these expectations was one way I demonstrated how my value of mutual respect was being realised in practice. I have suggested that Buber's ideas (1947, 1958) relating to educational relationships have helped to articulate my understanding of a mutualistic practice and that I have used this as a framework for analysing whether my value of mutual respect had been lived out; of note here is one particular aspect of this practice; that the students' needs were met. I now appreciate that my teaching about planetary issues was not as radical as I may have first thought. I understand that my practice has been tempered by the underlying tenet that in order to develop mutual respect I had to ensure that the students felt that their needs had been met. I suggest this is an example of how my value of mutual respect was reflected in my practice and therefore provided an integrity to everything I did (Ghaye 2010). It is important that this aspect of my practice is documented as it has major implications for any planning I undertake in the future.

I also suggest that I assumed I could make predictions about the students' expectations for the course and that these would be the same for the whole group. Despite appreciating Gregoire's (2003) argument that teacher education should be about helping training teachers to challenge and redefine their initial beliefs I had assumed that the students from Cycle 2 would be interested only in 'Top 10 Teaching Tips' and had wrongly classified the whole group as operating as Fromm's (1979) 'having' students. This was also regardless of the views made by students from Cycle 1 who had demonstrated otherwise. Responding to the writing I showed them where I had labelled many of my students as 'being' (Fromm ibid) Samantha and Francesca commented that;

> …this make us sound a little more passive than we actually are.
>
> (Francesca, Chapter Critique – Session 7)
>
> The NC tells us what to teach, but not how, and it is our responsibility to "fill the gaps" so appears to be beyond spoon feeding and top ten tips!
>
> (Samantha, Chapter Critique – Session 7)

8.3.3 More assumptions

In addition to my assumption that the students would be operating as 'having' students was my uncritical analysis of the module aims for Cycle 1 (Module title: QP344) and 2 (Module title: PEQ6044). The module aims for both courses were as follows;

> This module aims to consolidate students' understanding of the pedagogical issues related to the teaching and learning of science in the primary classroom and subject knowledge and understanding to a standard appropriate to a subject leader / learning manager.
>
> (QP344 Module Handbook, p.1; PEQ6044 Module Handbook, p.1)

It is only now that I can appreciate that these aims could be classified using Stenhouse's (1975) term as educational intentions. These intentions were not short-term, quantifiable objectives, as can be found in most secondary school syllabuses. It is important to revisit Kelly's (2009) claim that all curriculum planning is founded upon an ideological viewpoint and therefore a particular epistemological stance and I argue these aims were subjective in nature and open to interpretation. While I appreciate that my experience in schools placed me in a position of authority regarding how best these aims could be achieved I had never examined their uncertain and problematic nature. I now recognise that I was unquestioningly making decisions about what constituted an appropriate standard of a subject leader and how consolidation of a student's understanding of teaching and learning in primary science might manifest itself in my practice.

I suggest that these vague overarching aims meant that the choice of content and the manner in which it was taught was not specified. I appreciate that this allowed for flexibility and personalisation of the modules I taught even before I started this research. It is only now that I realise it was this autonomy which afforded me the opportunity to develop the curriculum for ecoliteracy during Cycle 1 and in helping develop ecological epistemologies during Cycle 2 and this probably would not have been possible in a school setting.

I have already written about my concerns of imposing my values and beliefs and whether this was commensurate with the values that informed my mutualistic practice. However, I now suggest that by explicitly articulating my values to the students and the process of negotiating a curriculum which would best serve their needs was, in fact, a transparent and equitable manner of working. While I appreciate Macfarlane's (2004) concern that disclosure of personal information and values could be a deliberate or inadvertent misuse of power over students I have concerns, as do Brockbank and McGill (1998), that covering up personal ideals is inauthentic and that they will eventually be revealed in the course of teaching. I suggest that my mutualistic practice demonstrates how it is possible to share personal beliefs without indoctrination or coercion.

In Chapter 2 I referred to my approach with the students as 'committed impartiality' (Kelly 1986) and outlined that I would make explicit my views while ensuring that these beliefs were not imposed upon the students. I have provided evidence in Chapter 5 that this attitude towards learning was appreciated by the students and at no time did they feel they were being forced to adopt a particular viewpoint.

I now appreciate Dewey's (1916) call for an effective authority; not one that neglects experiences but one that questions how this authority manifests itself in practice. I suggest that the structured freedom afforded myself in electing module content placed me in a position of great decision-making power and that; "with great power comes great responsibility," (Lee 1962). However, I concur with Nixon who proposes that often the academic practitioner is an; "operative and not a decision maker," (Nixon 2008, p. 29). By this I infer that module content can be chosen by academic practitioners unquestioningly and with limited critical engagement, resulting in a curriculum being presented as absolute and without challenge. I suggest that, by entering into personal and professional debates around curriculum and through the theorisation of my practice (McNiff 2013), I was able to explain explicitly my value system and how it was evinced in a way that was appropriate for the group of students from Cycle 1. While at this point I was not aware of Stenhouse's (1975) idea of a process curriculum, I recognise that the principles that underpin this form of curriculum can now provide an initial framework for my future practice and other practitioners who wish to adopt this approach. I propose that this form of curriculum is premised on the negotiation between practitioner and students of what is of value and worth to both. The process of negotiation helps to define the curriculum and the curriculum consequently becomes the process.

8.3.4 Time was a factor

Time is clearly an issue for developing the forms of relationships I have discussed and therefore in mediating a curriculum. I have previously highlighted the fact that students from Cycle 1 were chosen because their course spanned two academic years. I recognised that to develop the mutualistic relationships I was espousing required extended experience of working together. Ghaye (2010) suggests it should be obvious to those that observe us what our value systems are. In Chapter 5 I provided many examples of students from Cycle 1 who were able to do this and articulate the manner in which I worked; they were explicit that my practice was premised upon developing mutual respect. While I did not formally provide opportunities for the students in Cycle 2 to express their opinions I am doubtful that they would have been able to identify these traits after only five teaching sessions.

In addition to this I have also noted that I had been working with the students from Cycle 1 for three months before I introduced the seemingly radical suggestion of developing a curriculum for ecoliteracy. I argue that during this time trust had been developed between the students and me and they were aware that I understood their needs.

I have detailed in Chapter 5 how I believed I met these needs through an interplay between sessions which focussed on issues regarding planetary well-being and those founded upon more established classroom-based activities. Importantly this was recognised by Samantha who suggested the curriculum for ecoliteracy had; "been a very good focus for the two years. It has been something that we have gone away from and come back to," (Samantha, End of Course Interview 3). I question whether I would have been able to contend with this during the five session experience during Cycle 2. Furthermore, I have doubts whether a course with such limited time, however focussed, is likely to change the entrenched Newtonian epistemologies which Russell (1956) proposed have been accepted as common sense. Issues related to this will be developed below.

I have explained that it has been my aim to help the students develop ecological epistemologies. In Chapter 7 I provided evidence for the radical epistemological shift and the lengthy process I underwent in coming to think in an ecological manner. At this point it will be useful to detail the difficulties I faced regarding this transformation and question whether it is possible to achieve in either a five session course or even with one that spans two years.

8.3.5 Developing my ecological epistemology

The focus of critically examining my pedagogy has been an intensive and often uncomfortable experience and the radical shift from a Newtonian to an ecological way of thinking has been a prolonged and protracted experience. I maintain that this thesis contains evidence of what this years-long process has involved.

It is difficult to perceive how students will gain continued and committed opportunities to engage with such issues in the current education system. While Reason (1998, p. 154) has argued that; “a fundamental human capacity is the ability to inquire into and make sense of our world,” he signals that to achieve this it requires a; “loving and liberating education.” I have been fortunate enough to have received this form of education and support during my Masters and doctoral studies but I suggest this is not the norm either in many schools or in higher education institutions.

I recognise therefore that any suggestions concerning a critical examination of one’s practice may be regarded as alien by students and therefore rejected without critical consideration. This is corroborated by Elliott (2007) who worked with teachers in reconceptualising their views of pedagogy and curriculum. It transpired that despite having clear pedagogical aims to follow, and a desire to change, the teachers’ established practices continued to be reproduced founded upon old pedagogical frameworks. Despite four years developing my capacity for criticality during Masters studies it is evident that my views of epistemology had remained relatively unchanged (Sinclair 2010). In Chapter 3 I introduced the terms ‘superficial’ and ‘efficient’ to describe the forms of reflection I undertook throughout this process. Dewey (1933), Habermas (1976) and Mezirow (1991) do not recognise the ‘superficial’ reflection I carried out during Masters studies, which did not; “assess[ing] the grounds of one’s beliefs.” However, I have previously argued that this is a necessary first step.

In addition to the lack of a specific nurturing form of education which encourages and develops criticality (Reason 1998), Bourdieu (1971) describes the difficulty of interrogating one’s practice using the same form of logic that has defined it. He notes that this is because; "patterns of thought which organise reality by directing and organising thinking about reality and makes what he [sic] thinks thinkable for him as such and in the particular form in which it is thought," (ibid, pp. 194-195). I believe Kuhn's (2012) theory of science progression can also explain the difficulties of reframing one's worldview. My tacit resistance to new ideas represents an era of 'normal science' whereby cognitive differences are assimilated and explained within the current way of thinking. Only through prolonged periods of cognitive dissonance and exposure to alternative ways of thinking can an epistemological paradigmatic shift occur. Palmer and Zajonc (2010, p. 37) express similar experiences to mine when they discuss their transitions from academic life to work in the community. They comment on how their academic work had inculcated a way of knowing which produced; "purity obsession," and "objectivist intellectual habits." They then describe the time and cognitive demand required to unlearn these ways of working.

8.3.6 Difficulties facing the students

The previous section (and indeed this entire thesis) has outlined the difficulties I faced while transforming my worldview. I will now address concerns about how realisable helping students to undertake the same process is.

I propose that in Cycle 1 my mutualistic practice provided the; "loving and liberating," environment which Reason (1998, p. 154) argues is necessary for a critical evaluation of one's worldview. Yet I also accept, despite this, that there was limited success in helping the students to develop ecological epistemologies; I have written in Chapter 6 about this and suggested it was because of my adherence to a Newtonian way of thinking.

I appreciate Orr's (1992) insistence that the manner in which education proceeds is as important as its content. I recognise that during Cycle 1 I was promoting the type of educational experiences which he suggests are necessary to develop ecoliteracy yet understand that I had not been epistemologically ready to include the relevant content. I propose that I am now in the position to provide both through an ecological approach to science education but question the influence an isolated course can have against the back drop of students' other experiences. Sterling (2001, p. 32) notes that; "education for change is often outweighed by the larger education system which enacts vocational or socialising roles." I am reminded of Kahn's (2010) and Sterling's (2001) claims that, as yet, the field of environmental education has not been able to produce solutions for the planet's crisis and that it is unlikely to be able to within the currently dominant mechanistic form of education.

I suggest that my ecological approach to science teacher education which promotes an understanding of the relational nature of knowledge and which is premised upon the qualitative aspect of developing respect, reflects Sterling's (2001, p. 22) idea of a; "changed educational paradigm." However I am also cognisant that despite this my students' other, and predominant, educational experiences will be; "in a setting that does not alter their relationship to basic life-support of systems [and they] learn that it is sufficient to intellectualise, emote or posture about such things without having to live differently," (Orr 1992, p. 92).

While the influence of my teaching, or lack of, on future students is a concern I am buoyed by Schumacher's (1977, p. 140) call to; "leave these perplexities behind us and get down to work," and return to my claim at the start of this thesis when I identified that by engaging with debates and practices around these issues that I wanted to be; "part of the solution rather than part of the problem," (Whitefield 2004, p. no page). The following section will identify aspects of an ecological approach to science teacher education that were missing during Cycle 2 and which provide further educational directions for my future practice.

8.3.7 Cycle 2 - one facet of an ecological approach to science teacher education

In Chapter 7 I detailed that the focus of my practice was predominantly on one aspect of an ecological approach to science teacher education; that is helping the students to appreciate that scientific ideas can transform over time. I suggest it was a number of interrelated reasons which resulted in this facet becoming the main emphasis of my practice both with the students from Cycle 2 and other members of the primary science teaching community.

I am aware that the paucity of sessions in Cycle 2 may have been one reason for this. With a requirement within the module to ensure that I had also included the 'nuts and bolts' of teaching (Rudduck 1991) this left little time to develop other areas of my ecological approach. I have also suggested previously that gaining an understanding of the transformational aspect of science has been one of my greatest learning points from this research and may have influenced this temporary fixation. In addition to this, the articles (for example; Sinclair & Strachan 2016) and resources produced as a result of this work were being positively received by the primary science community.

I have demonstrated that the persistent self-critique of my thinking and the subsequent development of ideas has given rise to a constantly evolving thesis which is analogous to Stenhouse's (1975) idea of a developmental curriculum. This has resulted in the thesis being continually updated in draft in light of new insights. Throughout this work I have repeatedly championed the need to foster this transformational and cyclical approach which is a common feature of most action enquiries. However, I have started to ask questions regarding the benefit of remaining in a state of continual flux and wonder if the consolidation of this one aspect may have been a reaction to this uncertain condition.

While inquiring whether there is ever a need for consolidation I have also taken comfort in Polanyi's (1958) call for 'dogmatism'. This may initially appear at odds with his insistence for the need to demonstrate self-critique and criticality, especially when he declares that; "the possibility of error is a necessary element of any belief bearing on reality," (Polanyi ibid, p. 332). However, I believe that Polanyi's 'dogmatism' is not at odds with this viewpoint and is methodological in nature. It is a suggestion that one should justify and demonstrate commitment to one's ideas. There are, again, parallels with Kuhn's views on scientific progress (2012). Perhaps Polanyi's appeal for 'dogmatism' is actually a call for a period of normal science which provides space for consolidation and the time to embed new ideas. This dogmatism however must be tempered with the need to be sceptical and modest in light of possible, and maybe probable, error.

In addition to providing a possible suggestion for my actions in Cycle 2 I also suggest that this dogmatic stance provides grounding for the problems posed by the continual and transformational nature of the whole thesis. This thesis therefore is an articulation of my current thinking and thus provides the temporary 'dogmatism' and commitment to my ideas that Polanyi (1958) suggests is part of a process of enquiry. This is not to suggest that there is no longer an obligation for me to be self-critical but that there may be a need for a period of time for consolidation so I can feel in a position of authority defending my viewpoints against others' potential scepticism.

The following section now attends to the need to consolidate my work and I will summarise my findings and suggest how an ecological approach to science teacher education might manifest itself in my future practice.

8.4 A period of consolidation - a summary of my findings

The following summary section will articulate my current understanding of what an ecological approach to science teacher education might entail. In doing so I will aim to outline a unified pedagogical approach which brings together the subject content I might chose to teach, and the manner in which I will aim to do this; all of which will be mediated through my critical examination of the cultural and political landscape in which my practice and values are embedded.

8.4.1 Only one true claim about an ecological practice

Perhaps the only valid claim I can make about my ecological practice is the need to embrace uncertainty and transformational change mediated by new experiences and learning. This thesis has documented the non-linear and radical change in how I have viewed knowledge and therefore my teaching. It would be folly to believe that similar epistemological changes will not happen in the future. A facet of my mutualistic practice that was respected by the students from Cycle 1 was the honesty by which I expressed my values and ideals. The critical process of generating a theory of my practice (Carr and Kemmis 1986) has helped me to articulate these values and express my teacher identity (Price and McGee 2009). Consequently this process has provided justification for my actions and offered autonomy and empowerment of my professional life. I recognise that without adopting a critically reflective approach to my practice I would be operating in a disingenuous way which Barnett and Hallam (1999) refer to as a silencing pedagogy; the form of pedagogy which does not take into consideration the wider socio-political context in which it is situated.

I mention the need for criticality here because the following suggestions I will make about my ecological practice must be viewed as tentative proposals bearing in mind the changes in my thinking that have already occurred. In addition to this there should be an appreciation that the findings from this thesis have been obtained through work with a unique group of students.

I suggest that Stenhouse's (1975, p. 24) declaration that teacher and curriculum development are synonymous is part of this critical process. I appreciate that the module aims that I work from could be deemed developmental in nature and perceived, as Palmer and Zajonc (2010) do, as a commitment to explore an uncertain, but worthwhile outcome. From this standpoint the curriculum becomes a study into how best to understand the module aims in relation to a specific group of students at a specific moment in time.

8.4.2 Planning for an ecological practice

Importantly James (2012) reports that Stenhouse vehemently argued that a process curriculum does not dismiss the importance of subject content. Stenhouse (1975, p. 25) recommends there is a need for a; "provisional curriculum specification," which details the conditional content that has been identified from the outset. I suggest this was in contrast to my planning during Cycle 1. My interpretation of Stenhouse's (ibid) ideas about curriculum, which was focussed on process rather than structure, was founded upon an insistence that there was no-one size fits all curriculum for ecoliteracy (Barlow & Stone 2005), and my ill-formed understanding of ecoliteracy. It resulted in module sessions which were not well thought out or planned. I now appreciate that any future curriculum must ensure that this detailed and critical planning has been undertaken.

I propose that the articulation of a ‘provisional curriculum specification’ is not the key element but the process which has been undertaken in identifying what is important in meeting the module’s aims. Stenhouse (1975) and Elliott (2007) both highlight that these curricula are developmental in nature because of the teacher’s ongoing evaluation and the subsequent modifications that are made as it is lived out. However, I also argue that this development is initiated at the planning stage through the production of the session outlines for a course. This planning stage provides two benefits for understanding the proposed curriculum. The first is a commitment to analysing and interpreting the aims; had I undertaken this process prior to working with the students from Cycle 1 it may have resulted in my coming to a better understanding of what I valued in my practice at an earlier stage. I have previously expressed that my practice has been driven by two dual aims; to ensure that students’ expectations of the course are met and to help them develop ecological epistemologies. Any future curriculum planning will need to take these into consideration. The second benefit of planning is that it would require an articulation of how each session might help the students to work towards the aims. In order to accomplish this it would be necessary to specify the strategies required to achieve this and in doing so would give me the opportunity to provide a unified pedagogical approach (Alexander 2008); consideration would be given over to session content and the manner in which it was taught and learnt. This would be premised on my understanding that the promotion of relational knowledge can be strengthened through a mutualistic practice.

8.4.3 Content for an ecological practice

The following section details potential aims for any future curriculum that I plan for and the teaching content that could be used as a provisional curriculum specification. As have been observed, these have been transformed from the standards which I used to judge how successful I was in developing ecological epistemologies throughout the two Cycles. I suggest that any learning activity which is chosen with these aims in mind will provide the dual aim of developing the relational epistemologies I have championed while having direct relevance to the students’ teaching of science in the primary classroom.

- To help the students develop an understanding of the relational nature of scientific ideas;
- To help the students to develop an understanding of the temporal and transformational nature of relationships in science;

- To help the students to develop an understanding of the symbiotic relationship they have with the planet and those that share it.

I have detailed in Chapter 2 the type of learning activities which could be used to develop these aims thereby promoting an appreciation that science is an ecological act. For clarity I will summarise them here:

- An incorporation of the ‘big ideas’ of and about science (Harlen 2010) into sessions. This would require the students to gain specific science subject content knowledge alongside an appreciation of how scientific ideas are connected. As the ‘big ideas’ may be too abstract for young children I hope that they will be able to identify learning contexts which provide the foundation for their children to move from the ‘small ideas to the ‘big ideas’ at a later stage;

- Including learning strategies which help to develop the students’ understanding of the nature of science. I have detailed how this could be achieved by studying famous and contemporary scientists and by placing their work in a historical context. In addition to this I have suggested that studying how chosen scientists have worked can help to exemplify the ‘messy’ nature of scientific enquiry and the claim that there is no such thing as the ‘scientific method’ (Feyerabend 2010). I have also proposed that there is a need to cultivate an epistemology of ignorance (Firestein 2012) and have written that this could be promoted through the form of scientific investigations which do not signal an end-point and encourage children to remain curious and ask further questions for study;

- By providing opportunities for students to gain knowledge in context. In Chapter 2 I referred to this contextual knowledge specifically in relation to learning in an out of class setting. While I hope this form of learning may help to dispel the myth that knowledge is gained in an abstract manner and out of context I propose that its primary benefit would be in helping humans to connect physically with their lived environment and therefore gain a better understanding of place (Orr 1992). This reconnection with nature may go some way in helping to develop an ecological worldview (Sobel 2013). Despite an ill-founded commitment to ‘growing’ in Cycle 1 I still suggest that this curriculum theme provides a promising starting point for this. However, I am aware that this is an area of my practice which I need to develop as I fully appreciate that this in itself will not be enough. I need to be mindful of how to cultivate the subjective nature of science learning. Whilst research has shown that many Swedish teachers expressed a strong affiliation to a specific natural environment it also demonstrated that any associated emotional experiences were separated from science learning because of the rational and objective perception of science as a narrowly-focussed discipline (Danielsson, Andersson, Gullberg, Hussénius & Scantlebury 2016);

- Studying the work of Alexander von Humboldt. I have argued that von Humboldt lived by an ecological epistemology and that this was exhibited in the manner in which he conducted his studies. Further research into how his work could be used to exemplify ecological science is something I would also be keen to develop.

I appreciate that there is now a requirement to confront, and include, the potentially contentious issues surrounding planetary well-being; I can no longer hide behind a science curriculum to promote planetary well-being. I acknowledge that currently there is no reference to the issues facing the planet and its inhabitants in the primary National Curriculum (DfE 2013). However, I believe I have demonstrated in Chapter 6 that, despite this, the students were keen to learn about such matters. They noted that it was of relevance and interest to them and the children they would teach. However, I am also mindful that there are differing views between most scientists and members of society. For most in the science community, issues concerning planetary well-being (such as climate change) are not controversial. Borgerding and Dagistan (2018, p. 283) note that anthropogenic climate change is denied by certain members of society and term a collective adherence to this view as; "societally denied science." An understanding that scientific theories are generated through rigorous consensus may also need to be included in any future learning. I have also shown that one of the earlier reasons for not wanting to engage the students with such issues was because of my ill-formed belief that many were operating in the 'having' mode (Fromm 1979); that these students did not have the critical capacity to mediate what I was saying and act as free-thinking individuals and therefore it would not be appropriate to introduce such ideas. However, today I cannot perceive that future students will have dissimilar views or will be any less critical about what is being presented to them. It would seem, then, that the incorporation of learning activities about planetary well-being into future modules, alongside those outlined above, becomes a necessity. Within this framework I also recognise that planetary well-being cannot solely focus on the science related to such matters. Busch (2016, p. 137) highlights that focussing on the science behind issues such as climate, as I did, reinforces the; "dominant Science Discourse." She suggests that there is a need to engage with matters relating to the impact on humans which she terms the; "Social Discourse," and which is more likely to motivate individuals into action.

Perhaps of more importance is the issue that my desire to help the students cultivate ecological epistemologies cannot be separated from gaining an understanding of humans' effect on the planet and the crisis it is now facing. I am aware that I had paradoxically operated in a reductionist manner by excluding these matters during Cycle 2. I suggested in Chapter 2 that reconnecting with nature using activities related to the science curriculum may go some way in developing an understanding of the symbiotic relationship that individuals have with their planet. However, I am now aware it would be imperative to confront the three major crises which Orr (1992) outlines as; the global food crisis, the end of the fossil fuel era, and the issues concerning the planet being used as an infinite resource and waste storage unit.

8.4.4 But how might students learn ecological content?

While Orr (1992, p. 91) has identified that; "the way education occurs is as important as its content," I believe I have argued that the two are synonymous; helping students to develop ecological epistemologies can only materialise if modelled through a relational practice. Despite at the start of Cycle 1 not being able to theorise or articulate my mutualistic practice (McNiff 2013) other than in simple terms I have argued that the students respected the manner in which I worked with them and suggest it was ecological in nature. I hope I have demonstrated in Cycle 1 that the learning was; "grounded in the qualities of relationship rather than product," (Sterling 2001, p. 43). In particular I provided evidence of the types of activities which developed these 'quality' relationships. The students appreciated that these included a balanced blend between teacher input and small and whole-class group work. Students principally appreciated learning from each other's wide range of experiences in addition to mine and this was achieved mainly through discussion. I have argued that this discussion was dialogical (Alexander 2008) primarily because the students expressed that they felt they were not being judged by me or their peers.

It is difficult to identify whether it was any of the explicit strategies I used to engage the students in being critical about their teaching from me which promoted this community feeling. I propose that demonstrating I was a learner alongside them may have been the biggest influence. Identification of further strategies, such as sharing my draft writing with them, however destabilising would be another area for development of my future practice.

I am aware the Learning Logs did not have the anticipated effect, primarily because they were implemented because of my myopic drive to assuage any guilt I was feeling. I have already detailed how this was because of my narrow understanding of the concept of criticality. I do not suggest there would no longer be a need for me to provide students with an opportunity to appraise my teaching but that the remit should be widened to include helping them to uncover their science teacher identities and the social and cultural experiences that have informed them (Bourdieu 1990). Exposure to the ideas I have detailed about ecological science may play a role in this but a greater emphasis on how these identities were formed would also be necessary. I recognise that the production of science teaching metaphors (adapted from James 2013) by the students would be productive in this regard and that this may initiate the identification of what Alexander (2008, p. 3) describes as the; "attendant discourses," around education which he suggests is most often missing when defining pedagogy.

Despite the concerns I raised earlier about developing criticality I suggest this type of strategy is a preliminary phase in the articulation of values and the theorisation of the students' practice (McNiff 2013). At this point I return to insights from Chapter 1 about my time spent in school. I recognised that I was part of what Chomsky (2000, p. 17) calls the; "doctrinal system," and that uncritically I was implementing the normative theories which were set by others and expected of me. This form of passivity and blinkered thinking is not something I wish my future students to experience.

In addition to this I am mindful that those whose practice is being discussed should be able to express their opinion and not have it mediated through others (Foucault 1980). I have suggested that this whole thesis has represented a theorisation of my practice and that this process has provided me with the ability to describe and justify the reasons for my actions and gain a clearer understanding of who I am as a teacher educator. This empowering act has strengthened my professional voice (James 2013) and yielded me the tools and confidence to engage in debates around knowledge and knowledge generation; especially in the field of science and science education.

I recognise that my practice to date has not been specifically about helping my students to theorise their practice and benefit from this personal accountability. I suggest that this was because it was not until the point of writing this thesis that I fully understood the power I gained from theorising, and therefore, justifying my actions. While I modelled some of the processes I underwent while carrying out this first-person research, I appreciate that making many of these processes more explicit could provide greater insights for the students I work with.

8.4.5 A summary of the summary

For the purpose of clarity I will now summarise my findings and by doing so provide a justification for my claim that I have developed an ecological approach to science teacher education:

- My ecological practice is founded upon the continual need to reflect on the actions I take and that I must be willing to make changes to how I work in light of new experiences and evidence;
- That any future curriculum can be viewed as process and that it is through the act of researching my practice, and therefore a curriculum, that I can best ensure that my students receive an educational experience appropriate to themselves;
- The process of explicating the aims for the curriculum and providing a provisional curriculum specification is just as important as the content;
- The aim for a curriculum premised on an ecological approach should encourage students to develop relational epistemologies which can best be achieved through reconceptualising science as an ecological act;
- Ecological science could be promoted by helping the students to appreciate; the relational nature of scientific ideas, the temporal and transformational nature of relationships within science, the symbiotic relationships they have with the planet and those that share it;
- That students are interested in learning about planetary well-being and this aspect must be included in any ecological curriculum;
- A practice which is premised on developing mutually respectful educational relationships should be developed and that this needs to include opportunities for students to articulate their teacher identities and in doing so theorise their practice.

8.5 Nested Systems – the potential significance of my influence on others

I have sustained an argument throughout this thesis for the need to celebrate personal knowledge (Polanyi 1958) and suggested that this research, and the theorisation of my practice, provides an example of this in action. In doing so I have demonstrated how the process of holding myself to account for my actions has been of personal significance. This chapter has detailed the understanding I have developed and the empowerment I have gained through being able to articulate my previously emergent teacher practice. I now believe I have the capacity to claim that I recognise what drives my practice and therefore can state with confidence and authority that I have developed an ecological approach to my practice.

By doing so I have maintained throughout that this work should not be considered as a final product in the same way as most social science research theses and have, therefore, never made claims that the findings are either generalisable or replicable. However, I appreciate that my research was premised upon the intent to exercise my educational influence (Elliott 2007; McNiff 2014) and consequently may have significance for others' learning. My initial interpretation of this was in relation to the students I worked with from Cycles 1 and 2, to check whether or not I had influenced the manner in which they thought. This has been analysed in detail in Chapters 5, 6 and 7. I am now starting to appreciate how my influence relates to the systems I am in relation with and that; “all living beings are members of ecological communities bound together in a network of interdependencies,” (Capra 1996, p11). Capra’s idea of; “nested systems,” (2005, p.27) explains how classrooms are embedded within, and related to, wider communities such as the school/university and society at large. I propose that my influence does, and should, not solely remain within the classroom and that carrying out third-person research which empowers others should become part of my practice. While Moore Lappé (2007) states that actions are either consciously or subconsciously ‘rippled’ into the environment I claim, in this instance, that they have predominantly been transferred with intent.

I have demonstrated in Chapter 7 how the research process resulted in the production of resources related to studying famous scientists with the hope that this may play some role in developing an ecological appreciation of science. I have also detailed how writing about these resources has afforded me the capacity to engage in debates with the wider primary science community. At a recent primary science conference Tim Gregory (a scientist made famous through a recent television programme) stated there was a need to appreciate that science embraces uncertainty and is humble (which I interpreted as tentative) in its claims (Gregory 2018). He referred to science as a verb and not as a body of facts. While he outlined these key tenets, which I believe are similar to the underpinnings of the ecological approach I have outlined here, he did not give recommendations for how this could be achieved. I hope this thesis can contribute some provisional ideas to those within science education and science teacher education in order to help them integrate an ecological approach into their practice.

I do not propose that these suggestions should be adopted unquestioningly but hope that they can provide a starting point in defining a practitioner’s provisional curriculum specification (Stenhouse 1975); not in terms of a traditional syllabus (Kelly 2009) with fixed objectives but as guide which could be developed through working with a unique set of students. As I have noted previously it is the initial process of defining what should be included in the provisional curriculum specification which is just as significant as the learning gained from teaching the curriculum. I am confident that this thesis has demonstrated how my practice did not locate the ‘I’ in the centre of the enquiry but in relation to the students I have worked with (McNiff 2013). However, while I recognised the need to generate personal theories through research in to my practice (Elliott 2007) I also appreciate that this should not have precluded working with other colleagues in refining module content and module aims. Those considering this process should be mindful of the benefits that collaborative action, and a second-person enquiry can bring, and working with peers to define the curriculum for ecoliteracy is something I should have considered.

In addition to the empowerment I have gained through entering into debates with colleagues from the science community about the nature of science and science education is the authority this process has provided me with to articulate and justify my actions at the classroom level. While I appreciate the uniqueness of my mutualistic practice (both to me and to the students I worked with), I propose that this thesis might provide an example to other practitioners (whether in school or in a university setting) of how it might be possible to analyse and evaluate one's actions and educational philosophy and the importance of doing so. I recognise this point as necessary on two interrelated levels. The first is the ability to justify decisions related to daily interactions within the classroom. The second is the understanding gained of the constraints placed on these choices because of the social and cultural 'habitus' in which the practitioner is embedded. The unified nature of these two aspects is what I perceive to be identical with Alexander's (2008) description of pedagogy.

I acknowledge that the following specific examples are only relevant to my practice. However, I suggest that the process I have undertaken in identifying my educational values and making explicit my educational aims is important to other practitioners. In doing so I identified the disconnect between what I said I was doing and what was actually happening in my practice. I appreciate Whitehead's (1989) suggestion that analysing one's actions can expose the individual as a 'living contradiction'; that one's values can be negated in one's practice. In this instance I have shown that I assumed I was developing the students' criticality yet in reality this was not the case. Without a critical interrogation of my practice this belief and practice would have remained unchallenged.

Contrary to existing as a 'living contradiction' (Whitehead 1989) I was also able to identify how my values were being lived out in my practice. I have detailed that prior to this research I was unable to explicate what my mutually respectful practice entailed. The research process not only helped me to theorise and therefore articulate my mutualistic practice but also, I believe more importantly, allowed me to negotiate with the students that this way of working was appropriate for them. As McNiff (2013) notes, it is important to remember that not all values are for the benefit of others. Like Ghaye (2010), who acknowledges that our values become apparent through our interactions, I suggest that ensuring that this is not to the detriment of the students is a key element of any practice. This thesis has afforded justification and guidance for how this might be achieved.

While I have proposed that it is incumbent upon practitioners to identify their values and how they are demonstrated in practice I concur with Alexander (2008, p. 47) who states that; "if pedagogy is viewed only as the act of teaching this reduces the teachers to a technician who implements the educational ideas of the elite – not as thinking individuals with a purpose over their agency." I have referred to Chomsky (2000) who made similar claims that teachers can be positioned as unthinking implementers of other's educational policies. This has been reinforced by recent educational discourse that teachers should be consumers of other's theories (Carter 2015). Again, this current thesis may act as an exemplar for how an interrogation of one's practice could be achieved and the necessary empowerment to practitioners which may ensue; as difficult as this may be. Simon (2016) outlines that the form of action research of most value is one developed from a teachers' own line of enquiry. However, this research should not be seen as a 'one-off project' which many teachers may perceive it to be (Simon & Nicholl 2017) but as part of a transformative and cyclical journey of continual professional development.

I am also mindful that this has relevance to those working in higher education. Nixon (2008, p. 29) makes a comparable statement to that made by Alexander that the; "academic practitioner is increasingly treated as an operative rather than decision maker, as someone whose role is merely to implement the judgement of others and not to act on his [sic] own." Nixon proposes there is a need to challenge the entrenched scientific epistemologies that universities are premised upon and which he advocates do not reflect modern thinking. Barnett (2011) and Nixon (2008) also call for the reconceptualisation of the university. Barnett (2011) specifically references the need to develop 'becoming' ecological universities. However, largely these calls for change have been ignored with Stern suggesting (2009, p. 275) that many universities view themselves in a non-ecological fashion as institutions which are; "universal, permanent, and free from history and context," and subsequently as being 'complete'. While both Nixon (2008) and Barnett (2011) provide suggestions for how the transformation of the university might occur, it is their suggestions regarding the role the academic practitioner can play which is of most relevance to this thesis.

Nixon (2008, p. 10) believes that universities should act; "as a space within which the people of very different persuasions, beliefs and backgrounds come together to seek to understand the extent of their own ignorance and, crucially, to learn from one another," which is akin to second- and third-person action research. By doing this Barnett (2011) proposes the university's role is to develop a public and moral understanding of the world which is not limited by growth or constrained to existing relationships or a particular way of thinking. Nixon (2008) argues that these changes must be from the inside-out and can only be supported by seeing universities as a 'learning profession'. I propose a learning profession or, indeed, learning institution can develop from the study of an individual's practice; this thesis may be seen as a demonstration of this idea.

This thesis also adds to the debates around the legitimation of personal and practical knowledge. Much of the literature referring to action research makes reference to Boyer's (1990) claim that there was a need for a new form of scholarship of teaching which focussed on theory generation through practice. Similar to views expressed (such as in Stenhouse 1975; McNiff 2014) earlier, Boyer (1990, p. 16) saw the two as entwined with the focal point being pedagogy stating that; "theory surely leads to practice. But practice also leads to theory. And teaching, at its best, shapes both research and practice." He develops this by proposing that theories generated in this manner should be perceived as legitimate scholarly activities;

> Viewed from this perspective, a more comprehensive, more dynamic understanding of scholarship can be considered, one in which the rigid categories of teaching, research, and service are broadened and more flexibly defined.
>
> (Boyer 1990, p16)

As a consequence of Boyer's (1990) views, Schön (1995) suggested that this new scholarship required a new epistemology. I believe this epistemology is founded upon the ecological principles that have been promoted throughout this thesis and is one which celebrates the; "practitioner's generation of actionable knowledge," (Schön ibid, p34). It is important to note that despite his genuine call to reconceptualise scholarly activity and locate it within the practitioner's working context, Schön's methodological stance is that of the 'outside' researcher (similar to Stenhouse 1975). I hope this thesis will add to the canon of other practitioner's work which act as exemplars for how it is possible to locate the focus on one's research inside the 'messy' nature of the classroom.

Despite Boyer's claims in 1990, for the need to embrace the new scholarship, this claim still appears to be current. Schön (1995) has argued that the challenge of incorporating this new scholarship into higher education institutions is; "how to introduce action research as a legitimate and appropriately rigorous way of knowing and generating knowledge," (Schön ibid, p31). McNiff (2016) states that the initial process of legitimising research is by demonstrating that any claims to knowledge made are fair, accurate and honest and, that this kind of consideration can contribute to their validity. I hope that this thesis demonstrates the rigorous nature in which the research has been undertaken and therefore potentially contributes to the arguments about what is considered as legitimate knowledge.

I believe that the unifying significance of this research is best expressed through Stenhouse's (1975, p. 24) claim that there is; "no curriculum development without teacher development," (and by teacher I refer to any practitioner). This thesis has explored what curriculum means in a university context and how the module aims can be interpreted through the lens of a process curriculum. It has provided examples of the difficulties that practitioners can encounter when faced with uncertainty around the ‘destination’ of a curriculum but also the immense benefits in learning gained from undertaking this form of research and developing one’s practice. I believe that I have shown how I have generated a theory of my practice that has included gaining an understanding of what I taught, the manner in which I did so and the empowerment this process has afforded me.

8.6 Contributions to knowledge fields

I now return to the aims of this research which I defined at the start of this thesis as premised upon my initial desire to develop the students’ ecoliteracy. This aim was founded upon the following research question; “can a curriculum for ecoliteracy be developed through a mutualistic practice?” I have suggested that the success of the outcomes of this original aim was mixed. I have previously highlighted that the development of the students’ ecoliteracy was limited because of my ill-conceived understanding of ecoliteracy and ecological thinking. The students were, however, very positive about the educational nature of the relationships I helped to form within the group which, they said, were premised on self-respect. I am not disappointed by the apparent lack of achievement in attempting to answer the initial research question. I hope that this thesis has shown that I now have a reasonably deep theoretical, yet evolving understanding of my practice. I am optimistic that the transformational nature of this thesis, and therefore my learning, establishes how it might be possible to undertake research where there is an expectation that aims may not be met and what is most valued is the learning gained through the process.

By researching in this manner, and through a continuous cycle of reflection over Cycles 1 and 2, I believe I can now make the original claim that I have developed an ecological approach to science teacher education. A suggestion of what this approach might entail has already been summarised in Section 8.4.5.

I have previously identified how my practice is located in a range of nested systems and that the potential contribution of my work may be considered for a range of fields. The following will summarise some of the contributions I suggest this work might make to these different fields.

- **Science education and science teacher education**

  In Section 8.4.3 I outlined possible prospective aims for any future science curriculum which might help to develop an appreciation of the ecological nature of science. I also detailed the forms of learning activities which might assist in developing ecological epistemologies. Some of these activities have already been adopted by students I have taught and other primary school teachers I have worked with. My hope is that I will continue to influence those students I work with to think relationally and that I can continue to help them perceive science as an ecological act. I suggest that this thesis can provides a framework for others in science teacher education to follow should they wish. I am also aware of the teachers who are already using these approaches and the influence they might have. Consequently, the children they teach may also develop the ecological epistemologies I have spoken about throughout this thesis.

- **Teacher education and higher education**

  This thesis may act as a stimulus for others in teacher education who may wish to redress the power-constituted nature of traditionalist forms of teacher/student relationship and demonstrate that they too are learners alongside their students. I appreciate that this first-person research is a unique reflection of my practice and the strategies I used were therefore specific to me and the set of students I was working with. However, I believe I have established how it may be possible to represent the academic practitioner as one with the experience and knowledge the students expect whilst also demonstrating an epistemological readiness to learn more. By developing the curriculum for ecoliteracy I have also tried to show the potential for devising a 'curriculum' premised on the practitioner's values and beliefs and that this was a more honest educational experience for the students. By undertaking this process I have highlighted some of the difficulties in this approach but also made recommendations throughout the thesis about how it may best be achieved.

- **Student teachers and teachers**

  I hope that this thesis has demonstrated why I believe there is a need for those in the teaching profession to reflect in a critical manner about their pedagogical practices and not just about the 'art of teaching'. A core aim of this thesis is to add to the debates around the forms of reflection which should be undertaken. I suggest that to ensure that those in the teaching profession do not become either a conduit for policies from those in power or the recipients of research undertaken by others that reflection which identifies the practitioner's values is necessary. In addition to this a critical interrogation of the social, cultural and political discourses in which the practitioner is embedded is essential in defining their pedagogy.

- **Research**

  As part of defining a teacher's pedagogy I have suggested that teachers are not consumers of others' educational theories but producers of their own. This entire research has been a demonstration of first-person research which places the practitioner, in relationship with participants, at the heart of the process and eschews the dominant research epistemology which places little value in personal theories. In documenting my learning as the research progressed I have identified difficulties I encountered and provided suggestions for how the research process could have been improved. I have provided suggestions for this in Chapter 4. This thesis, therefore, provides a loose framework for other practitioners to follow should they wish to undertake a similar form of enquiry. I hope that my work will add to the canon of other practitioner-based research and will strengthen the legitimisation of this form of practitioners' theory-generation.

8.7 Concluding Remarks

I am aware of the irony of completing the final stages of this thesis in an air-conditioned library, thus contributing to increasing atmospheric carbon dioxide levels, during the British heatwave of 2018. Much of the scientific community is advising that the heatwave's occurrence was made far more likely because of anthropogenic climate change (for example; World Weather Attribution 2018). Some reports suggest that these heatwaves will occur far more frequently in the future, while others propose that climate change will result in much heavier downpours of rain during the UK's summers (Kendon et al. 2014). The overall consensus, however, is that more extreme weather conditions of different sorts will become the norm. It is clear that the effects of climate change and the other crises which the planet is facing are here to stay.

I recognise more than ever that there is a need for humans to develop a mutualistic relationship with our planet and that my research can play a small role in this. I hope my future research can build upon the work outlined in this thesis and assist the students and peers I work with in reconceptualising science as an ecological act. I hope to do this by identifying how I can incorporate the 'big' ideas into my teaching to demonstrate the related nature of scientific knowledge. I aspire to go beyond this to show how science might be related to knowledge in other 'curriculum' areas. In addition should be the development of authentic out of classroom experiences which can help the students develop their scientific knowledge while gaining emotional experiences of their lived environment and an appreciation of the physical and emotional connection they have with their local area. Further research regarding ways to develop the students' capacity for critical thought will also be necessary.

Ultimately, I will need to ascertain whether these strategies have influenced the students I teach to reconceptualise science and consequently change their perception of knowledge and knowledge generation. In doing so I will be able to explain whether I have helped the students to develop the ecological epistemologies I have championed throughout this thesis.

As has been the premise for the rest of this work, I cannot be certain of the success of these approaches but I cannot look into my children's eyes and say that I did not try.

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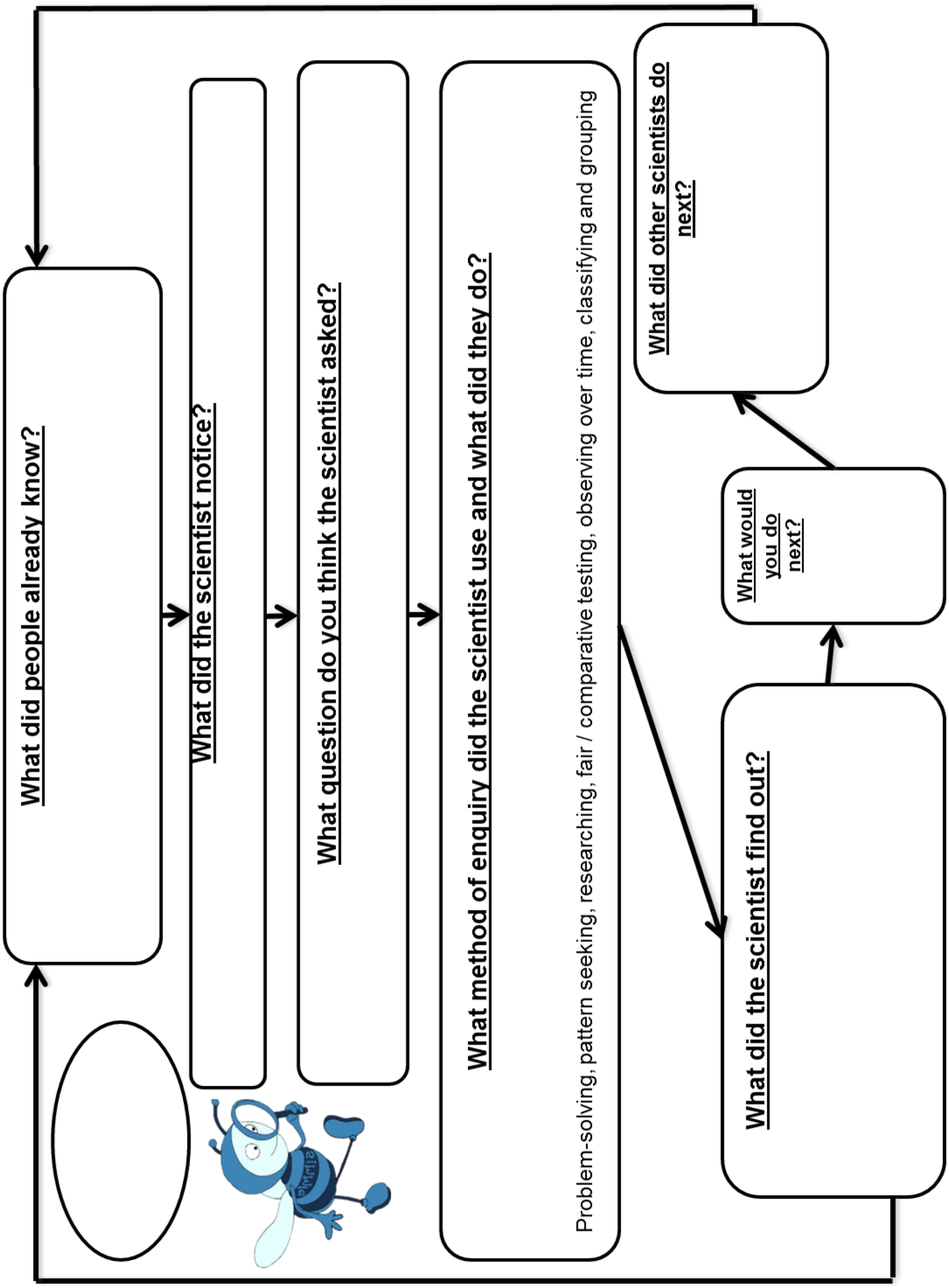
Appendices

Appendix 1 – Famous Scientist Template

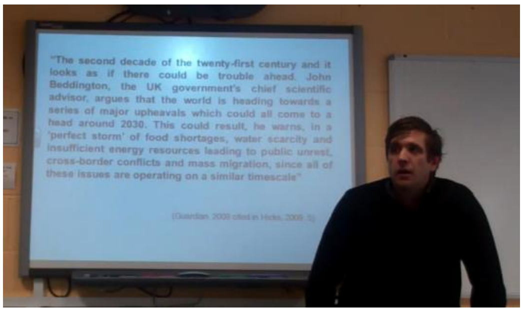


Appendix 2 – Initial Presentation (10.1.2012) Transcript

OK, um, thank you very much guys.

This has taken, and it's going to be an abridged version of a, er, a presentation that I gave in Viennna which sounds really rather posh but, er, it's taken about a year to come to this kind of conclusion, I mean what I don't want to do, is that I don't want this to sound very preachy, so this is my kind of personal opinion and, huh, I very much, sort of value what, what you think about this. For me, I think there's something wrong with the planet (shrugs shoulders), Ok, and sort of how we look at it.

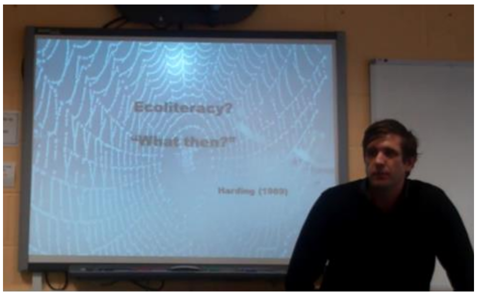
I mean I look at that statement there, and I'll give you just a couple of seconds to sort of read it (20 sec pause)

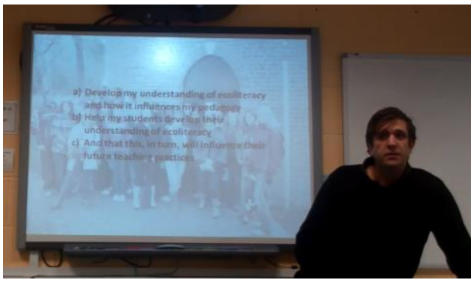


Now, there's all sorts of scare stories around, I think, I don't know if you believe that or if you believe 2030 is too soon, all those types of things, what I do, what I do believe is that the sort of future is going to be slightly different from what it is, what it is at the moment, ok, so if all those things come to pass, then, um I think we may be in a little bit of trouble

This guy here is a bit of a hero and he talks about schooling creating and again this may be where we you kind of go hang on a minute I'm not happy with that, he talks about how schooling is producing people who are ecologically illiterate and that we have a system now that just gets people to get jobs, which is, there's nothing wrong with that. But the jobs really are just about amassing as much money as you can with very little, sort of, thought about the environment, you know and I've put, these were all schools that I worked at or, um went to. So I consider myself to be fairly ecologically illiterate as well, despite having read quite a bit around it, Ok.

And I've used the term sustainability in, in all of your documents but I am not really happy necessarily with that word cos I'm not really sure what we are trying to sustain and whether, you know, our current lifestyles, how we live them at the moment, is, is sustainable and, again, that's up for conjecture, that's my personal opinion. Um, what I think is, this guy Harding came up with a nice term about someone who is ecoliterate and understands these things, is someone that can say well what then?, if I do this action, what will be, what will be the consequences of that action?



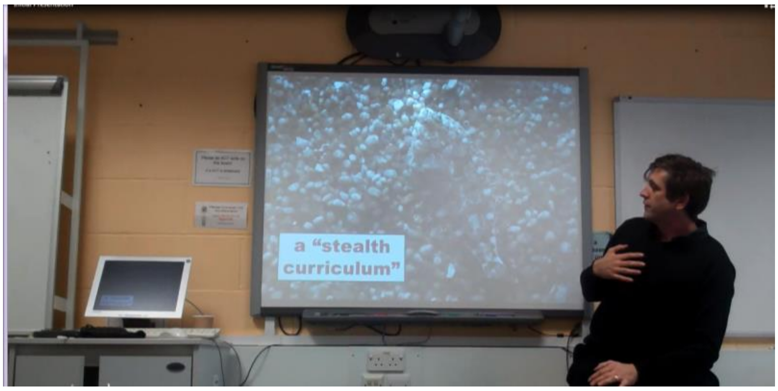


So, my kind of research I'm hoping is really to, to look at these three areas, it will certainly and because I don't call myself an expert in anyway in any of this, and I think that's what is reasonably exciting, about what is someone who is ecoliterate, what do they look like? What do they do? And what kind of values, that sort of thing. I want to develop my understanding of that.

What I would like to do, and again this up to you guys to buy in to this or not, is maybe to to help you develop that understanding as well, but also, maybe whether this will have an effect on your future teaching practice. Is it important enough to have an effect?

Ok, um, however, there is huge tensions and I don't know, I've been really quite nervous this morning about doing this because, you know, people are saying, this is going to eat into my time and this and that, so I do have great concerns about imposing my thoughts and my values on you, so if I can just go through a little bit about them,

I mean I question what my role is here sometimes, you know, what do you expect from me? Because I would love to sort of spend most of the science curriculum developing these kinds of ideas, however I've got to be realistic, I don't know if anyone's seen that book before, you can nod or shake your head. It's Wenham and ovens, understanding primary science, nothing in there about sustainability and about and about issues to do with that. Is it my role to be talking, discussing things when it's not in a common text book? I don't know if you know this but the review of the national curriculum has stated that they are not going to make climate change mandatory to learn about. They've kind of wiped it from the curriculum and said it's up to you whether to teach about it. So again am I forcing something on you, which you may or may not need in school. Finally this was the sustainable schools strategy, the framework for it, which went with the new government came in and it was quite nice, it had a few detractors to it, quite a few detractors to it, but what it stated was that every school needed to be a sustainable school by 2020 and it gave some guidelines of how to do it, so actually from top down schools were saying that we have to do this and that. They've withdrawn that. Um and I have first-hand experience of that, um, from a school that I've worked in. when this was in place, I went round a did INSET and was preparing how we would look at this, planned all that for the following year. This went, and then all of that that went and they were just not interested in everything that we did. So the context, kind of , for you guys, is a lot of people are saying it's not very, very important, so my worry is, is am I asking that if we were to do stuff around this, to enhance our science am I forcing something on you, that, that is my real concern?



Um, what I've done before, with the year group before I've called it a stealth curriculum because I did it kind of did it with the specialists in the third year I didn't tell them about it and that I was trying to dip feed things in, to be quite frank it didn't work . You know, I think have to be up-front about this, so what I suppose I'm asking is can we work together and I think that for me that will be quite exciting because I certainly don't hold myself to be the expert, with 20 odd people in here, you know, the kind of knowledge we could create could be amazing, could we create some kind of curriculum that maybe we could take into schools I'm not saying that we do that, but you, um, further your understanding of the science behind it, how it could be taught in schools, and so on and so on. Now, if people don't want to do this what I might do is for those that are keen, we could do this as a subsidiary and do it elsewhere, so like a little club or something. I'm not sure about using the term eco-club, I'm not so keen on that, um, so, um , my suggestions here are would you be willing on the back of that sheet just to write down your thought about what I've just, what I've just said. Um, have I been preaching to you? Do you think I've been fair? How do you feel about what I've just said? Am I talking a load of rubbish? Um, and maybe from that is some people are willing to share, and you don't have to, then we could put that on the cameras as well.

Appendix 3 – Student Consent Form

St Mary's
University College
Twickenham
London
—
Education

January 2012

I am undertaking an action enquiry as part of my doctoral studies into how I can improve my practice, with a particular focus on whether issues of sustainability should be taught as part of the science elective course, and am asking you to be a participant in my research.

To assist me with this action research, I would like to ask you to become an active participant within the research. I therefore ask for your informed consent to participate within the research by signing and dating this letter.

Participation and subsequent data collection in the research may include the following:

- Completion of questionnaires
- Completion of log books
- Class and individual interviews
- On-Line Discussions
- E-mail correspondence

I will give priority to your interests at all times and promise the following;

- Your identity will be protected at all times unless you give me specific permission to name you.
- Data will be stored in secure, password protected computers and will only be accessed by myself and my supervisor. You may view this information if desired.
- You are free at all times to withdraw from the research, whereupon I will destroy all data relating to you.
- I will check data relating to you before I make it public
- I will make a copy of my research report available to you prior to its publication.

I confirm that permission from the Ethics Committees at St Mary's University College has been required for this research.

Once signed, I will photocopy this statement and return the original for your files.

With thanks,

ALEX SINCLAIR

Signed: Signed:

Date: ____________________ Date: ____________________

Appendix 4 - Ethical Consent

Appendix 4.1 - Ethical Consent: St Mary's University College

St Mary's
University College
Twickenham
London

St Mary's University College

ETHICS SUB-COMMITTEE

APPLICATION FOR ETHICAL APPROVAL

This form must be completed by the researcher for all undergraduate, postgraduate and staff research proposals involving contact with, observation of, or collection and storage of confidential information or data about human participants.

Undergraduate and postgraduate students should have the form signed by their supervisor.

For staff research proposals the form should be forwarded to the School representative of the Ethics Sub-Committee for signature.

If ,for research projects (staff, undergraduate or postgraduate), the proposal is being submitted for approval to a properly constituted ethics committee external to the University College (e.g. LREC), please submit a copy of the letter approving this application to the Secretary of the Ethics Sub-Committee. External ethical approval may not cover research/ work carried out in the University College and the Secretary will advise if further action is required.

Before completing this form, please refer to the University College's ethical standards for research and any relevant professional guidelines. As the researcher/ supervisor, you are responsible for exercising appropriate professional judgement in this review.

Please refer to the '*Guidelines for completing the Application for Ethical Approval*' when completing this form. All Ethics Application forms must be submitted and signed by your supervisor. If appropriate, your supervisor will refer your application to the School Ethics Sub-Committee representative for Level 2 or Level 3 consideration. For Level 2 consideration, the form will be approved and sign by the School Ethics Sub-Committee representative. For Level 3 consideration, this form should be signed and submitted in hard copy to the Secretary to the University College Ethics Sub-Committee, at least 10 working days prior to the meeting at which it is being considered. All forms and guidance notes are available on the intranet:
http://portal.smuc.ac.uk/ethics-committee.html

Please note: the signed, completed Ethics form must be included as an appendix to the final research project.

Ethics Sub-Committee
Updated November 2010

If you have any queries when completing this document, please consult your School's Ethics Sub-Committee representative.

1. Name of Proposer(s) 2.SMUC email address	Alex Sinclair alex.sinclair@smuc.ac.uk
3. Name of Supervisor *(if applicable)*	Professor Jean McNiff (York St John University)

4.Title of project
How do I develop and encourage a pedagogy of ecoliteracy?

5.School	Education
6. Programme (if undergraduate research or taught Masters)	PhD
7.Type of activity/research (Staff/undergraduate student research / postgraduate student)	Part time PhD. York St John University. Staff of SMUC

8. Confidentiality	
Will all information remain confidential in line with the Data Protection Act (Amendment 1998)?	YES
9. Consent	
Will written informed consent be obtained from all participants/ participants' representatives?	YES
10. Pre-approved protocol Has the protocol been approved by the Ethics Sub-Committee under a generic application?	YES
11. Approval from another Ethics Committee	
Will the research be approved by a Local Research Ethics Committee (NHS) or other Ethics Committee?	NO
Are you working with children under 18 years of age or vulnerable adults?	NO
12. Identifiable risks (not covered in response to Item 4)	
a) Is there significant potential for physical or psychological discomfort, harm or stress to participants?	NO
b) Are participants over 65 years of age or have limited ability to give voluntary consent, including cognitively impaired persons, prisoners, persons with a chronic physical or mental condition, or those who live in or are connected to an institutional environment?	NO
c) Is any invasive technique involved, or the collection of body fluids or tissue?	NO
d) Is an extensive degree of exercise or physical exertion involved?	NO
e) Is there manipulation of cognitive or affective human responses which could cause stress or anxiety?	NO
f) Are drugs, including liquid and food additives or other substances to be administered?	NO
g) Will deception of participants be used of a nature which might cause distress or which might reasonably affect their willingness to participate in the research?	NO
h) Will highly personal, intimate or other private or confidential information be sought?	NO
i) Will payment be made to participants other than to cover expenses or time involved?	NO

j) Is the relationship between the researcher/ tutor and the participant such that participants might feel pressurised to take part?	**NO**

Please note it is still incumbent on you to observe the College's rules on ethics in the conduct of your research, and in particular to ensure that your research complies with the Data Protection Act by which you are legally bound.

When any doubt arises in relation to the above, always discuss this with your School representative of the Ethics Sub-Committee.

13. Proposed start and completion date **Please indicate when the study is due to commence, timetable for data collection and expected date of completion**
Data collection to commence on approval from ethics committe – January 2012 until May 2013 (the end of their course at St Mary's **Further data collection will take place during the academic year of September 2013 after trainees have graduated and are teaching in schools.**

14.Sponsors/Collaborators **Please give names and details of sponsors or collaborators on the project** **N/A**

15. Other Research Ethics Committee Approval Please indicate whether other approval is required or has been obtained (e.g. NHS, LEA etc) and whether approval has previously been given for any element of this research by the University College Ethics Sub-Committee
As my PhD is a continuation of my Masters work, previous permission was given for this work in 2007.

16. Purpose of the study Please give the aims of the research and provide a brief rationale for the study including any existing knowledge and benefits of the proposed research.
The aims of the research are to improve my practice as a senior lecturer in relation to developing a pedagogy of ecoligical sustainability. In tandem with my students, I hope to explore whether it is possible to develop a curriculum for sustainability within the confines of the science curriculum that these students have elected to study. In turn, I hope that the influence of this research will improve the student's understanding of ecological issues and how they may tackle these in their future teaching. I have already been instrumental in arranging for the following at St Mary's ; the arrival of a colony of bees, an allotment, and the start of an orchard – all of which are potential resources which could be used during this research.

17. Study Design/Methodology **Please provide details of the design of the study (qualitative/quantitative etc) and the proposed methods of data collection (exactly what you will do and how; nature of tests, questionnaires, type of interview, ethnographic observation etc) including what will be done to participants, the extent of their commitment and the length of time they will be required to attend for testing. Please also include details of where the testing will take place.** **Copies of questionnaires to be used and/or interview schedules should be attached to this application.**
The methodology for this research will be a self-study action enquiry into how I can improve my practice. Data collection will mainly be qualitative. Due to the nature of self-study research data collection opportunities will arise as the enquiry progresses but will be taken in the following ways; Video Recordings : of presentations at conferences, meetings with critical friends, of my teaching, interviews with students Audio Recordings : meetings with critical friends, interviews with students (if this method is preferred) Learning Journals : completed by students at appropriate times throughout their course (given the opportunity to make these anonymous), completed by myself Virtual Learning Environment : Through online discussions between myself and the students Initial data collection will stem from students watching a presentation of my ideas and justification of a case for developing a pedagogy of ecoliteracy given at CARN 2011. I will ask them to make comments on this process and their thoughts around being involved in the research.
18. Participants **Please describe how many participants will be required to complete the study, their age, sex, how they will be chosen/recruited and inclusion/exclusion criteria.**
Participants for this research will come from two cohorts of students studying on the BA ITE with QTS undergraduate degree programme ; those that started in 2009 and those from 2010. Both groups of students have elected to study science in greater depth in their second and third year. Currently there are 25 in the 2009 group and 21 in the 2010 group. These students have been chosen as I am the lecturer for their science elective group and I therefore have greater contact with them. All students are over 18 and groups comprise of both sexes.

19. Consent **Please provide copies of the consent form, information sheet, debriefing sheets (if relevant) for participants and any other documentation in relation to consent, e.g. letters to parents, Heads of Schools etc.** See attached

Ethics Sub-Committee
Updated November 2010

19a) Are there any incentives/pressures which may make it difficult for participants to refuse to take part (i.e. will coercion be used in the recruitment of participants)?
No

19b) Will any of the participants be from any of the following groups?
Children under 18
Participants with learning disabilities
Participants suffering from dementia
Other vulnerable groups
No

If children under 18 years of age are participating has the researcher/investigator a current CRB disclosure?
N/A

19c) How will consent be obtained?
Via written permission – see attached letter of consent

20. Risks and benefits of research/ activity
20a) Are there any potential risks or adverse effects (e.g. injury, pain, discomfort, distress, changes to lifestyle) associated with this study? If so please provide details including information on how they will be minimised. No 20b) Does the study involve any invasive procedures? If so, please list the researchers' or collaborators' experience in the use of these procedures. No 20c) Will individual/group interviews/questionnaires include anything that may be sensitive or upsetting? No 20d) Please describe how you would deal with any adverse reactions participants might experience. Participants will have the right to withdraw from the research at any time. Information from/about them will not be published without their permission. Participants will be informed that they can seek advice through their programme director should they feel the need. 20e) Are there any potential benefits of participating in the research to the participants (e.g. Gaining a knowledge of their fitness, finding out personality type, improving performance etc)? The students will gain a deeper, personal understanding of ecological issues and what a pedagogy for teaching about these may look like in the classroom. Alongside this it is hoped that they will develop their capabilities for critical practice.
21. Confidentiality, privacy and data protection
21a) What steps will be taken to ensure participant's confidentiality? Learning Logs will be made anonymous (if the students prefer). Students will not be identified by name within any publications unless the student states otherwise. 21b) Will the data be stored securely? Data will be stored on a password-secure computer. Only I have access to this. Students will be able to access their data alongside me. 21c) Who will have access to the data? See above 21d) Will the results of analysis include information which may identify people or places? It will be necessary to highlight that I work at St Mary's University College, but any mention of students will be through the use of participant A, participant B, etc, unless they wish for their name to be included.

22. Feedback to participants Please give details of how, if appropriate, feedback will be given to participants.
Participants will be asked to review material prior to publication. Feedback will taken from this process.

The proposer recognises their responsibility in carrying out the project in accordance with the University College's ethical guidelines and procedures and will ensure that any person(s) assisting in the research/ teaching is also bound by these. The Ethics Sub-Committee must be notified of and approve any deviation from the information provided on this form.

Signature of Proposer(s) A SINCLAIR	Date: 02/12/11
Signature of Supervisor (for student research projects)	Date:

Appendix 4.2 – Ethical Consent: York St John University

York St John University

Alex Sinclair
PhD Student

Lord Mayor's Walk
York YO31 7EX
T: 01904 624624
F: 01904 612512
www.yorksj.ac.uk

Dr Simon Rouse
Chair of Research Ethics
Direct Line 876901
e-mail: s.rouse@yorksj.ac.uk

20 March 2012

Dear Alex

RE: How do I improve my practice through developing a pedagogy of ecoliteracy?

REF: UC/20/3/12/AS

We can confirm that your research ethics re-submission is now approved. We note your reply and clarification of the 13th March 2012 regarding the issues of consent and coercion raised by the committee on the 23rd February 2012.

Yours sincerely

Cc Professor Julian Stern and Professor Jean McNiff

Appendix 4.3 – Ethical Consent: Cycle 2

Mon 02/01/2017 20:10

Jemima Davey [redacted]

Re: Thoughts

To Alex Sinclair

You forwarded this message on 05/01/2017 10:41.

Dear Alex,

I am so sorry for the delay! I wrote it before Christmas but in all the madness of data collection, assignments and Christmas, I forgot to send it.

Here's what I wrote, I hope it's what you were wanting and you have my full permission to use it at your conference and in your work.

Science is an evolving subject, with new knowledge constantly being discovered and researched. This is true, but I only fully understood the meaning of this after a science lecture as part of my Primary Education degree. When discussing the impact of well known scientists and how we might use them to give context to our teaching, I realised that I had been thinking of science as 'finished' in a sense. When Alex asked the question "who thinks the science we teach now will be the same in 50 years?" I put my hand up, not really thinking about the gravity of this. I was always taught science as fact, and never asked to question it or be critical. This lecture made me see that the science we teach now is not the science we will be teaching in 10, 20 or 30 years time. It was a moment of huge realisation, as I began to see the scope of science and the power we have as teachers. I also became aware of the unspoken responsibility we have to keep abreast of the wider scientific world, and not just the curriculum. As a result of Alex's lectures I am excited to see what future scientists I will be telling children about and what I might do to help children to examine the world around them, and most importantly, question what they find.

If there's any more I can do, let me know!

Kind regards,

Jemima

Tue 31/07/2018 16:53

Elizabeth Chilvers [redacted]

Re: Ethical Clearance

To Alex Sinclair

You replied to this message on 31/07/2018 17:37.

Hi Alex,

No apology necessary. I'm fine with you using both of them in your thesis. One thing though, shouldn't it be begin not being in the first one?

Good luck with the thesis, I'm sure you will be fantastic.

Liz

On 31 July 2018 at 13:58, Alex Sinclair <alex.sinclair@stmarys.ac.uk> wrote:

> Hi Liz,
>
> Sorry to disturb you during your holidays.
>
> I have attached two separate excerpts from my thesis which use quotes from your email responses to me about your thoughts about the famous scientist resources. Are you fine with me including them in my PhD thesis to provide evidence of the influence of the resources please?

Tue 31/07/2018 14:06

Helen Spring [redacted]

Re: scientist resources

To Alex Sinclair

You replied to this message on 31/07/2018 15:30.
Click here to download pictures. To help protect your privacy, Outlook prevented automatic download of some pictures in this message.

Hi Alex,

Yes, told them that I was going to send their comments to the authors.

Best wishes
Helen

On Tue, Jul 31, 2018 at 1:54 PM, Alex Sinclair <alex.sinclair@stmarys.ac.uk> wrote:

> Hi Helen,
>
> I know this appears a little random replying to an email from over a year ago.
>
> I have used some of the students quotes in my PhD thesis and appreciate I really should have got ethical clearance to use them.
>
> Do you remember if you told them that you were going to send them to me?
>
> KR, ALEX

Appendix 5 – Pre and Post Course Questionnaire

Registration Number / Personal Identification:

1. What is your understanding of the term "sustainability"?

2. How important do you believe it is that trainee teachers should be taught about sustainability as part of their course? (please ring)

1	2	3	4	5	6
Very important				Not important at all	

Please give your reasons:

3. If issues about sustainability were taught as part of this degree whose role should it be to deliver it? (please ring)

a) Covered within professional studies

b) Covered within subject-specific lectures

c) Embedded throughout the whole course

e) Other - Please specify:

Please give your reasons:

4. At what age do you feel children should START to learn about sustainability? (please ring) Nursery Reception KS1 KS2 KS3 KS4 Not at all
Please give your reasons:

5. Should teaching about sustainability and ecological issues in schools be? a) mandatory and embedded within the National Curriculum b) optional and decisions whether to teach it made by the school c) optional and decisions whether to teach it made by the class teacher d) not taught e) other - please specify:
Please give your reasons:

Appendix 6 - End of Course Interviews

Appendix 6.1 – End of Course Interview 1

J = Jessica, C = Clarissa, H = Hayley

M = Maria (Interviewer)

M – Well you've been talking with Alex about sustainability and learning about sustainability and how has that felt for you? Have you, have you felt able to engage with the ideas around sustainability in your lessons or your lectures? How has that been? Over to you really.

J – Erm, I think the way that it's been put across in the lectures, erm, has made us consider it more as a subject. I know that before the lectures started I didn't really have that much knowledge on it, so I think it has very much been a case of educating us, and also getting us to independently consider our views.

M – Fine, thank you.

C – Erm, it covers quite a broad range of subjects and you can see how it impacts everything in the curriculum. You don't really see that in specific curriculum subjects which I think is quite good.

H - and there's a lot of collaboration in it. Yeah, I feel quite empowered sometimes when we talk about it, for example, and independently, for example when Jess and me are doing Art, when I'm like doing work I'm constantly thinking about sustainability because we did like a cross-curricular project and we did focus on sustainability so we've been able to look at it in a wider context in the curriculum which has been really handy.

M - so it permeates the whole curriculum?

All – yeah

M – so it's not only in science?

All – No

M – That's what you're saying. That's fine

M – So a difficult question, a really difficult question, do you have a better idea of what we are talking about when we are talking about sustainability now?

J – Yeah definitely.

M – So if you were to give a definition of it, that's a really difficult question.

All – laugh

M – What would you say sustainability is?

H – To ensure a better future for future generations or to…keep…

J – Strategies to ensure a better, a better, erm, you know, a healthier planet (YEAH)

H – Without, yeah, future generations, without (IMPACTING, YEAH) impacting our own.

H – I know exactly I just can't think of it.

M – It's hard to put into words. (Yeah)

M – It's really hard to put into words.

M – Ok, so that's great, that's great, thank you. Now, I know, I know, erm, you've built up relationships with each other in the class, and you've built up relationships obviously with Alex, what has it been about the ethos, or the atmosphere of the class that has enabled you to talk about sustainability, because it's a big deal isn't it? It's, er, a big issue. Um, have you felt, have you felt the way the class has been sort of organised, or, or has there been an atmosphere to talk about those things?

H – I think it has been quite relaxed (YEAH) which has been good. For example I didn't know anything about sustainability and I can imagine that there are people in the class that knew loads about it, but it's sort of, everyone's been able to say what they believe and no one has really been like embarrassed to say, oh, I don't know anything about it, because I didn't know anything before I started whereas now I feel like, er, I know quite a bit and I'm confident teaching about it as well which is quite good.

C – You are kind of free to like, share ideas (YEAH) quite easily and feel in a relaxed learning environment.

J Everyone is quite sort of understanding about, you know, each other's position and there's no sort of judging or anything I don't think in the class. I certainly feel, you know, relaxed when I'm in the class and able to express my own opinions or, you know, query if I don't understand something, so.

M – Thank you. Alex would not want to coerce anybody, I mean he has got a big thing about sustainability, obviously, erm, as you know, but he wouldn't want to coerce anybody or force anybody to take on his values as it were. How have you felt about that? Do you feel that he's sort of left the ideas out there or has he really sort of pressed them home? Or, you know, has he been coercive in any way? Would you, you know, would you have considered doing sustainability before you went to, to the group or?

C – He kind of makes you make up your own decisions and your own opinions so it's really up to you what you take from the lecture and how, yeah, it actually change your opinions and values of it.

J - I will definitely say it's been an impact and I will definitely teach that.

M – Can you, can you identify one way Alex is, that has allowed you to do that? You've talked about the freedom aspect, haven't you and and not, and him not being forceful in that sense. Is there something that you can say, yeah, he's like this and that makes me feel this way?

H – I suppose he like plants a seed and then, here, you kind of think of that in your own way. He'll just give you a little bit of an idea and then everybody goes off and thinks about it differently.

J – Yeah, I wouldn't say that he sits there (NO) and just tells you, you know, what's (YEAH) right or wrong. I mean, speaking for myself, I know that I'm quite stubborn, so I know that if somebody was standing there, you know, spouting off about their own personal views, and, you know, they feel that I should take upon those views that I immediately would put up a defence and say, no, well hang on a minute, that's not what I think, but , I think suggesting something and considering that suggestion is completely different, erm, you know, a way, a way of teaching the topic rather than just, you know, telling what's right and wrong. I mean, we as teachers, we are told, you know, don't just tell children the answer get them to think about it, so I think he has employed that same strategy really.

M – That's great. So in, so in your own lives has what you have learnt about sustainability changed your own practice in anyway?

J – Sometimes, I know that there are certain things that, you know, taking it to a basic level, that I do in the home, like you know, I don't leave the tap running when I'm cleaning my teeth and, I mean I don't drink tea but I wouldn't fill up the kettle. You know, so things like that I, I do consider more and, you know, turning lights off and things but I think that's how I've been brought up, to do those things, but this has definitely made me consider, you know, other aspects to it more.

M – Perhaps you have become more mindful.

J – Yeah, it's, I'm aware of it when I'm (YEAH), you know, doing it.

H – I work in a supermarket and I'm on the fruit and veg department and before I was just like we get, can I say it, yeah its Waitrose so they are really like quality is a really big, so I have to chuck away loads of fruit and veg if it's just got a little bit of bruises on it and now when I'm doing it I'm a bit more, oh someone will buy that and I've got really like, they might get a bit annoyed but I leave loads of fruit and veg there because I know somebody is going to buy it, it's pointless me just throwing it away, and yeah I've become a little bit more mindful about that and chucking things away and wasting things when it will last, so.

C – I think I'm more aware of all of the little things, and how it makes a big impact.

M – It will be interesting to see how you carry that into the classroom (YEAH) with your children, you can imagine anything you do in your classroom or, you know, how you are in your classroom when you go out there, because you are year threes aren't you? (YEAH) Yeah, so one more year, less than that, what do you think, what do you think you will do in your classroom to make a difference or get the children to think about sustainability?

J – I think as Hayley said earlier and Clarissa as well, it's quite a cross-curricular subject so I don't think it can be, you know taught singularly, it's very, you know, you could include it in all of your practice and I know Hayley and I in our enhanced placement, you know, managed to combine it with art quite easily, erm , and as a result it was all linked to the theme within the school too, so , I think it, you know, its effecting my practice, it's just going to make me consider it more as a cross curricular link when I'm, when I'm planning so.

C – I think you act as a role model, as well, and all the values that you show kinda kinda comes off towards the students as well.

H – When we were doing the allotments as well I didn't think just about the sustainability you also think about the skills it's developing in the children. So its teamwork and they are starting to be a little bit more independent, so when I go into schools I kind of look closely at eco clubs a lot more and then how they've done it like, so making a scarecrow out of like recycled material and things like that and I think it does have a lot more with extra-curricular, which is quite good.

M – Great, great, thank you very much. Right, let's just move onto something else just for a minute. You've been keeping a learning log, (YEAH) you've been keeping. We really want to find out how you feel about completing it. Truthfully, you know, we're out there and.

H – Sometimes I felt that I was writing the same thing in it (YEAH, YEAH). Quite a lot.

M – Like what?

H – I think, what were the questions again? What have you learnt from the lesson? I felt like I was just writing out the learning objectives. They did like, I think I found it quite hard writing about how I like feel sometimes and it's better just to speak it (YEAH), so I think writing it down, like, I was looking through my book when I filled it in last time and it is quite repetitive what I have written .

J – I mean I know that obviously it is a reflective piece of work (YEAH) and you know we are reflecting on the lesson and what we've learnt but I think doing it at the end of the lesson when you've said right that's it for this week can you just full out your books I think the automatic, erm, you know, approach to it is just to scribble down something quickly and briefly (YEAH) in order to leave the lecture. It mightn't be worthwhile actually handing them out halfway through the lecture and, you know, what are your thoughts so far and then at the end maybe reflecting as well, so there's maybe a progression in, erm, or development in ideas.

M – That's a great idea, so you would get the transition in your thinking (YEAH) throughout the lesson. And from what you are saying it's also probably a very good idea to actually leave it for a while before you write in them (YEAH) so you, so things can filter through and you can reflect on them (YEAH). Great, I know, I know some people struggle with the learning logs, so, erm, what do you think the purpose of you keeping the learning, really , learning log really was.

J – I think perhaps reflection (YEAH) and a bit of reflection, I mean I know that it would possibly help Alex's, erm, research as well, to get an idea to see how his teaching has affected his pupils, but from our point of view, erm, I would definitely say that it's, er, you know, a method of analysing your knowledge and reflecting on what you've learnt so far.

M – Uh huh, OK. Was there? Did you feel able within those learning logs to actually critique Alex? Did you feel free to be able to do that? Or did you feel that that was a bit, a bit of an awkward thing to do?

C – I think it was, but it was more about our learning rather than his teach.., do you see what I mean? It was more about what we learnt, our reflections, rather than maybe his method if that makes sense.

M – It does.

H - I think I could have, I, we didn't have to write our name on it so if I had wanted to (YEAH) I think I would have been, but it would have felt quite mean, still.

M – Mm, but he was looking for that (YEAH)

J – But then there's different ways of expressing that (YEAH) isn't there, you know, you could be quite harsh and mean about certain aspects, but then, you know, that, that's not constructive, you know, if you are giving, you know, constructive criticism then that will be of benefit, whereas (YEAH), just writing down the lesson was rubbish and I didn't learn anything, you know, well you need to explain why, and so I think it, it is down to the individual as to how they filled it out really.

H – I think, was there a question like improve or something? Because I think I did write in there (YEAH).

H - Well I felt quite open and I.

J - I think because of the environment in our class, as well, I mean I know, we've all said that it is very relaxed, and, you know, you don't feel judged or anything like that, I think, that environment is then, that's erm, you know, that's the right sort of environment to feel comfortable enough to express your opinions, I think.

M – Excellent. Ok is there anything else you would like Alex to know, about, you know either his teaching or your learning or sustainability generally? I mean he's asking you for critique isn't he? He wants that because he wants to improve (YEAH, YEAH) erm, like you would ask critique, you know, as you have made the point that it has to be kindly, it has to be. Is there anything? Is there is one single thing that you would say to Alex this would really help us learn more in your sessions, during our sessions together, what do you think you would say to him?

H – I can't think of anything really.

J – I mean I know I don't know whether this is sort of answering the question, but I know that, sometimes I think, um, there, er, I know that he is very keen to make sure that this didn't happen, but, um, sometimes his, er research may have taken over our, em, you know, our classes and something like that, um. I know that it, it sometimes he was worried that it may take over the lesson, I don't think it did to a huge expense, but a lot of the time I felt rather than learning about sustainability we were helping him to complete something, but then it sort of was that way, because of what he's, he's taught us (YEAH), so it wasn't a huge deal, it was just an observation really.

M – That's a very interesting point. Yeah. He'll learn from that, I know he will.

H - I think at the beginning I felt a bit like that, but then as I was going on and when we were on enhanced placement I think I realised how much it did effect the way I taught (YEAH, YEAH) and it was really positive, like it affected me like in a positive way and I think, I've become a lot more aware of things like, for example sustainability but I think I've also become a little bit more passionate about it and when I'm teaching about it I think I'm a bit more like yeah its really excited, whereas before I was a bit like we have to save the planet and talk about, not like that, obviously, but now I'm a lot more.

M – Just one more thing to do (YEAH).

H – Now I think I'm a little bit more passionate about it and I can think about how to do it in really exciting ways and how I can make it exciting for the children.

M – Yeah, that's great, keep on talking.

J – I would definitely agree with that. I think being able, if you haven't taught it, in er, in er, sort of, this is this kind of way, it's definitely been very creative, and (YEAH), erm and, you know, like Hayley said it's when we come into the classes and put it into practice, I've not had any difficulty trying er find a way of teaching it or trying a way to include it in my lessons or anything, it's always been, erm, it's always been quite easy to link it.

M – Well, one of Alex's questions here is, did you feel that you had the opportunity to say that you did not want to learn about sustainability? Coming back to that coercion thing isn't it? Did you ever feel that you wanted to shout out, Alex we've done sustainability for a few weeks?

C – I think because of the learning environment, we had every opportunity to say, or step in and say, no I don't particularly want to do that, but I don't think that ever was the case, really.

M – Great.

J – Yeah, I mean, I don't, I don't feel like, I would of, I would of, I got to the point where I wanted to say no I'm fed up of sustainability now (NO), erm, you know I , I valued the teaching and, you know, the information and the knowledge, erm, like I say, occasionally it was a bit, you know, linked more, more sort of sided to his, his research occasionally, but like I say it's not a negative point purely because of the balance of the knowledge that we were gaining, so.

M – Because you can be learning through his research can't you?

J – Exactly, yeah.

M – Yeah.

H – Yeah, I think when we did it, it wasn't, we've done so many different areas of sustainability , for example we've had someone come in to talk to us, and they've all been giving us, like, a different insight into sustainability, so it's not just been the same thing, like recycle, it's all been like different things, one we had recycle, then we did allotments, we've done different things and we can all see the different learning behind it, so , so it's always linked in, with science learning for example plants and things and light and dark and.

M- Great

Appendix 6.2 – End of Course Interview 2

L = Lucy, S = Samantha

M = Maria (Interviewer)

M: We've been, you've been talking about sustainability in your class, er, classes together, um, how do you feel about that? And how do you feel about doing all of this work on sustainability in your science lessons and do you ever feel like you want to just say Alex we've had enough about sustainability let's move on?

L: No, I think all the ideas that we've talked and discussed about in the lecture have been really helpful I think for our future practice to integrate sustainability throughout, like, all of the curriculum, rather than just science I think is important for children to understand how they can have an influence on their environment, erm, geography is my other elective so it has been helpful for me to relate what we've done in science, as well, into a cross curricular way.

S: I think it has been a very good focus for the two years it has been something that we have gone away from and come back to and, um, I think it has been good to heighten our awareness because we are the ones that can go in and change people's opinions in school.

M: How do you think that will look in a classroom setting? How will you, how will you go about that? What will you do in your classroom, how will you be in your classroom, that will actually take that in?

S: Sustainability by stealth, even if it is not a practice of the school then I intend to practice it in my classroom.

M: Mmm, mmm, thank you.

L: Yeah, making sure that children can offer their own views so we can influence, erm, hopefully pass on our knowledge but allowing them to also, erm, think about what, what they believe sustainability to be and how they can, um, change the way in which they live now to support the future.

M: What….? Sorry.

S: Children often don't have, um, control over what they can and can't do at home, but if you make, if you give them that choice in the classroom it's something they can then start to have a choice in at home.

M: And they can influence their parents big time in that can't they (YES - BOTH) Thankyou very much, um, I know Alex is a very relational teacher, um, what is it about the relationship between you, er, together as a group or you with Alex as a, you know, a tutor and er student that has encouraged a sort of honesty or um a discussion around these sustainable issues? Can you think of anything that he is or the way he is, um, that has, that has helped that?

S: It's a very safe environment, um, there's never a fear of being put down or laughed at unless you have been particularly, um, humorous. I think that everybody does feel that they can say anything.

L: I think that knowing our ideas are valued as well that he's an approachable character, um, again we have issues to be flexible within our elective so if there's something that we wanted to raise there's always opportunities to discuss it (Mmm - Maria), with each other.

M: So you said that your views are valued, can you give me an instance or not necessarily an example but how is that, how do you know that? Because, you, you know that you spoke that with conviction that your, that your views are valued. How would you know that through how you are in the classroom with Alex?

L: I just think that giving us opportunities to put our viewpoints across, erm, discussing and obviously being able to argue our viewpoint.

S: It's, it's the feedback that we give (YEAH - L) each other. It's not, it's not just from us to Alex and Alex to us. It's, it's feedback within the group as well.

M: Mm, so it's the relationships go all over the place in that sense, that's lovely. Thankyou. Alright, thankyou very much. Er, did you feel confident to express your views was one other question, I think that you've already answered that, (ABSOLUTELY – S) you have done.

L: I just think that as the course went on, um, whilst our knowledge was enhanced I think we sort of gained more confidence to express our ideas and Alex definitely supported and ensured that we were able to do this.

M: Thankyou, um, I know Alex's big thing is sustainability and obviously his PhD is about that in part, but much more than that. Did you ever feel coerced, did you ever feel, um, you know, Alex you are taking us down this path because it is your interest, er while not necessarily ours, did you ever think sustainability again that sort of thing?

S: Not at all (NO - L).

M: No

S: But it was an interest of mine anyway, um, I think that Alex has probably focussed my mind more on it and he has certainly alerted me to some issues that I hadn't really dwelt on at all (YEAH - L), um

M: Like what? Can you say?

S: Well just, um, I can't, I can't think of anything of hand now.

L: I just think that all the stuff we covered in elective there was natural links to sustainability (YEAH - S) and knowing how we could integrate the science curriculum with sustainability and again just making sure that the children had opportunities to discuss sustainability whether it was through different activities or outdoor learning.

M: Good. Thankyou, thankyou very much. OK, erm, how did you feel about completing your learning logs?

L: Yeah, it was a good thing to do weekly I think, then Alex had an understanding of how we felt definitely improving his practice because we had opportunities, um to write down what could be improved and how we felt about the new learning in that week and I think it would have been helpful for him to evaluate how we could move on our learning..

M: So did you give them in on a weekly basis?

M: Yes, good, yeah, yeah

S: I didn’t like them.

M: No

S: But only from the basis that I like to go away and think about something before I give my views and, um, having to fill them in at the end of the lesson I would quite often go away and think, oh, think about it more and reflect more and then I would have had, I would have a better answer to give, a more evaluative answer..

M: Was there an opportunity to do that, to come back to the learning log or was that?

S: I suppose I could have, I could have always come back and asked Alex for the book and filled it in then but when you are busy with everything else (MM) you know (MM) it is just one of those things that doesn’t..

M: I think that, I think that it is probably his reasoning for doing it at the end, isn’t it? That people forget (YES - S). Maybe, maybe that’s something that he can actually think about, you know, giving you more space possibly to do that.

L: You see I am the opposite. I think that having the knowledge there fresh in your mind and your emotional attachment as well to that lecture or er important discussion was there with you and I think it came across as easier to write.

S: It’s personal preference isn’t it.

M: Mmm, mm.

S: I would say what works for one might not work for another.

M: So if you were to say to Alex, you know it would be better to do it this way, what would you say to him about that, I know that you want that space, you want to come to it later…

S: I would just say I could have asked to take my book away and, um, reflected on it and then write my piece and then bring it in (YUH - M) but as I said you have, you know, so many other pressures on your time.

M: Mm, It’s hard isn’t it? (YEAH - S) Exactly. Thankyou, erm, what did you feel the purpose of doing the learning log, really?

L: Again, just for Alex to develop his teaching, knowing the key issues that we had after each lecture and how he could possibly, erm enhance or change the way in which he exposed our ideas, the ideas of sustainability.

M: So you saw it very much in terms of him rather than yourself? Or both?

L: I think, I mean again, a bit of both actually. I think for us to elaborate on how we felt and giving us another opportunity to describe and put down our ideas.

S: It was a good opportunity to put the ideas of the lecture into, you know, a soundbite.

M: Mmm.

S: You could tell immediately what you may have learnt that was different to somebody else.

M: Mmm. Thankyou, thankyou, alright, did you ever feel, did you feel able to critique Alex's teaching through these or at any other time?

L: Again, one lecture we actually had the opportunity to watch Alex in, um, in practice, which was really good, I think, for initially, for initially, for our, our picking out different things that we would improve or things that he done well I think it was good to see, um, obviously as a teacher you like reflect on other people's practice and gaining new knowledge from others..

M: What did you feel when he did that? It very rarely happens.

L: I, I know, I think it was a really good opportunity. No, I didn't feel awkward I think in Alex's nature he knows that we will be sensitive to his needs and that we would feedback appropriately, I think and take into consideration his…

M: Can you think of one thing that you sort of put forward to him that he might improve?

L: I can't remember it now.

M: Don't worry, it's just it might come in your own lessons (YEAH - L) or lectures with him.

S: it was good for us to see something, you know, what should really be best practice (YEAH – L), at the end of the day we are still students we are still learning, you know, Alex has been a lecturer for a long time so it as good for us to see (MMM - M) how our lecturer performed in the classroom (MMM – M).

M: It's a very brave thing to do.

S: I think we had the opportunity as well to, erm, critique part of his, um, um, dissertation? (YEAH - L), that he had already written and, um, that was interesting, to see his style and to see how, how, how academic the writing is at that level (MMM - M).

M: So he gave you some of his writing? (YES - S). Ah, that's interesting (YES - S) and what did you have to do with it? Read it?

S: Critique it.

M: critique it

L: It was nice that we could be involved (YES - S) and…

S: I thought that was very brave of him as well.

M: How did that make you feel, because it's obviously an emotive thing, really passing over your work to people?

S: It should have made us feel empowered but I think we were all slightly worried that if we said something awful then… (LAUGH - L) we are poor students.

M: Yeah, OK. Alright, Is there anything else that you would like to add, I think we have, sort of, covered the questions that Alex, er, Alex wanted, you feel free to express your views don't you, sustainability didn't feel as though it was a layer that was put on, that you felt it came naturally…

S: I think that it was a good theme to run through the two years (Mmm - M) because it's something that, you know, is the thread that has tied our science lectures all together.

L: Also the opportunity at the beginning of our elective to fill out the questionnaire about what we initially knew about sustainability and at the end, last week, we actually done it again to see how the progression in our knowledge and how we, sort of, the course has fed into our pedagogy.

Appendix 6.3 – End of Course Interview 3

A = Anthony, S = Suzanne

M = Maria (Interviewer)

M – How did you feel about doing the work on sustainability throughout the course, it's over two years I think you've been looking at sustainability? Um, and did you ever feel that you could really say actually that's enough about sustainability let's, let's go back to something else? Over to you.

A – Um, yeah, I think, well when it was first sort of thrown at us as an idea, um, right at the beginning of the course, it was, you know, would you be interested in particip.., it was like the group coming together making a decision rather than Alex saying, you know, I want to teach this or to talk about this (Mm- M)

S – We had a decision in it.

A – Yeah, we, yeah we and everybody had, sort of (Mmm – S) a say which was important (OK – M)

M – Did some people not like the idea? I am not asking you to snitch on them? (Laugh – both). You know, did, did they not like the idea or did you get the feel that, ah, most people were…

S: I think, I think with individuals, um, always you get some people that are more enthused than others, so , um and you will get also in a group you will always get people that , um , want to take part more than others as well, and, um, mainly with discussions, and I just think that the people that kept quiet didn't mean to say that they weren't interested in it and actually they gained from it because I think what you found throughout this course is that people tend not to participate as much, um, that occasionally they would come up with something that they'd realised that they'd been on a journey and they had learnt quite a lot, that at the beginning they probably weren't as keen, or that they were scared that they didn't know enough about it (Mmm – M) . That's also something isn't it? (Yeah – A).

A – Yeah, yeah that's a good point really, um, I think, that, yeah, the way that lectures and things are structured and things, its very sort of, informal is the wrong word but very, sort of , I well certainly have never felt like, um, anything that I've had thought was worth saying in front of people, um wasn't welcomed, so I think there's a sort of environment which everybody contributes to whatever, sort of, extent they wish to, and um..

S – You are not penalised by (No – A) the fact that if you didn't know enough, or act.., in fact there's been some people in the class that have gone, do you know what I don't understand that , I don't understand where we are going with this and why do we have to do this and Alex is always very good at kind of, not taking that as a negative and (Mmm – A) and going well let's just discuss it and let's transfer it to a positive and how can we overcome this, and I think in fact, as individuals and as a group we are all the better for that (Mmm – A) really.

M – Mmm it's all about you being in the classroom as well (Yes – S)

S – Absolutely

M – Excellent. Thankyou. I was going to say to you, what, what about the relationships within the classroom between you and each other, and you and Alex, how, erm, how effective has that been in that sort of free speech, that free discussion being able to, have you, have you been able to say, you know, negative things, or exactly the things that you've been saying? It sounds like you have. Do you want to add anything more about the relations, I mean, how is Alex as a teacher, um, elicited that, how has he encouraged that really? Hard question.

S – It is a hard question (Yeah – A) because you will, you will take that as a, you know, as an individual I suppose (mm – A). Um, er, having other electives and other and in fact I am with Alex in core science, he's taught me this year in core science and there is a very different dynamic in core science, but that might be, um, and I spoke to Alex about this, um, and that might, we've had this discussion, it might be that they're not there because they really want to be there (Yeah – A) and we're, we're here because we chose it and we want to do well in it. Um, so we have, we have an ulterior motive in some respects.

A – It makes a difference to the classroom environment doesn't it?

S – But we all get on (Mmm – A) very, very well and there's always individuals that very, very much stick together and it's like that wherever you go, so that, that doesn't change but, um er, I think what's happened with Alex, and I'd like to think that I'd take something from his style of teaching is he earnt our respect (Mmm – A), that's what's happened.

M – Can you say how he did that, because that's a lovely thing to hear about, you know, a colleague who I esteem highly? How has he done that? How has he earned you respect? Again, that's just a difficult question and it may need a lot of reflection but it is, it is, not everybody has that do they in their classes?

A – I think, for me, well, I'm probably slightly biased because he's my academic tutor so he helps me with all sorts of things outside of the subject as well, but within lectures he's very much, um when we are discussing things, sort of the way that he phrases his own opinions and things, he is very clear that it is his opinion and it's not just because I'm the lecturer what I say goes kind of thing (Mmm – S) and, yeah, it's very much about discussion a lot of the time, so when he sort of throws ideas out and things he's , welcoming of what people have to say and other people's views and opinions and things so it's not, sort of, um, not like he's sort of (LAUGHS), pour knowledge in your head (LAUGHS) (Mmm – M) he is very much getting you involved and the whole group I think.

S – Yeah, I think, um, one of the things he does as well is, um, he, he always, um, responds to us and he always tells us if we have done well, so if we have been into school he will very, very quickly respond and say you were great I've had positive feedback from you , some people did this and they really liked that, so we always get feedback and, all, actually thinking about it know, always at the end of a lecture he will summarise what we have done, and, and the praise is always there…

A – That's true actually…

S – He does, doesn't he?

A – It's just sort of something that now you mention it (Yes – S) he does do that, it's you know, very subtle because it's not (Yeah, Yeah – S), up to this point has not been obvious to me. Sounds silly, because it should be…

S – and so you come out and go that was great, I , I never think, huff, here we again, and there are lectures that I go in to and I go why, why? What have I got out of this? Has that made me a better person? Have I learnt something here? And I can guarantee on a Monday or it used to be a Tuesday I can guarantee that I would have learnt something.

M – Excellent.

A – First thing on a Monday morning as well, to be quite happy and content (Yeah, Yeah – S) with a lecture for two, three hours is…

M – You said about him praising at the end of the session, so what sort of thing would he typically say about, you know, he'd summarise first and then he'd say something? Can you think of something, you said he was subtle so it may not be possible to…

A – Yeah, difficult to say, to be specific, because as I have said I hadn't really noticed it so much until Suzanne said it now, but then you think actually Alex does do that and it's sort of not the case in other lectures so much.

S – Yeah, I think he would, he would reflect on the work that we'd done so, um, he would say, OK, what we did today was whatever, and he would always say I really liked...the fact that you, you took this, and this isn't, actually what I was thinking about but you took it, er, further along, and do you, it was really great, do you think you would use that in the classroom? And you say yes and he would as well how would you use it, could you even expand it further, and you'd talk even more, and you'd go that was great and in, in fact, also the class would go, would also notice each group's work as well and say I liked that..

A –Yeah, they've done this

S – So, we all talk about each individual's work. I think that's what he does, he kind of steers us in this way by saying like, you know, you've done some really good work today, do you think you could use this? How would you use it? It makes you reflect, so you walk out of there going oh yeah, maybe I could use that, and take that and…

A – We did do this and that did work, or...

S – Yeah, yeah.

A –What we learnt from that kind of thing.

M – I know you saw, you saw a video of him teaching, didn't you? And you saw a bit of his academic work that he's writing for his PhD and you had to critique that, oh , brave people, how, how did that make you feel as, as, students, student-teachers, er, how did that make you feel about that and your relationship with him in that?

A – I quite liked reading his academic work because it's nice to know that he, he, because obviously we are doing assignments all of the time and bits and pieces it's nice to sort of, you almost share in that, I think you can very quickly think of lecturers as, you know, having gone through that and not doing it anymore but the fact that we've been involved in this sort of, well Alex's learning process, whatever you want to call it has been quite nice that you're seeing both sides of things and knowing that you're, well, academic work, well academic writing is something that I struggle with and I have to put a lot of work into it, so it's nice to see somebody who's in a position as Alex is in and, he's sort of working on it and improving in that as well, so it was quite, enjoyable is the wrong word, but it was nice, nice to see it.

S – I think that, em, er, I am the same , I , I think that um, I'm more of an abstract person so, you know, I'm always, I like to do it and I'm never sure whether, you know, when I read things I like completely take it in all of the time, um, but I was reading it, and, for me, um, I've read so many journals and so many academic journals that his work was quite refreshing because, um, you could understand it and, that it was funny, because I was sitting next to Francesca and Francesca, um, who's very clever, um , started to critique it and I was uncomfortable critiquing it but, then again, maybe I don't have the skill to critique it, but she critiqued it, and she spoke to him about it and it was quite interesting to, er, to kind of watch this dynamic happening because I think he has a great deal of respect, well he has a great deal of respect for all of us, but I think that Francesca writes very academically and it, you know, he was, he, he took it all and it was like yes that's interesting I hadn't really considered that , so that was quite nice to watch that going on but personally I'm like, you know, do you really want me to give you feedback when I'm not as good as you?

M – Well he did, he did…

S – But you know, that's difficult. But I could give him feedback on the, on the video, but maybe not (Yuh – M)

M - I know, I know, I totally understand why, but he was searching for it and I think that is a mark of the humility of the man isn't it? (Yes – S) that he would bring that to you. That's great thank you. Um, did you ever feel coerced into studying sustainability? Did you..?

S – For me, no (No – M), because my other specialist subject is design and technology and, erm, I feel very, very angry that sustainable, sustainability is not in the curriculum anymore, so, if we, if we can get it in anywhere I'm all for it and so I'm, I'm like hand raised up as high as I possibly can, and I will challenge, and champion it the whole way through. So for me. No.

A – I wouldn't say that it's at all been, speaking as a member of the whole lecture group, I wouldn't say it's sort of been forced upon us in anyway, um, from my personal standpoint, I think, I don't know, I think, the more I study the more I view education, well, primary, in particular, as sort of preparing children for their later, whether academic life or just life in general and it, it seems like an issue which is go… certainly is important now as in the future it's going to be very, very important and, I think, Alex has helped me to draw those two things together. So, I, I think it's been really useful, um, especially considering the things that we need to know for science teaching we're doing in cores so this is, sort of, our breadth of study, you now, our deeper understanding of how, erm, issues for future and present issues as well are, can be linked up with the curriculum, it's not the curriculum something that stands alone, it's, you know, without moving children forward.

M – Thankyou very much, thankyou. OK, could we just go on now to the learning logs? How did you feel about completing those? And what did you see the purpose of that…as being?

S – Um, I'm, I'm not, er the best writer in the world I suppose so, um, I think mine was fairly basic, um, I could have probably if I'd had more time put some more thought into it, um , er, maybe. Maybe it would've been better if, if I'd had like a er, er a little questionnaire to fill out , um with a couple of sentences underneath saying why I thought this was good, could, or, or, doing something where I could level how, how well this was being taught or what was being taught. It might have helped me personally, so, um…

M - So, more structure to it really.

S – Yes, I think so, because I will probably, looking back on it now, I would probably just wrote very similar things each week, and I'm better talking about it.

M – Mm, maybe that's a way forward. Perhaps you all have one of these little things and you actually put thoughts down, um, you know, together maybe in twos or something that might be a way Alex could take his practice on. OK.

A – Um, I think it was use... , I found it useful in terms of reflecting on my own learning, erm, …in terms of how useful what I wrote down was to Alex I obviously don't know, um, but, yeah I suppose I was going to say the same as Suzanne, the kind of things I wrote, see, I think were quite similar week to week, um, but yeah, I found it useful just to sort of draw lectures together at the end and think, you know, how I'd developed my understanding and what sort of went on and things, um, but yeah I'm not sure how useful it was, um, from the other side (laughs).

M – Mmm, another question, did you feel able to critique Alex's teaching through those or was it very much a reflective, um, position you took up?

S – I think it was just reflective

A- Yeah, I was purely reflective (Yeah – S). I don't think I critiqued.

M – Perhaps it might be more helpful if you did have those sections that you were talking about and maybe critique there.

S – It was interesting, one time, one lecture, and, er, we got on to a dis… and some of us were left behind, were you there? And we got left behind and we started talking (Oh Yeah, I was there – A) about the teaching that had happened and then about sustainability and how we can teach children (It was something like – A). Yeah, it kind of went off into a tangent, so Alex just said can I, can I just record this? So we were there for over half an hour and we were just talking, there were about six of us left and we were just talking (Mm – A) and that was really nice because he probably got more information out of that than writing and reflecting on…

M – That was a very natural response, wasn't it?

A – Yeah, a sort of stage to be on rather than putting something permanent in writing when you are just discussing and talking you are sort of going off each other's ideas and stuff.

M – It's lovely to hear you at the end, you know, he, he gives you praise and, so I am just wondering, you know, is that a two way thing, can you at that point at the end of the lecture come back and say to him well we really liked your way of doing it this or, you know, perhaps you could rethink, that way, do you have, do you feel you could say that at that point?

S – I would say so, definitely.

M – Alex would be open to that sort of working (S – yeah).

A – Yeah, I don't think, erm, the kind of person that Alex is, I wouldn't hesitate to say that didn't work either, that hasn't helped me, he wouldn't see that as, well, a criticism yes, but would see it as a positive criticism (Yeah – S), but I certainly wouldn't hesitate in…

S – I agree, I agree with that.

M – You say that, at that point, the sort of person that Alex is (A – yeah), if you, if you could sum up Alex in a couple of, maybe adjectives or words, I mean it's very difficult to sum up a person in that way, but what is it about Alex in the classroom, specifically, you've said it already I think, but specifically that would say, I could say that to him and he would take that in the right, in the right way?

S – Approachable

A – Yeah, definitely, so he's again, because he's my academic tutor I'm coming at it from a slightly biased point of view because I email him all of the time about other things, but, yeah, definitely approachable person.

S – And transparent (Mmm – A), as well, and not, and not in a kind of in emotions, you know, this, this is it, this is everything that we are gonna do, it can work, it might work, it might go off in a different way, but let's see how we do with this, you know, we are all in this together, so, that, that's what I mean by transparent.

A – Yeah, yeah, there's a number of times when things have been said in lectures or sort of people presented different activities they put together or something that you can see Alex has said, well this is very good, they only problem I might have is this, so you can see that, and, you know, you can see that he is helping people to develop in that way, so yeah, very much, you know, know what, so everything that he says you can see what his intentions are, things aren't sort of throw away comments or things aren't sort of masked (M – No).

M – Anything else you want to add?

S – I think maybe quite a lot of lecturers, and I've said this to Alex as well, could, we are all told, as, as, on this course to be reflective practitioners and I think that some lecturers should come in and look at how Alex teaches (Mmm – A) and be reflective because, personally for me, he's exceptional.

A- Mmm. No, I would agree. I have thoroughly enjoyed, um, our elective science, I think I have really benefited from it and, in fact, talking to people who don't do elective science and attend just core lectures for science, it always seems the case that people just don't have a bad word to say about his teaching in terms of them being engaged. Yeah, I would say in terms of my experience of core science over three years it hasn't compared to my elective lectures, it's sort of apples and oranges in terms of how I've engaged, it certainly engaged with it and enjoyed it . It makes all of the difference.

Appendix 7 – My Learning Log

Session 2 - 24th April 2012

Despite positive thoughts from the learning logs last week and the fact that each group had identified areas of their subject knowledge that they would like to discuss I thought that using the puppets as a context for the class to discuss ecological issues, may act as a 'foil' for this as I was still concerned that I may be forcing my ideas on them.

The students were asked to use their puppets to develop a concept cartoon about an ecological issue of their choosing.

The topics that were chosen were; sea levels rising, recycling a coke can, and water usage.

Following last week, I was again surprised how engaged the students were around each subject area. The concept cartoons that were produced allowed for thought-provoking discussions.

From this I knew that I needed to develop my understanding of why the sea levels are rising and I think I may have confused the students in helping to explain this phenomenon. Perhaps I should have kept quiet.

I need to develop my understanding of why there are droughts; "where does the water go????"

Again, as with last week, I felt invigorated with the depth of discussion. For many I think it was still a fact-finding session, but at times you see signs of action – the fact that one group wanted to invent an object which transports bath water to your water butt – I felt guilty telling them that this had probably been invented.

A cursory reading of the learning logs is pleasing. Some saw the session as an opportunity to develop their understanding of the use of puppets, which it probably was, with little focus on the ecological issues. Many commented that they really enjoy and benefit from the group discussions (although I do think we have done this for 2 weeks now so may need a change of teaching strategy) and some mentioned that the session had highlighted weaknesses in their subject knowledge and that they were going to go away to find out more!

Have put a lot of related subject knowledge links and questions on simmscap related to today's session. We will wait and see how many contribute if any – assignment time!

Session 3 - 1st May 2012

No responses from last week's posts on simmsCAPital. Disappointing but understandable as assessments are due in. But one student didn't even know there was a post

Rain all last night meant that the planned session of planting wheat and looking for snails as an activity to introduce biodiversity was probably not possible, so at 6am was trying to plan the session. Flooding seemed to be pertinent considering all the rain. So the plan was to plant the wheat (it has to be done this week). Introduce them to mind mapping, ask them to produce their own mind map around floods and then make rafts out of straws and foil.

I was really concerned that the students wouldn't want to come out in the drizzle, plant the wheat and get muddy. Really pleased with students attitude, interest in the process. We even had a chance to have a look at the neighbouring strawberries and discuss fruit formation and asexual reproduction. I get the sense that many people are interested but are we just at the fact-gathering stage? Is it enough to get them enthused? At some point I am going to need to join the dots up.

I felt by asking students to mind map ‘floods’ really was just forcing an issue on them and so gave this as suggestion but asked that they made a choice around science. One group was inspired to look at the life cycle of the strawberry, another ‘biodiversity’ because this interested them and others on rock cycle and space.

The raft model was very unconnected and as one student in their learning log has mentioned lacked any science theory behind it. More worringly for me was that the activity was not commensurate with my values; straws were being used and thrown away and even though we recycled some of the foil the whole activity used potentially non-renenwable resources. As Orr says this is the hidden curriculum – I say one thing but promote something else. I want to share this with the students and gauge what they feel. I know some may say that we recycled the foil but I also need to bring up the fact that school’s /society is obsessed with recycling – which is not the way forward.

Having read students’ learning logs – not many are being critical about the teaching – 2 maybe. How do I help develop this form of reflection.

Session 6 - 1st October 2012

A real eye opener today. Following our visit to the River Crane, I brought up the issue that Thames water had decided to flood the river with sewage rather than Heathrow runway. I gave them time to discuss their thoughts and to feedback what they felt about it. At the end we voted on whether Thames Water had made the correct decision. I was quite shocked and disappointed that only one student felt they shouldn’t have flooded the river – 2/3s said it was the right thing to do and approx 1/3 were undecided. My worry is that money and inconvenience is given priority over the disruption of a living ecosystem with the students knowing that all life in the river (from the where the sewage was emptied down) was killed. The students seemed to justify this by stating that life had returned to the river within the year.

The students would like to read the chapter I have written ‘about them’ for the st mary’s book next week. This should be interesting. They didn’t really make much comment about the video of me teaching. I wonder if they feel they can critique my writing more because it’s about them.

Session 7 - 8th October 2012

A mish mash of a day**.** Initially it was so much fun to get outside, even in the rain with another group. I was certainly well aware of my awe and wonder for nature, which I believe the others had as well. I certainly learnt from them today.

I wasn’t so worried about showing them my writing. I wonder if this is because a) I feel secure in what I have written, b) think they may be more interested because, in part, it is about them.

Comments (although they may be difficult to hear on the mp3 recording) were very positive about what we do in science. In fact it was more about the style of teaching than ecoliteracy. Comments about good relationships, feeling more like a class, the flexibility were very positive and justifies what I have done with them and about what a ‘good’ class should look like. A comment that I was being too harsh on myself resounded and that this student would have told me if the focus was not to her benefit. Discussion was limited to about a third of the group, should I be concerned?

This is in stark contrast to how I was feeling at the end of last week's session about their choices to flood the River Crane with sewage. However, what is the next step if I am doing something correct. How satisfied can I be with how much influence I have had?

I am interested to know what they feel about the process, although did not ask them to fill out their learning log this week as I felt that this would be too much…a thought for a later time.

Session 8 - 15th October 2012

I was a little worried that the group would think that I had chosen the topic for the science week – even though it had been requested by the headteacher ie ramming it down their throats, but there didn't seem to be an issue. I was even hoping that it wouldn't be around sustainability so that we could cover some other areas of science. We must focus on other areas – although this doesn't seem to be an issue according to the learning logs from last week

My slight concern is that for some of them, their knowledge around the issues of energy, water and waste may be a barrier. I kept holding back from putting in my thoughts around the issues for fear of confusing. Is this something I should have done? Will they come to the same conclusions?

We spent an hour and a half on this planning. I felt this was productive and hope that the students felt this way.

Many groans about filling in the learning log! What do I do? Am I getting quality feedback?

Session 9 – 22nd October 2012

Kathy Hill from Sunny Schools came in. Her brief was to link her work about energy, solar power, to science.

This was the session I would have liked to have done with the students as it really got to the nitty gritty about the 'problems' in the world although it did not focus too much on 'people' until the end of the session. This was somewhat off the science curriculum and I would have felt conscious of delivering this. However, it provided a background for all of the work that we have done, or its justification. I was a little embarrassed about their lack of knowledge around climate change, energy etc when I had told her that we had been doing a lot of work around this. Although the work we have been doing has been about making it accessible to schools.

By the end of the three hours I did wonder if it had gone on too long, but their comments seemed to suggest that it had not. I am positive that had I done this first thing at the beginning of the course that they would have questioned the relevance and am pleased how receptive to these issues the group has become.

Session 10 – 11th February 2013

I asked a lot from them today. Reflection on sustainability week (a slight worry – when asked how it went the first comment was; it went well because they provided a lot of blue paper), followed by filling in the initial questionnaire again and making a comparison. Again, I wonder how much criticality I can expect in a group – also do I explain it enough?

Paul was great again, although the first half is always doom and gloom before he goes on to report the success stories. He talked about needing a new kind of schooling and being non-conformists. I wondered how many of them got that. I know it's taken me all through my Masters and up to the current to get to grips with that idea. For this reason it was difficult to see if they got the bigger picture or whether they thought it was just another rant. Only about 6 were involved in the conversation at the end. Was this because they had been talked to for 100 minutes odd? Were they bored?

I decided against asking them to complete their final evaluation of the course at this point as I think I would not have got a fresh response. So have read out the questions I would like them to answer so that they can have time to think about it and complete during presentation eek.

Appendix 8 – Learning Diary Example

Session 1 – 17th April 2012

During this session we discussed as a class the experience we had on our school placement. Alex lead this discussion and through this, we all had a voice.

We used the seeds that had been harvested to re-plant for our allotment. Would have liked to have planted more. Very eager to get over to the allotment. Very relevant as am interested in planting in schools.

Session 2 - 24th April 2012

Today's session started with using puppets in the classroom, mainly in science. I did not need any persuasion on using the puppets as I believe that they can break-down barriers and difficult concepts. It can also direct your teaching to be more child lead

Thinking about the global issues from last week we used the puppets to bring the issues into the classroom. Good direction from Alex – Really enjoyed this session. Made me really think about how both subject (areas) could be tackled.

Session 3 – 1st May 2012

The session today incorporated mindmaps, planting, memory route, floating and sinking.

Mind maps – How they can benefit teaching in the classroom – I use these all the time and can see how they help learning and remembering different topics. Interesting to find out about the psychology behind it.

Memory route – Alex suggested it could be used in a plenary – wonderful idea as it keeps teacher talk to a min and also allows the children to take control of their own learning.

Planting – I think this is a great thing to do and children love being outside. Also there is so much that they can learn by doing.

Session 4 - 8th May 2012

The first part of the session we looked at the website for looking at snail. This fed into collection and classifying. Showed how you could use this in school and enhance learning.

We also planted the seeds that we grew in class. Going out of the classroom can then see the process of seed-plant-veg.

Watching the film was interesting as it makes you think about how there are misconceptions – How would the children feel? What impact do the films have in science?

Session 5 – 24th September 2012. River Crane Trip. No diary entry

Session 6 – 1st October 2012

Today we discussed as a group how we would tackle the assignment. This was very good as was able to take lots of different ideas to comprehend how to develop the writing.

Using ideas for LOC at the river crane was very interesting. All of us came up with lots of original and creative ideas of how to engage learning and utilise the area.

Session 7 – 8th October 2012. Chapter critique. No diary entry

Session 8 – 15th October2012

Today's session started with the video of the 'space man' how could we use to science to stimulate learning in the c/room.

Thought about what science was involved how could adapt it in our teaching.

Started to work towards a lesson plan to take into class around sustainability.

Good idea to work as a group, bounce ideas around and then take them away with other members to reduce it to an effective lesson plan.

Noted that some of us really started to have creative ideas that we could bring into the classroom.

Session 9 – 22nd October 2012

Sunny Schools

This session focused on how we could discuss climate change / sus and re-newable energy in Primary school.

Kathy was very informative and gave a clear argument on why we should use this in school.

Lots of interesting ideas came out of the group activities. Kathy also gave some good example on how we could use it in class.

I learnt something new in this session and now feel a lot more confident in teaching this.

Session 10 – 11th February 2013

Reflection on teaching.

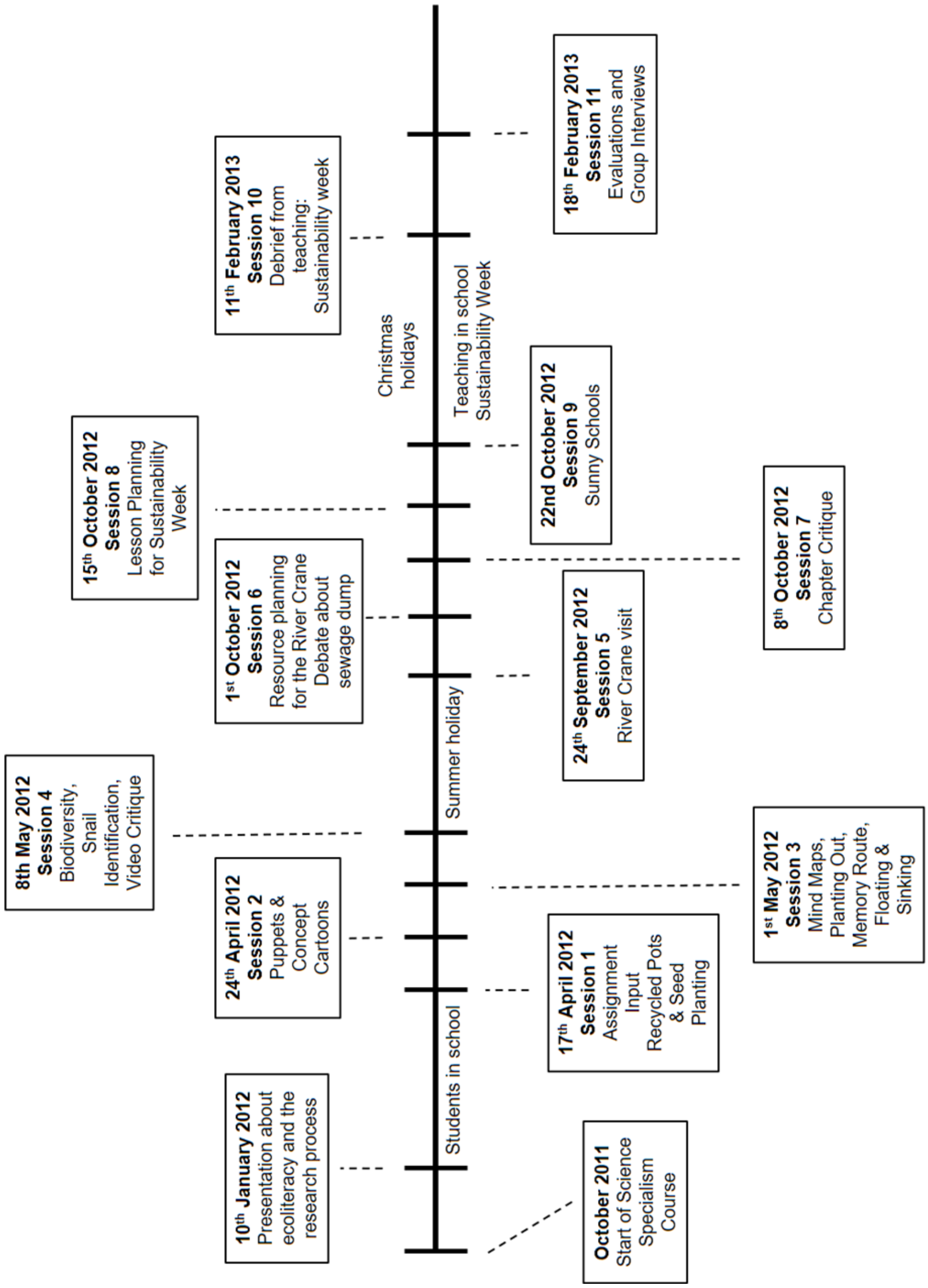
When planning for Year 2 our group had lots of ideas. However we quickly realised that we would have to restrict it with the amount of time given. What we were able to do was start a topic that could create discussion. The mandate was for an investigation – which we achieved, but it would have been nice to relate this to the water process.

What would have been better is if we had more time to continue with one more lesson.

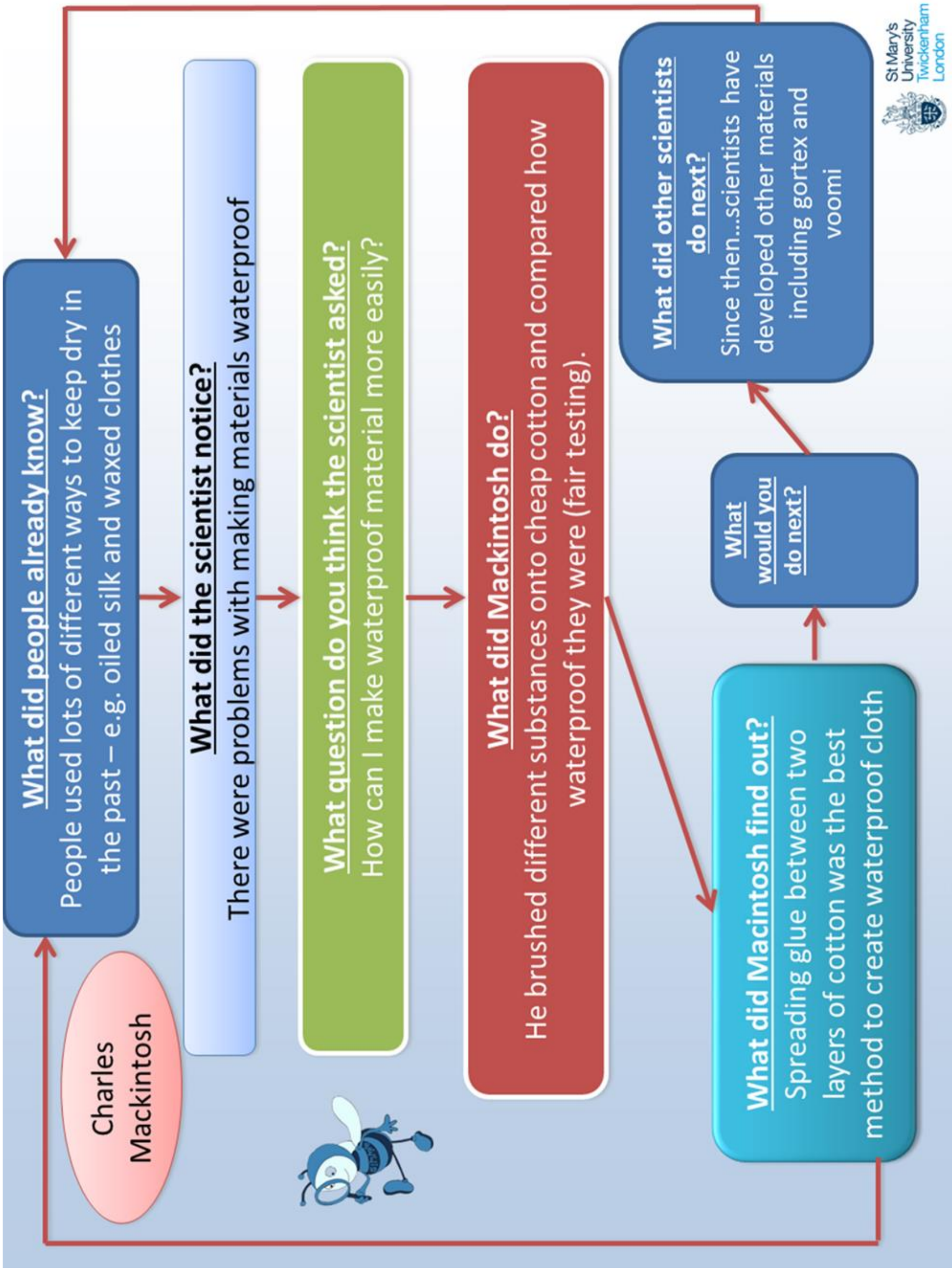
When teaching, the children were engaged from the start. There was lots of scientific talk and most of the class were able to understand that they were investigating. By the third lesson, I decided to change the way they would investigate. I set them a challenge to see who could make the cleanest water. This allowed each group to discuss what process they used and why this was best.

I believe that having more understanding at how each class worked within the lesson allowed me to adapt and adjust it to meet the individual's needs.

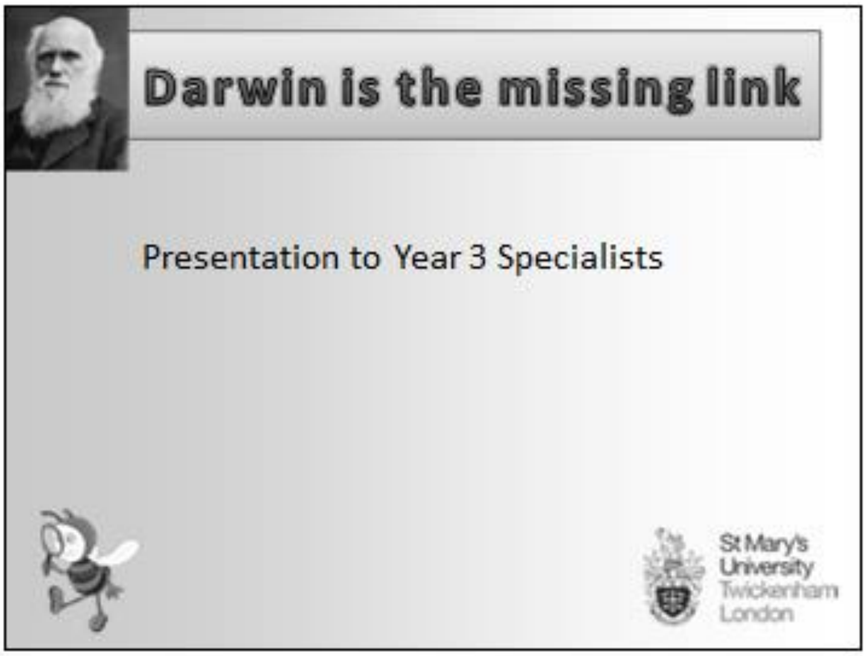
Appendix 9 – Course Outline: Cycle 1



Appendix 10 – Completed Famous Scientist Template



Appendix 11 - Famous Scientist Presentation to Students in Cycle 2, December 2016



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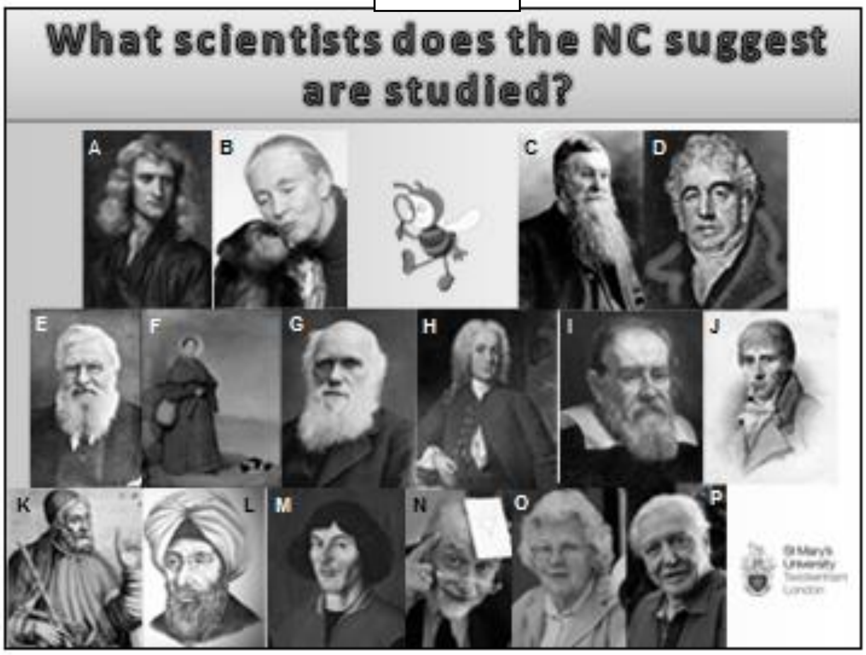

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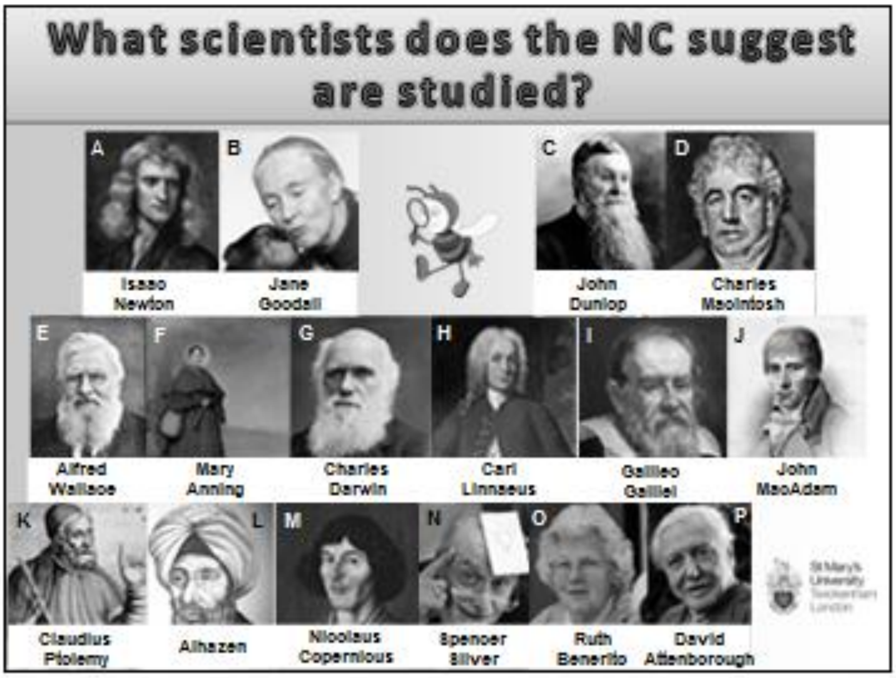

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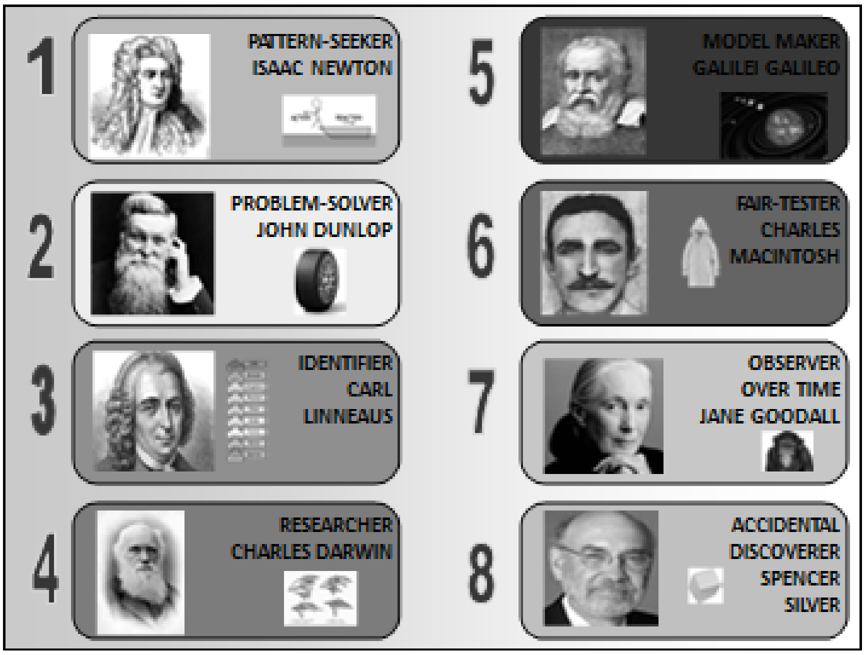

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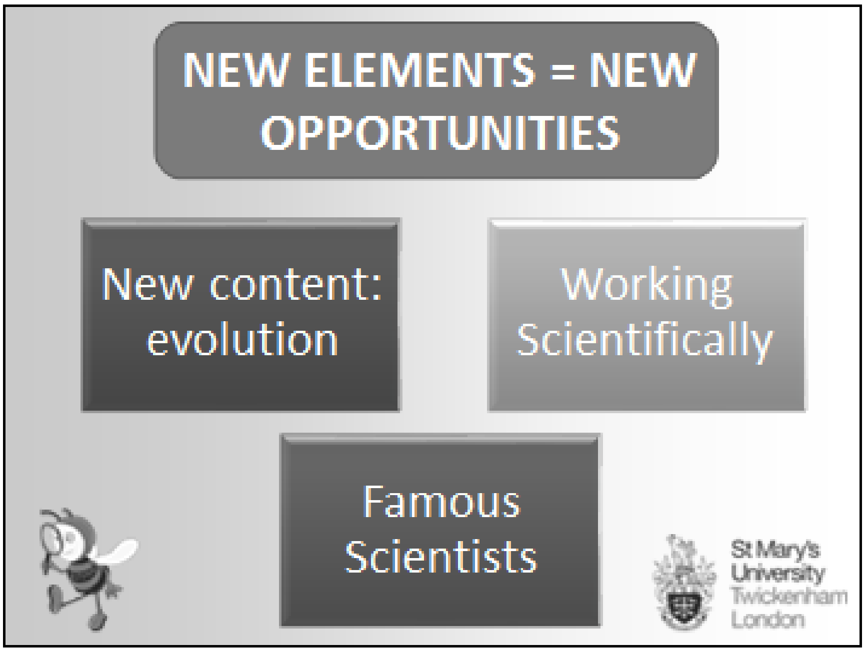

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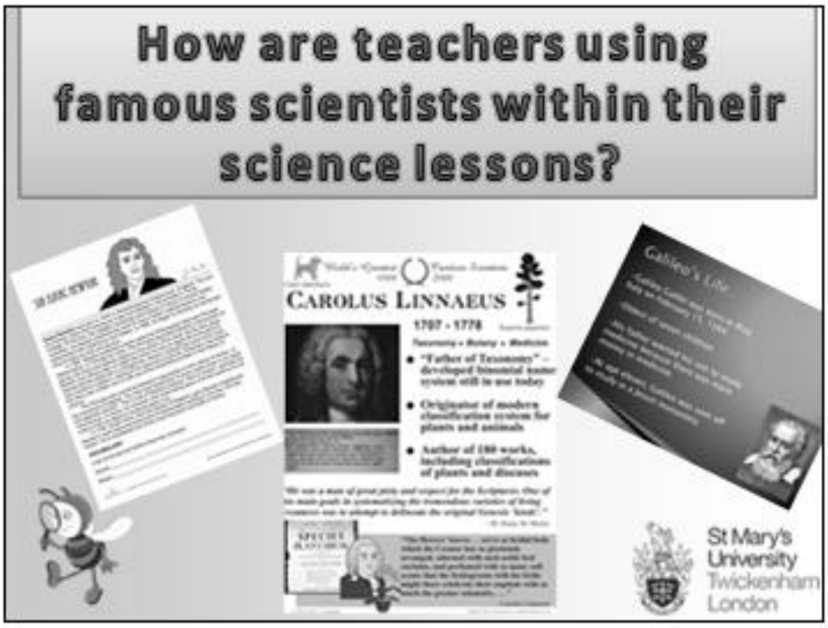

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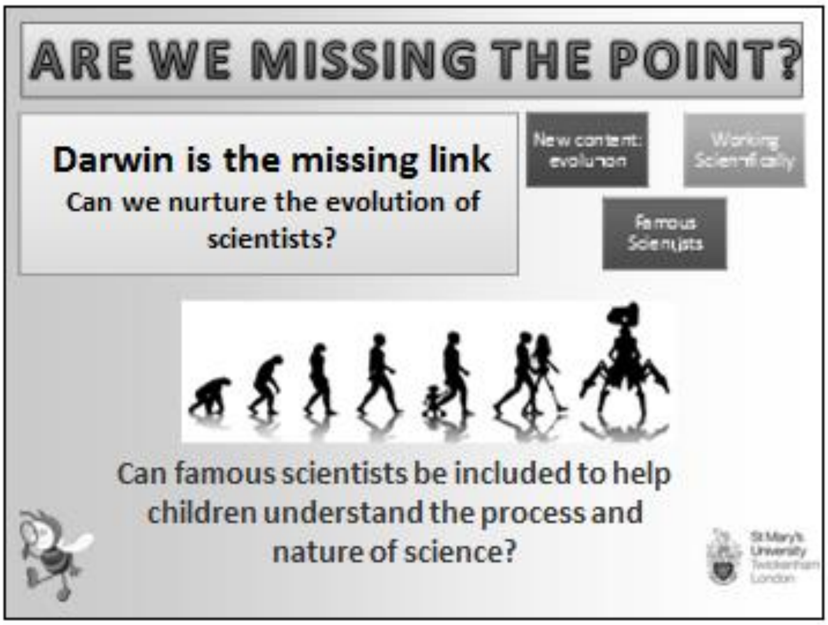

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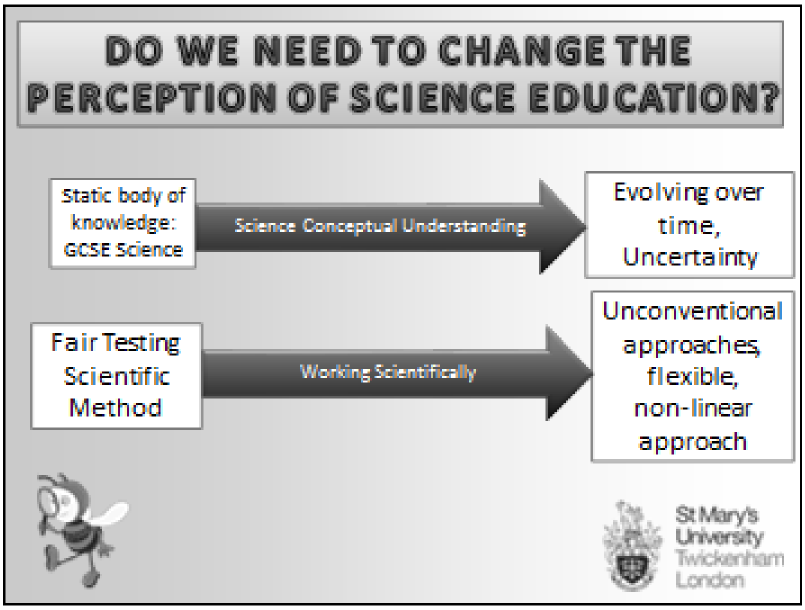
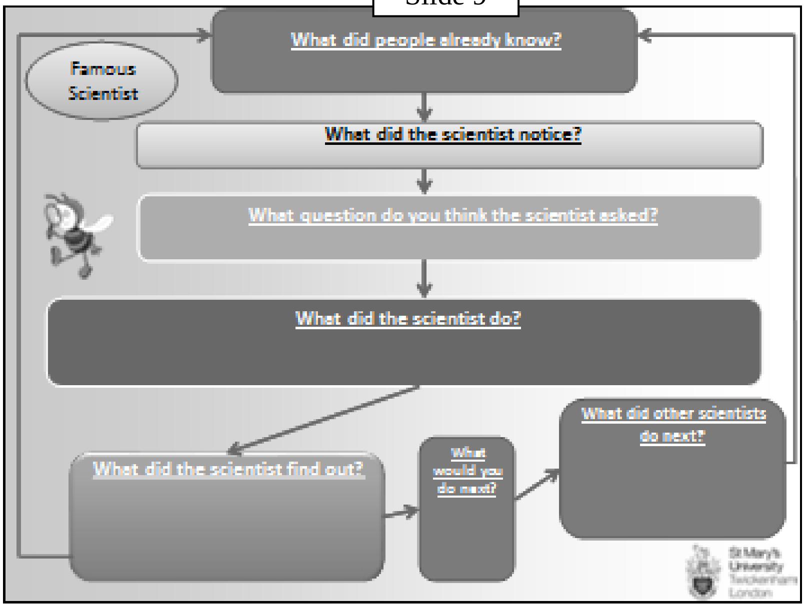


Slide 9



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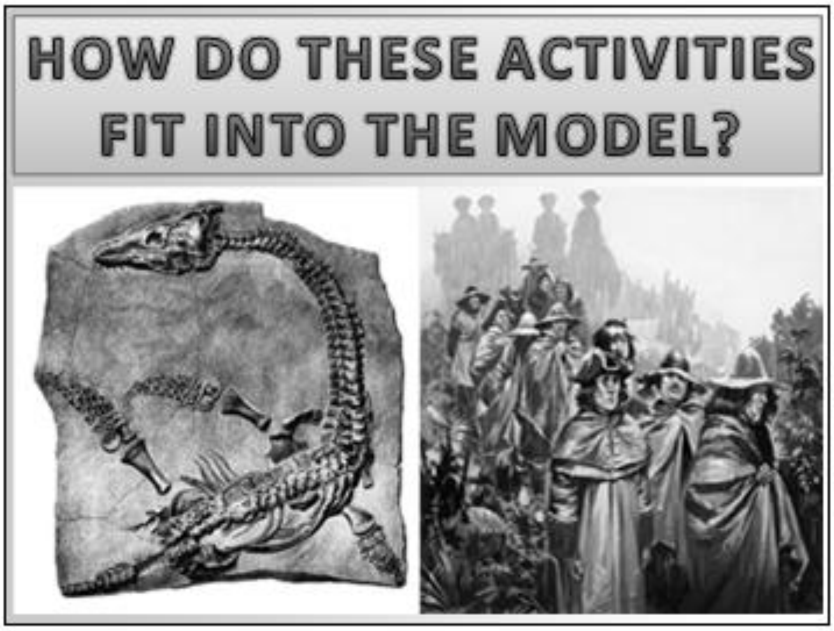

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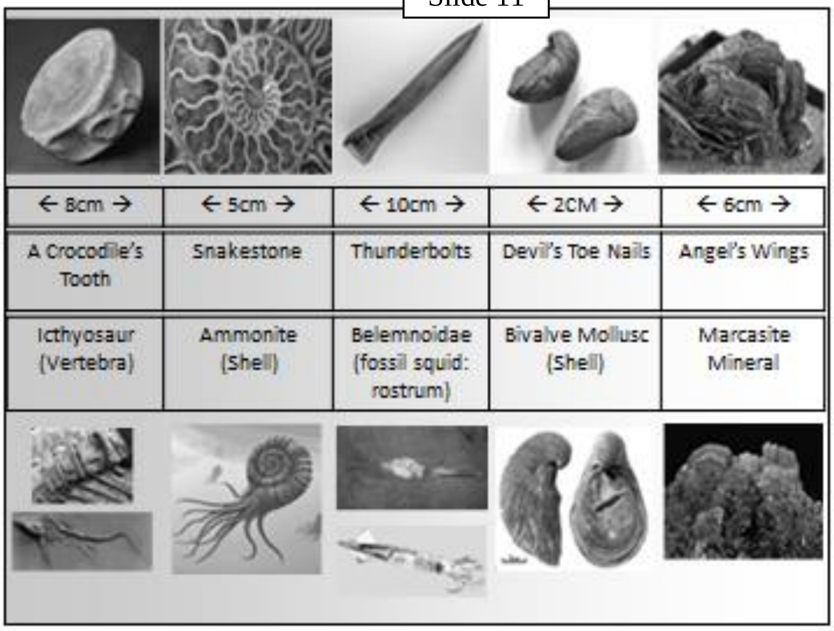

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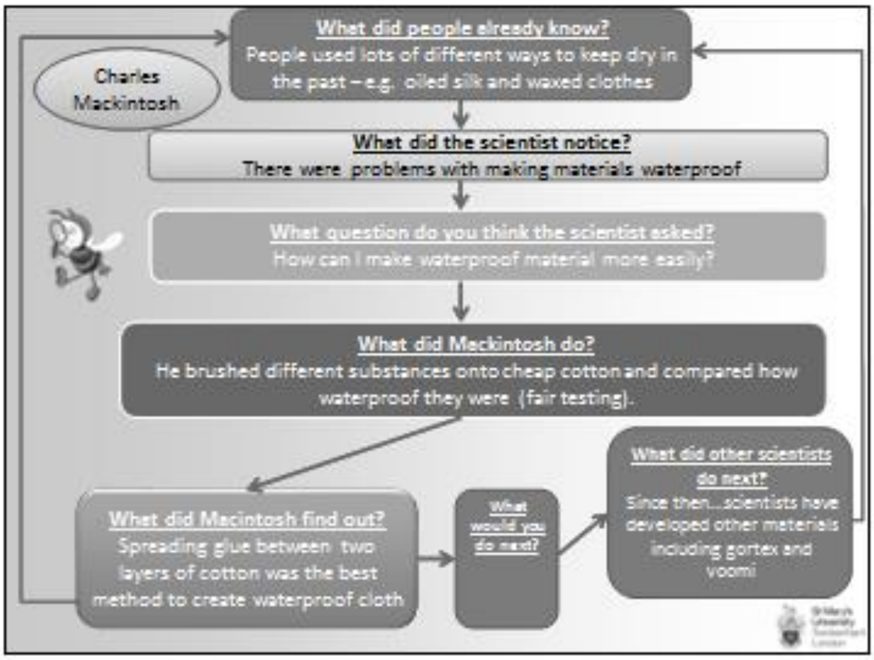
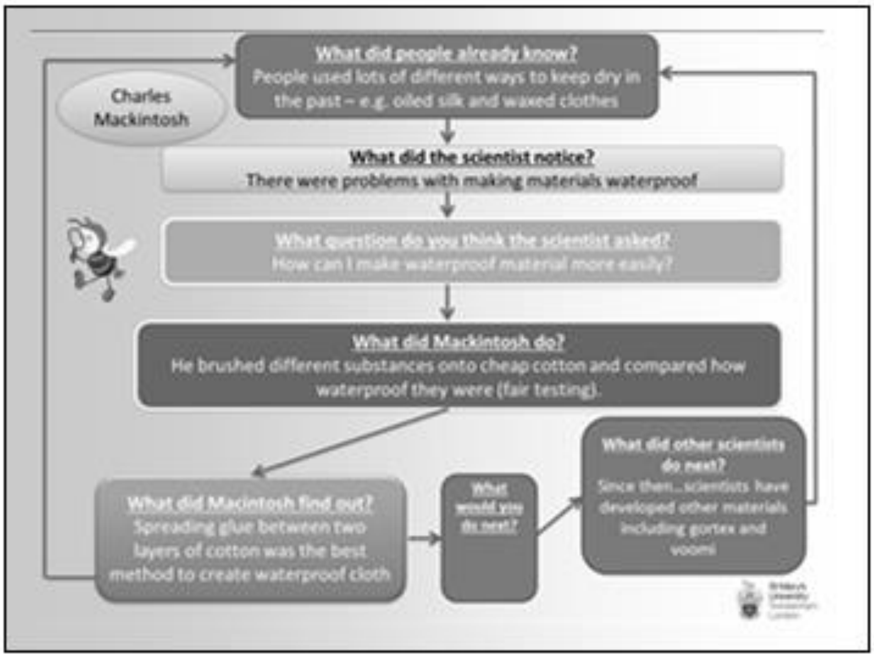


Slide 13



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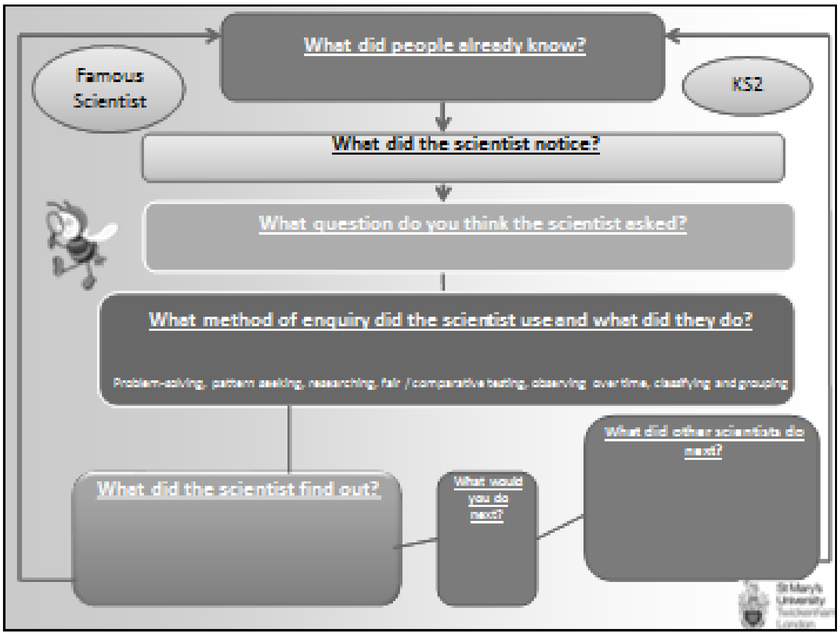

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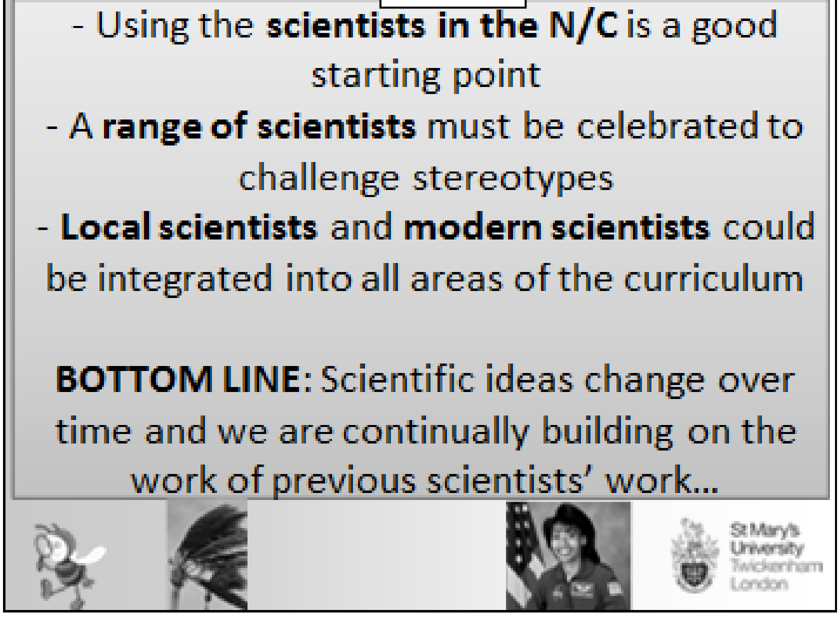

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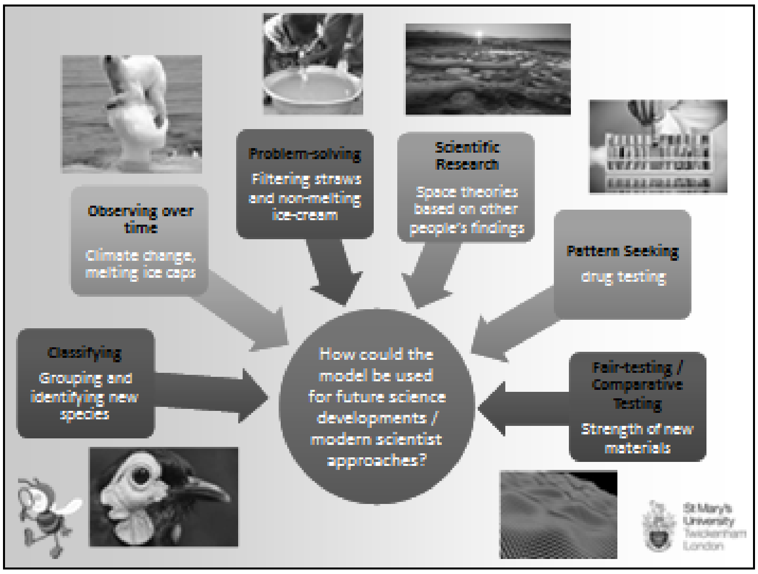

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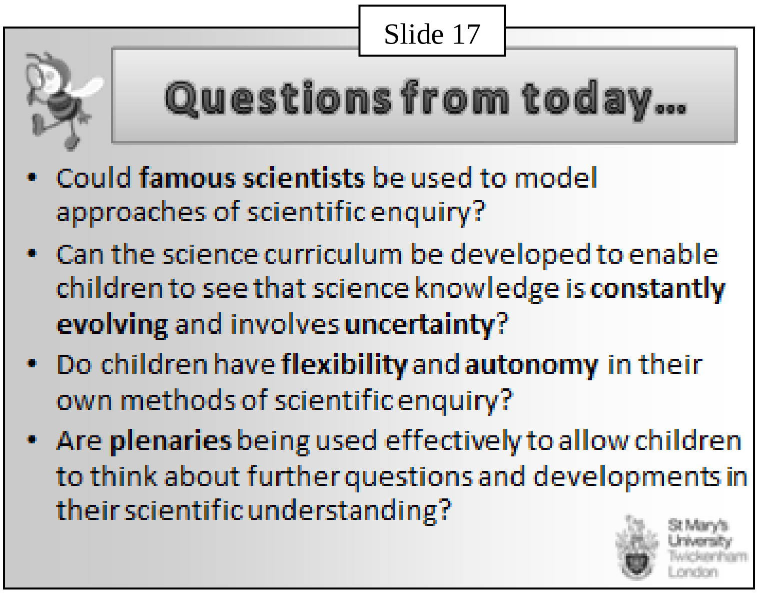

Slide 18