# TOWARD ECOLOGICAL LITERACY: A PERMACULTURE APPROACH TO JUNIOR SECONDARY SCIENCE

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# ABSTRACT

Environmental, economic, and social trends suggest the need for more sustainable ways of thinking and patterns of behavior. Such a shift would require humanity to function at high levels of ecological literacy, which relies on a certain amount of scientific literacy. However, troubling evidence indicates an international pattern of student disengagement with science at the secondary level. Evidence also suggests that it is difficult to integrate environmental or sustainability education at this level, both within New Zealand and elsewhere. This research was aimed at examining the use of a novel approach, using permaculture, in junior secondary science (years 9 and 10) to enhance students' ecological and scientific literacy, as well as their attitudes toward studying science in school.

Permaculture is an ecological design system based on science and ethics. A permaculture approach to science education involves eco-design thinking as well as the use of local permaculture properties and practitioners, and the science behind common permaculture practices. The approach is also meant to be relevant and engaging, and to promote systems thinking. This study involved the design and delivery of an intervention based on permaculture principles to one year 10 science class in New Zealand.

Research took the form of a naturalistic, interpretive, mixed methods case study, which included the use of questionnaires, interviews, and observations. Data collection focused on the impacts of a permaculture approach on the teaching and learning of science, on students' ecological literacy, and on students' attitudes toward learning science in school. Pre- and post-intervention questionnaires probed students' opinions on the environment, science, and learning science in school, and tested their sustainable thinking and systems thinking with concept mapping and SOLO Taxonomy exercises. Classroom observations took place over the course of 12 weeks, on average 3 days per week, totaling 31 days. Before and after some classroom visits I had informal conversations with the teacher, along with three formal interviews before, during and after the intervention. Three focus groups of students were interviewed immediately following the intervention.

Findings show that a permaculture approach to junior secondary science can impact positively on students' understanding of science and sustainability, and may impact on their attitudes toward studying science in school. It also appeared to impact positively on the science teacher's attitude toward including sustainability in his teaching practice, and on his own sustainability learning. Regarding both students and teachers, a permaculture approach appears to have been effective to *cultivate* attitudes and *trellis* learning.

The teacher and the students responded favorably to many aspects of the intervention, including the overall focus on the environment, the field trips, and some classroom learning activities. The teacher reported appreciating the way the intervention contextualized science with real world examples. Most students reported appreciating the experiential aspects of the intervention, as well as the relevance that a permaculture approach to science education provided. Findings indicate that advances in ecological and scientific literacy varied among students. Some students appeared: to improve their use of science and sustainability vocabulary; to become more aware of select socio-scientific issues; and, to better recognize scientific and ecological limits and possibilities. Some students also showed advances in sustainable thinking and systems thinking. Although many students expressed concern about issues such as pollution, wildlife, and genetic engineering – and prioritized protecting the environment over making money – there appeared to be a disconnect between these feelings and a sense of personal responsibility to act. Most students reported enjoying learning science with a focus on the environment, with one cohort indicating much greater enjoyment of the permaculture approach than their usual level of enjoyment of learning science in school.

Trends in environmental degradation, population growth, energy inflation, and economic stagnation – especially pronounced since the beginning of this inquiry in 2008 – indicate that the world of the future will require ecologically literate citizens who can design and create truly sustainable systems for all human endeavors. Cultivating such citizens, and trellising their science and sustainability learning has implications for science education. This thesis identifies an innovative approach for junior secondary science in New Zealand that provides a way towards a more sustainable future.

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I wish to thank my supervisors, Dr. Chris Eames, Professor Richard Coll, and Dr. Katherine Otrel-Cass. This thesis is dedicated to my parents, Carol and Nelson, my wife, Dani, and my newborn baby, Verti. Verti comes from the root word for green and for truth. Hopefully, this thesis will advance both in our world.

I also would like to express my gratitude to the teacher and students who participated in this study.

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**"It's a new way of teaching science basically, isn't it? It's about making it relevant, global, and it's passionate, passionate"**

(Teacher)

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# CHAPTER ONE - INTRODUCTION

## 1.1 Chapter Outline

This study explores the potential impacts of a permaculture approach for junior secondary science on students' ecological and scientific literacy, and how it may also affect their attitudes toward studying science in school. This chapter begins by explaining the rationale for the study and the role of the researcher. Next, the context of the study is presented in three parts: education in New Zealand; environmental education (EE) in New Zealand; and, science education in New Zealand. This context is followed by the research focus, which consists of the research questions and a brief outline of the research. Next is a section explaining the significance of the research, and the final section provides an overview of the thesis chapters.

## 1.2 Rationale for this Study

Dire warnings have been issued regarding the environmental destructiveness of many contemporary human activities (Brown, 2008; Lovelock, 2006; United Nations, 2012). Many authors argue that education systems have failed to develop ecologically literate citizens who behave in sustainable ways (Blumstein & Saylan, 2007; Orr, 1994; Sterling, 2001). Some authors go so far as to claim that many times education works in direct conflict with the vision of a sustainable future (Blumstein & Saylan, 2007; Orr, 1994; Sipos, Battisti & Grimm, 2008; Sterling, 2001). Yet, education does have the potential to be part of the transformation to a sustainable world (Capra, 2008; Cutter-Mackenzie & Smith, 2003; Littledyke, Taylor & Eames, 2009; Sterling, 2001; United Nations Conference on Environment and Development, 1992). Considering the challenges and opportunities facing our planet, there appears to be an urgency to foster a transformation to a sustainable human presence on Earth. Any new approaches to transformative sustainability education should be grounded in research, yet innovative beyond that which has gone before. This inquiry seeks to do just that.

First and foremost, this inquiry identifies one potential solution for what have been identified as two problems: the difficulty of incorporating sustainability education in secondary schools (Bolstad, 2003; Cowie & Eames, 2004; Eames, Cowie & Bolstad, 2008; Gough, 2002; Steele, 2011); and, concerns about students' attitudes toward and engagement in learning science (Caygill, 2008; Crooks, Smith & Flockton, 2008; Tytler, Osborne, Williams, Tytler, & Cripps-Clark, 2008; White, 2003). These challenges are felt both internationally and in New Zealand. In the long term, these challenges threaten the scientific literacy and ecological literacy of adult populations of consumers, voters and decision-makers. Without improved levels of scientific and ecological literacy within the world's democracies, it is unlikely that we will be able to make the changes toward a more sustainable world that scientists and researchers advise (Brown, 2008; Intergovernmental Panel on Climate Change, 2007; United Nations, 2012).

A recent review of international science education literature (Tytler et al., 2008) found that students' disengagement with science learning after the primary/secondary transition is caused by an increase in transmissive teaching styles, more demanding schoolwork, and the perception among students that the science curriculum lacks relevance. In New Zealand, Bolstad and Hipkins (2008) report that disengagement in school science begins at year 8, accelerates during year 9, and continues into year 10. Compared to other nations in a 2006 Programme for International Student Assessment (PISA) (OECD, 2007) study focusing on scientific literacy, "New Zealand students collectively ascribed a below-average value to science" (Bolstad & Hipkins, 2008, p. 10). In other words, New Zealand students reported to value science less than students in half of the other participating nations.

The trend of student disengagement with science poses significant threats to both scientific and ecological literacy. Scientific literacy can be said to fall within the bounds of ecological literacy, which consists of: a significant level of scientific knowledge; an attitude of care for the environment; an overt tendency to take actions for the environment; and systems thinking skills. From this perspective, ecological literacy appears to be farther reaching, yet supported by scientific literacy. Some authors have recognized the potential for synergy between science education and sustainability education (Capra, 2005; Gough, 2004; Greunewald, 2004; Hart, 2007; Hodson, 2003; Stevenson, 2007). According to Gough (2004):

> Science education curriculum at lower secondary levels is in urgent need of change if we are to retain student interest in science studies in and beyond the

> compulsory years. Environmental education might be an appropriate emphasis for rekindling students' interest in the relevance of science, because young people are concerned about the state of the environment. (p. 231)

What Gough calls the ‘lower secondary years’ in Australia are known as the junior secondary years in New Zealand, which include years 9 and 10. Year 10 – the level at which this inquiry took place – is the last year of compulsory science education in New Zealand. She goes on to argue this mutualistic relationship:

> Science education needs environmental education to reassert itself in the curriculum by making science seem appropriate to a wider range of students and making it more culturally and socially relevant. Environmental education needs science education to underpin the achievement of its objectives and to provide it with a legitimate space in the curriculum to meet its goals because they are very unlikely to be achieved from the margins. (Gough, 2004, p. 237)

This type of synergistic outlook is shared by another Australian, and co-founder of the permaculture concept, Bill Mollison, who is known for insisting: “The problem is the solution” as he did in a documentary, *The Global Gardener*, about his work (Russell & Gailey, 1991). From a permaculture perspective, turning two problems into one solution is not unusual. For example, manure runoff may pollute a waterway while the fertility of nearby land diminishes by over-grazing. The solution to these two problems would be to compost the manure (to stabilize the nitrogen) and reapply it to the land. Permaculture, as a way of seeing, seeks out and maximizes beneficial relationships, the best of which are mutualistic. While permaculture was originally developed four decades ago to address food production, the design system can now be applied to all aspects of human society (Holmgren, 2002).

This inquiry sought to address the dual challenges of incorporating sustainability education at the secondary level and student disengagement in science with one solution: incorporating permaculture into the teaching and learning of junior secondary science. Permaculture is a science-based ecological design system developed in the 1970s in response to the perceived environmental and energy crises of the time (Mollison & Holmgren, 1978). Among other things, practicing permaculturists use their knowledge of science to develop energy efficient dwellings and landscapes full of organic food. In doing so they demonstrate the characteristics of ecological literacy: knowing, caring, acting, and systems thinking. Permaculturists are experts in sustainability, but may know little about teaching and learning. Teachers are experts in teaching and learning, but may know little about sustainability. This inquiry sought to understand to what extent those two groups might enter into partnerships that focus on improving students' ecological literacy. As a former science teacher, practicing permaculturist, and education researcher, I feel I am in a unique position to explore the common ground between science teachers and permaculturists, and to try to develop a common language between them so that each can do what they do best while students benefit from the resulting synergy.

## 1.3 Role of the Researcher

Although I am new to education research, I spent 14 years as a science teacher and 10 years off and on as an organic farmer and green builder. During that time I was struck by how much more engaged I was with science as a farmer and builder than as a science teacher. Applying science to organic food production and energy-efficient building felt so much more relevant and valuable to me. Although my teaching practice had evolved over a decade and a half to be more student-centered and experiential, I felt there was more I could do to cultivate higher levels of scientific relevance and value in my students. Ironically, it was after I gave up teaching that I found a potential way to do just that.

Although I had heard the word permaculture off and on over the previous decade, it was only when taking a course on ecological design in early 2008 that I recognized its potential breadth and depth. Nearly everything I learned about permaculture was consistent with my farming practices, building practice and general worldview. One might say I was a permaculturist but did not know it. While I am not an advocate for labeling people, I appreciated that there was a worldwide network of ecological designers who shared my beliefs and visions for a more sustainable world. Once I learned there was a name for a well established, all encompassing, practical system of ecological design I could focus my learning by using permaculture as a search term rather than my previous scattershot approach.

What I quickly came to appreciate about permaculture was its comprehensiveness, its long history of development and its ethical and scientific groundings. What is also significant about permaculture as a shared philosophy of ecological design is that it allows self-identified permaculturists to identify with other self-identified permaculturists anywhere in the world. This common bond is made possible by a common understanding of ecological design and sustainable living, and the adoption of a common ethical code: care for the Earth and for people, and share surplus to needs (Holmgren, 2002; Mollison, 1988). In the context of this inquiry it also opens up a worldwide network of practicing permaculturists as possible partners for science teachers. I saw it as my role – having experience as each – to explore ways in which classroom science teachers and local permaculturists could enter into mutually beneficial relationships that focus on student science learning, but also have potential benefits relating to ecological literacy and attitudes toward school science.

Specifically, this role involved: reviewing the relevant literature, forming a robust theoretical framework, obtaining ethical approval for the research, designing an intervention for a year 10 science class, recruiting a teacher, negotiating with the teacher, obtaining permission from students' guardians, working alongside the teacher to co-deliver the intervention, collecting data, analyzing the data, and writing this thesis. Although much of this is standard in education research, special attention should be given to a number of the roles listed above, especially the co-delivery of the intervention and data collection and analyses. As seen in the Table of Contents, issues surrounding data handling and analysis are addressed in Chapter 4, and the intervention is described in Chapter 5, but still I feel the need to disclose as full a picture as possible from the beginning.

Research is long and difficult work, and I would not have entered into this process had I not felt passionate about the Earth and about education. Having sold my farm to fund this endeavor, it would appear that the stakes were high to demonstrate the great success of this innovative approach to the teaching and learning of science. In other words, the potential for researcher bias was high. I remember one of my supervisors telling me early in the process that I was not going to save the world with my PhD. It took a long time for me to come to terms with what she said, but eventually I came to see the wisdom in the words of this experienced researcher. I came into this process as an ecological designer intent on finding solutions, but I leave it as an education researcher intent on finding truth. I really want to know what works, what does not work, and why. But those answers do not come from me. They only come from the human participants with whom I interacted. Above all else, this four-year process of learning as a researcher has helped me understand that the best way for me as a citizen of planet earth to advance the cause of sustainability is to listen to other people. I have learned more than I ever expected, and am excited to apply that learning to develop better and better models for sustainability education. While the recommendations for those better models will not appear until Chapter 9, the context in which my learning took place is described immediately below.

## 1.4 The Context of the Inquiry

### *1.4.1 Education in New Zealand*

New Zealand's education system ranks among the best in the world (OECD, 2010). Education is provided in both English-medium and Māori-medium schools, and is free for children from their fifth birthday through the end of the calendar year after their 19th birthday. It is compulsory for children from age six to 16 (15 with guardians' and school's permission). While most New Zealand schools can be classified as primary (years 1-6), intermediate (years 7-8) or secondary (years 9-13), in some small towns where the cost of building separate schools is prohibitive, schools can be classified as area schools that run from year 1 through year 13. The data collected for this thesis came from a year 1 – 13 area school in which the intervention described in Chapter 5 was carried out in 2010.

*The New Zealand Curriculum* (Ministry of Education, 2007) is the official policy statement for teaching and learning in English-medium schools. "Its principal function is to set the direction for student learning and to provide guidance for schools as they design and review their curriculum" (Ministry of Education, 2007, p. 6). The current *Curriculum* represents a shift toward a more democratic approach to education when compared to the previous *New Zealand Curriculum Framework* (Ministry of Education, 1993). Of particular significance, it is less prescriptive, and empowers schools to make educational decisions that are most appropriate for their students and communities (Chapman & Eames, 2007; Chapman, 2011). Some of those decisions are made by Boards of Trustees that govern every state school. Each Board works with a principal and school staff to develop and implement a curriculum for all students in years 1-13 grounded in certain principles, values, and key competencies contained in *The New Zealand Curriculum* (Ministry of Education, 2007). Additionally, each Board – working alongside the principal and school staff – "is required to provide all students in years 1-10 with effectively taught programmes of learning in: English; the arts; health and physical education; mathematics and statistics; science; social sciences; and technology" (Ministry of Education, 2007, p. 44). Of particular relevance to this inquiry, year 10 marks that end of compulsory enrollment in science. Year 10 is also a preparatory year for the National Certificate of Educational Achievement (NCEA), which commences assessment of subjects, skills and knowledge in year 11.

### *1.4.2 Environmental Education in New Zealand*

Environmental education (EE) in New Zealand has a history that stretches back four decades and can boast a number of popular and widespread programs, as described in Chapter 2. However, much of the history and success of EE in New Zealand has been at the primary school level (Bolstad, Eames & Robertson, 2008; Eames & Cowie, 2004; Eames, Cowie & Bolstad, 2008). Part of the popularity of EE at the primary level has to do with the successful application of the whole school approach embraced by the Enviroschools program (Hamilton City Council, 2001). Since EE is inherently multi-disciplinary (Ministry of Education, 1999), it is widely believed that the whole school approach is highly desirable (Davis & Cooke, 2007; Department of the Environment and Heritage (2005); McKeown & Hopkins, 2007; Ministry of Education, 1999).

However, the whole school approach to EE faces significant obstacles in secondary schools in New Zealand (Eames, Cowie & Bolstad, 2008). A 2006 baseline assessment of EE in formal education in New Zealand indicated that schools were constrained in their curriculum design by assessment accountability as well as by other pressures (Bolstad et al., 2008). Teachers at all school levels identified an over-crowded curriculum (Bolstad et al., 2008; Chapman & Eames, 2007; Eames et al., 2008) and insufficient time and resources (Bolstad et al., 2008) as barriers to including EE in their classrooms. At the secondary level, additional pressures on teachers include national standards and assessments. Eames and Cowie (2004) found that in secondary schools where EE is not formal policy, it appears often to be organized within departments. They also found that some departments used integration within a subject as a preferred strategy where timetable difficulties existed. These findings would appear to support the choice of incorporating EE into the science learning area made for this inquiry.

### *1.4.3 Science Education in New Zealand*

Science is a compulsory subject in New Zealand through year 10. "In science, students explore how both the natural physical world and science itself work so that they can participate as critical, informed, and responsible citizens in a society in which science plays a significant role" (Ministry of Education, 2007, p. 17). This statement implies an emphasis on scientific literacy, and the top 15-year-old science students in New Zealand scored among the world's best in their achievement in scientific literacy on PISA 2006 (Telford & Caygill, 2007). However, science education in New Zealand also suffers from a 'long tail' of underachievement (Telford & Caygill, 2007), as well as concerns about students' engagement with science (Caygill, 2008) and their attitudes toward learning science (Crooks, Smith & Flockton, 2008).

Science education in New Zealand takes a constructivist view of students learning, a view that has been recognized internationally as the dominant model for the teaching and learning of science since the 1980s (Hodson, 2004; Labudde, 2008; Malcolm, 2003). *The New Zealand Curriculum* (Ministry of Education, 2007) identifies effective pedagogies as those that: create a supportive learning environment; encourage reflective thought and action; enhance the relevance of new learning; facilitate shared learning; make connections to prior learning; provide sufficient opportunities to learn; and, embrace teaching as inquiry. The *Curriculum* (Ministry of Education, 2007) explains the need to study science as follows:

> Science is able to inform problem solving and decision making in many areas of life. Many of the major challenges and opportunities that confront our world need to be approached from a scientific perspective, taking into account social and ethical considerations. (p. 28)

The Ministry's emphases on problem solving and decision making align with many of the precepts of both scientific and ecological literacy, as well as with the application of permaculture design. The acknowledgement of social and ethical considerations also aligns with the permaculture ethics: care for the Earth; care for people; and, share any surplus.

Additionally, the *Curriculum* (Ministry of Education, 2007) highlights the role that science can play in the transition to a more sustainable world:

> By studying science, students use scientific knowledge and skills to make informed decisions about the communication, application, and implications of science as these relate to their own lives and cultures and to the sustainability of the environment. (p. 28)

Once again, the Ministry's emphasis on the role of science in environmental sustainability aligns with scientific literacy, ecological literacy and permaculture. Testing these apparent synergies was the task of this inquiry, the focus of which is presented below.

## 1.5 Research Focus

### *1.5.1 Research Questions*

The question addressed in this thesis is:

> In what ways can permaculture be used to increase ecological and scientific literacy in junior secondary science in New Zealand?

This question is supported by the following sub-questions:

- What are the characteristics of a permaculture approach to junior secondary science?
- How does a permaculture approach to junior secondary science impact on the teaching and learning of science?
- How does a permaculture approach to junior secondary science impact on students' ecological and scientific literacy?
- How does a permaculture approach to junior secondary science affect students' attitudes toward studying science?

### *1.5.2 Research Outline*

Seeking answers to these questions, a program of research was developed that included: a review of the literature; the design of an intervention; the development of questionnaires and interview schedules; data collection in a year 10 science classroom; data analysis; and, the writing of the thesis.

## 1.6 Research Significance

While potential synergies have been recognized between EE and school science for decades (Department of Education, 1988; Gough, 2004; Hart, 2007; Ministry of Education, 1991), this inquiry explored the potential for a new and largely unresearched context in which the two could support one another: permaculture. While others have identified a role for permaculture in schools, it has come largely in the form of gardens in primary schools (Lewis, Mansfield & Baudains, 2008; Nuttall & Millington, 2008; Praetorius, 2006), or, in Australia, as the teaching of permaculture in some high schools as an accredited Level I or Level II certificate (Permaculture Australia, 2011). In New Zealand, permaculture is included in the Level III certificate in Production Horticulture (New Zealand Qualifications Authority, 2006), but not as a stand-alone qualification. The former relies extensively on teachers to embrace gardening and the latter relies on students to self-select into a minor elective course offering.

Rather than viewing permaculture as something to *teach*, this inquiry viewed it as a *way* to teach (and a *way* to do research). The difference is that when permaculture is viewed as the *ends*, teachers may resist it as one more thing to be added to an overcrowded curriculum. However, when it is used as the *means*, it recognizes teachers' perception of an overcrowded curriculum as a key element to design around. As a system of design, permaculture seeks to recognize and maximize beneficial relationships while minimizing or eliminating negative relationships. Some of the potential beneficial relationships recognized in this inquiry include those: between EE and junior secondary science; between permaculture and *The New Zealand Curriculum*; between scientific literacy and ecological literacy; and, between science teachers and local practicing permaculturists. Most significantly, perhaps, a permaculture perspective recognizes how the dual challenges identified in Section 1.2 can be combined into one opportunity. Specifically, the inquiry was driven by a curiosity to discover if EE could improve the teaching and learning of science by engaging students in the science of sustainability as demonstrated by local permaculturists and permaculture projects.

On this level of the inquiry, permaculture was not used as a design lens, but as the context within which students could learn about science and sustainability. This adds to the significance of the research because there exists a network of hundreds of thousands of permaculture practitioners worldwide (at least several hundred in New Zealand) that could potentially enter into relationships with the millions of science teachers on the planet. Besides being in a position to role model ecological literacy, permaculturists are ethically bound to share their surplus (Holmgren, 2002; Mollison, 1988), be it a surplus of food from their harvest or a surplus of knowledge about the science of sustainability or their enthusiasm for being a guardian of the Earth. As mentioned above, permaculturists are experts in many aspects of sustainability and teachers are experts in student learning. Both, one may assume, are concerned about preparing children for the future. By entering into relationship, the potential benefits include: science teachers being supported by an adult in their community in the delivery of high quality science education; permaculturists advancing the cause of sustainability in their community; and, students becoming more engaged in high quality science and sustainability education. This type of win-win-win situation is often called regenerative design, and lies at the heart of permaculture thinking. As mentioned above, permaculture thinking influenced all aspects of this inquiry, an overview of which is presented below.

## 1.7 Overview of Thesis Chapters

This thesis is organized into nine chapters. The literature review is divided between Chapters 2 and 3. Chapter 2 consists of discussions on science education and environmental education with a section on the New Zealand context. Chapter 3 examines transformative learning and permaculture, and then provides a synthesis of both chapters in a section that shares the name of this thesis: a permaculture approach for junior secondary science. Chapter 4 describes the methodology and methods used in the inquiry. An emphasis is placed on the interpretivist paradigm and qualitative, naturalistic research, as well as data collection strategies, data handling and analysis, and ethical considerations. Chapter 5 describes the intervention in three sections: the theory; the intervention design; and, the way in which the intervention was carried out.

The results are presented in the next three chapters based on data collection using questionnaires, interviews, and classroom observations. Chapter 6 examines how the teacher and the students responded to certain pedagogical practices employed during the intervention. Chapter 7 examines data regarding student learning within the characteristics of ecological literacy: science knowledge, attitudes of care, taking actions for the environment, and systems thinking skills. Chapter 8 examines the data for evidence of change in students' attitudes toward science and toward learning science over the course of the intervention. The thesis concludes with Chapter 9, which consists of a discussion of the findings, conclusions, implications, limitations, and recommendations for further research.

# CHAPTER TWO - LITERATURE REVIEW

## 2.1 Chapter Outline

This chapter reviews international and New Zealand literature on environmental education and science education with special emphasis on ecological and scientific literacy. The first section provides a brief history of environmental education (EE), takes a closer look at environmental education for sustainability (EEfS), and identifies the key components of ecological literacy. The second section provides a brief history of science education, and then contrasts two dominant views on science education – science education as pre-professional training and as scientific literacy. A number of key components of scientific literacy are highlighted. The third section examines some challenges to ecological literacy in schools and within the dominant Western culture. The fourth section provides a New Zealand context for environmental problems, environmental education and science education. The chapter summary contains a number of key principles of ecological, and scientific literacy that relate directly to the intervention design that will be described in Chapter 5.

## 2.2 Environmental Education (for Sustainability)

Environmental education (EE) has evolved as a field over the last five decades and continues to evolve. Definitions of EE and what constitutes EE have matured with the movement but have not strayed far from the original goals set out by the first intergovernmental conference on EE held in Tbilisi, Georgia (formerly part of the USSR) in 1978. Sustainability and sustainable development emerged as foci for the field in the 1980s and remain the foci today. Of particular interest to this study is the thinking around and support for environmental education for sustainability (EEfS) and its relationship to the concept of ecological literacy. These are addressed in the sections below following a brief history of EE.

### *2.2.1 A Brief History of Environmental Education*

In many ways, April 22nd, 1970 – the first Earth Day – was a milestone for environmental awareness and particularly for EE. In previous decades significant groundwork had been laid by the likes of Leopold (1949) who developed the idea of a ‘land ethic’ and Carson (1962) who warned about the dangers of chemical pesticides. Meanwhile, educational groundwork was also laid by the nature study movement, conservation education, and outdoor education (Nash, 1976). But one spring day in the first year of a new decade seemed to galvanize widespread awareness and support for the environment. Conceived by Gaylord Nelson in late 1969 as an environmental teach-in, the first Earth Day drew the participation of thousands of colleges, universities, high schools, and grade schools, as well as several thousand communities in the United States alone (Nelson, 1980).

What followed could easily be called a decade for the environment. Significant legislation was passed in the United States and internationally, and the fledgling field of EE made substantial progress. Following meetings in Nevada, USA, and Stockholm, Sweden, the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the United Nations Environment Programme (UNEP) convened a meeting in Belgrade, Yugoslavia, in 1975 that drew educators from around the world. The meeting resulted in the *Belgrade Charter* being published a year later, which describes the goal of EE:

> To develop a world population that is aware of, and concerned about, the environment and its associated problems, and which has the knowledge, skills, attitudes, motivations and commitment to work individually and collectively toward solutions of current problems and the prevention of new ones. (UNESCO-UNEP, 1976, p. 2)

A year after the *Belgrade Charter* was published, the first intergovernmental conference on EE was held in Tbilisi, Georgia. The resulting *Tbilisi Declaration* expands on the *Belgrade Charter* by setting broader goals:

> • to foster clear awareness of, and concern about, economic, social, political, and ecological interdependence in urban and rural areas;
>
> • to provide every person with opportunities to acquire the knowledge, values, attitudes, commitment, and skills needed to protect and improve the environment;
>
> • to create new patterns of behavior of individuals, groups, and society as a whole towards the environment. (UNESCO-UNEP, 1978, p. 3)

The 1980s saw the emergence of the terms 'sustainability' and 'sustainable development,' first in the *World Conservation Strategy* prepared by the International Union for the Conservation of Nature (IUCN, 1980), and then in *Our Common Future* produced by the World Commission on Environment and Development (WCED). The latter, often called The Brundtland Report for its chair, Gro Harlem Brundtland, contains what is likely the most widely recognized definition of sustainable development: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 8).

The final decade of the 20th century witnessed a continued emphasis on sustainability as scholars and researchers agreed that EE needed to re-focus itself on addressing quality of life issues for all peoples of the world (Tilbury, 1995). The sustainability approach explicitly broadened the scope of EE to address the economy, society, and the environment simultaneously (Jenkins & Jenkins, 2005; Parliamentary Commissioner for the Environment, 2004). On the international level, the United Nations Conference on Environment and Development (UNCED), also known as The Earth Summit, was held in Rio de Janeiro, Brazil, in 1992. *Agenda 21* emerged from the Summit as a plan of action to address every aspect of human impact on the natural world. Chapter 36 of *Agenda 21* specifically addresses the role of education in sustainable development, but education in one form or another plays a role in nearly every chapter (UNCED, 1992).

But 10 years later so few advances had been made on *Agenda 21* that the United Nations itself admitted that both environmental degradation and poverty had worsened over the decade (World Summit on Sustainable Development, 2002). That year, Johannesburg, South Africa, played host to the World Summit on Sustainable Development, sometimes called Rio + 10. This Summit pledged to reaffirm the international commitment to sustainable development, but failed to include education as one of its "mutually reinforcing pillars of sustainable development—economic development, social development and environmental protection" (United Nations, 2002, p. 1). Three years later, the UN initiated the Decade of Education for Sustainable Development (DESD), set to run from 2005 through 2014. But despite what appeared to be international support, the push for Education for Sustainable Development (ESD) to replace EE has not been without controversy. Jickling and Wals (2008) expressed their concern over the effects of neo-liberalism and globalization on EE, and pointed to an on-line forum known as the ‘ESDebate’ in which more than half of the 50 EE experts from 25 nations answered yes to the question: “Should ESD be abolished as a concept?” (Jickling & Wals, 2008, p. 5). Jickling and Wals insisted that environmental thought and environmental ethics are continually evolving, and should not be fenced in by sustainable development.

Along with a shift by some in the field to ESD, others embraced education for sustainability (EfS). In the US, the President’s Council on Sustainable Development (1994) embraced an EfS approach that addressed a sound ecology, a prosperous economy and an equitable society. Among the underlying principles, the Council included a strong academic core that recognizes multidisciplinary opportunities, experiential learning, community-based learning, partnerships, and systems thinking.

As debates and disagreements on definitions, emphases and acronyms continued during the first decade of the new millennium, Blumstein and Saylan (2007) simply concluded that EE had failed. They identified problems with content, development and evaluation, and suggested that evidenced-based approaches could improve EE. Their concern centers on the EE tradition of teaching awareness, respect and appreciation for nature, and its inadequacy to bring about behavior changes regarding consumption patterns. In response, they advocate a more holistic approach, something that is considered a key aspect of contemporary EE (Barker & Rogers, 2004; Parliamentary Commissioner for the Environment, 2004; Williams, 2008). Holism, in the case of EE, can refer to content, context, process, and purpose. Additionally, a wider view can be taken of the learner, learning, and what is learned. At its core, however, EE involves experiential learning and is focused on behavior change (Daudi & Heimlich, 2002). EfS addresses values, attitudes, and action through shared, constructive, and reflective learning experiences (Littledyke, 2009). Balgopal and Wallace (2009) describe students who demonstrate engagement with their cognitive, affective, and behavioral domains as 'authentic learners.' These learners, and this type of learning, appear to be among the goals of a number of researchers and educators internationally and in New Zealand that have embraced yet another acronym: Environmental Education for Sustainability (EEfS). I count myself among them as explained in the following section. A history of EE and EEfS in New Zealand is included in Section 2.5.1.

### *2.2.2 Environmental Education for Sustainability*

Names, acronyms, and definitions only go so far. In circles of advanced thought on any topic, differences may be small and arguments subtle. Instead of offering a limited definition of EEfS in this section, I submit a detailed argument. The argument is that this study, for which ecological literacy and permaculture play central roles, nests comfortably within the literature on EEfS both internationally and in New Zealand.

First and foremost, EEfS "retains the emphasis on the foundational status of environmental education and acknowledges the clear focus on sustainability that is now required" (Chapman & Eames, 2007, p. 12). A foundation of EE – recognized for its emphasis on nature study and conservation education (Daudi & Heimlich, 2002; Nash, 1976) – is largely a foundation of science, and particularly ecology. A focus on sustainability emphasizes the ultimate goal of EEfS: behavior change for the future (Chapman & Eames, 2007). A preposition does not normally warrant mention in an acronym (USA, for example, not USoA), but in the case of EEfS, the 'f' does warrant inclusion because the word 'for' implies action, and taking action is an essential part of contemporary EE (Lewis, Mansfield & Baudains, 2008; Tilbury, Coleman & Garlick, 2005). The structure of EEfS described above brings an image to my mind of a learner whose feet are planted firmly on the ground but is reaching for the stars, as shown in Figure 2.1.


Figure 2.1 EEfS has a solid foundation and great aspirations.

For me this image represents the foundational status and clear focus that Chapman and Eames (2007) include in their description above. The feet are grounded in a rich history of EE and the natural sciences. Yet the learning strives for something higher, which is out of reach at the moment but remains in focus: a sustainable human existence on the planet.

Tilbury (1995) drew broad support from international EE literature when she argued that all EE should be directed toward sustainability. In New Zealand, Bolstad (2003) used the term "learning for a sustainable future" (LSF) (p. 12) instead of EEfS, but her arguments are directly aligned with those of Tilbury. Addressing opportunities for EE in New Zealand, Bolstad offered: “The purpose of environmental education is for students to learn how to be active participants in a society that is capable of achieving sustainable solutions to social and environmental problems” (2003, p. 12). Among others in the EEfS camp, Tilbury (1995) includes Huckle, Orr, Sterling, Fien, Cooper, UNESCO, the British Council, and the Queensland Department of Education. More recent advocates include the Australian Government (Department of the Environment & Heritage, 2005) and leading researchers in New Zealand (Bolstad, 2003; Chapman & Eames, 2007). Giving a nod to the Brundtland Report, a tentative definition of EEfS in New Zealand reads:

> To develop in individuals, groups, and society as a whole, new ways of thinking and patterns of behaviour that meet the needs of the present generation without compromising the ability of future generations of all living things to meet their needs (Chapman & Eames, 2007, p. 13).

Although the Brundtland Report has been criticized for linking sustainability with development and lacking any indication of how to build sustainable communities (Capra, 2005, Milne, Ball & Gray, 2005, Porritt, 2007), when compared side-by-side, the above definition is more specific about what needs to change – “ways of thinking and patterns of behaviour” – while remaining open to what specific forms these changes might take. As described in the following sections, ecological literacy also suits this aim, and a permaculture approach to science education is one potential pathway toward it.

Considering that EEfS is the approach recommended by leading researchers in New Zealand for re-writing the *Guidelines for Environmental Education in New Zealand Schools* (Chapman & Eames, 2007), that it enjoys international support (Tilbury, 1995), and is endorsed by the Australian Government as a national strategy for EE in schools (Department of the Environment & Heritage, 2005), it would appear that EEfS carries significant weight, particularly in Australasia. Additionally, EEfS retains a foundation in the natural sciences, it focuses on a sustainable future and endorses the type of thinking embodied by ecological literacy as described in the next section. For these reasons, EEfS is the evolved form of EE embraced in this study.

### *2.2.3 Ecological Literacy*

Ecological literacy is a concept introduced by Orr to a wide audience in his book of the same name in 1992. It addresses the role of education in the transition to a "postmodern world that protects individual rights while protecting the larger interests of the planet and our children who will live on it" (Orr, 1992, p. ix). Among this series of essays written between 1984 and 1989, the essay at the heart of the book describes an ecologically literate person as a systems thinker, one who "has the knowledge necessary to comprehend interrelatedness, and an attitude of care or stewardship" (Orr, 1992, p. 92). Seventeen years later, Balgopal and Wallace used a review of literature on the topic to form the following definition: "An *ecologically literate person* [original italics] can recognize the relevance and application of ecological concepts to understanding human impacts on ecosystems" (2009, pp. 14-15).

Although Orr never uses the term EEfS, the type of educational reform he calls for is aligned with it, particularly the need for "new ways of thinking" (Chapman & Eames, 2007, p. 13). One way of thinking and seeing the world supported by advocates of ecological literacy is systems thinking:

> Systems thinking and ecological literacy are two key elements of the new paradigm, and very helpful for understanding the interconnections between food, health, and the environment, but also for understanding the profound transformation that is needed globally for us to survive. (Capra, 2008, p. 4)

Along with Orr and Capra, Balgopal and Wallace (2009), and Stone and Barlow (2005) place the concept of interrelatedness at the heart of ecological literacy, where it is joined by ecological knowledge, an attitude of care, and an overt tendency to take actions for the environment (Orr, 1992). In addition, Orr (1992) emphasizes the importance of experiential learning.

In the context of science education, Hipkins (2009) defines systems thinking as "recognising that events might not proceed in a linear orderly fashion, and that many parts can contribute to a dynamic ever changing world" (p. 2). Systems thinking involves pattern recognition, a concept that comes up in descriptions of ecological literacy (Berry, 2005; Callenbach, 2005; Holt, 2005), sustainability (Clayton, Clayton & Radcliffe, 1996; PCE, 2002), sustainable education (Sterling, 2001, 2003), and permaculture (Holmgren, 2002; Mollison, 1988, 1991; Morrow, 2006). Capra (2005) emphasizes the perceptual shift from contents to patterns, that is, discovering the relationships that exist within living systems instead of being concerned simply with their material make up. He encourages a "move from biology to ecology" (p. 1), and from "objective knowledge to contextual knowledge" (Capra, 2005, p. 21) as representative of the need to widen our perspective.

Regarding knowledge, or what is most important for ecologically literate citizens to know, Bowers (1996) suggests requiring educators to make a radical shift in what they consider high-priority knowledge. This high-priority knowledge includes, first and foremost, the interdisciplinary nature of ecology because it emphasizes the interrelationships between living organisms and their environment, and therefore crosses over into all of the fields of science as well as mathematics, economics, medicine and sociology (Klemow, 1991). Callenbach (2005) emphasizes the use of "all the resources of science to see how life operates and how we can fit responsibly into its patterns" (p. 44), and Holt (2005) encourages combining physics, biology and chemistry using themes such as patterns. While Klemow (1991) includes a total of 11 important topics that should be included at all levels of education, of particular relevance to this study are his final four: energy and energy flow; nutrient cycling; the constance of change; and the negative impact humanity has had on the Earth's ecosystems. Regarding energy, Porritt (2007) emphasizes the importance of the laws of thermodynamics for understanding economic growth. He submits that the current economic model, relying on continually larger throughputs of matter and energy, "is as close to biological and thermodynamic illiteracy as it is possible to get" (Porritt, 2007, p. 56).

Like Klemow (1991), Orr (1992) – the consummate list maker – explains that an ecologically literate citizen would understand concepts such as carrying capacity, overshoot, thermodynamics, trophic levels, energetics, succession, and evolution. He insists that educational institutions should only graduate students who have at least a fundamental understanding of important ecological principles. Along with the laws of thermodynamics and the basic principles of ecology, Orr (1994) lists: least-cost and end-use analysis; the limits of technology; appropriate scale; sustainable agriculture and forestry; steady-state economics; and, environmental ethics. A number of the concepts included on this list rely on a basic level of scientific literacy regarding what is possible within the laws of physics and principles of ecology, and what is not. Orr (2002) suggests that in order to facilitate sustainable cognitive and psychomotor adjustments, such as those promoted by EEfS (Chapman & Eames, 2007), there is a need "to calibrate human behavior with ecology, which requires a public that understands ecological possibilities and limits" (Orr, 2002, p. 31). I submit that these two understandings are particularly significant regarding a person's ecological literacy or lack thereof. In other words, understanding ecological limits and possibilities are special types of knowledge that allow individuals to critique the unsustainability of humanity's current patterns of behaviour and then to design ecological systems that can help shrink the human footprint on the Earth. As will be discussed in Section 3.3, permaculture designers possess this type of knowledge, and can be said to work from a position of high ecological literacy.

But ecological knowledge alone is not enough. Balgopal and Wallace (2009) suggest that an ecologically literate student is able to transfer knowledge to a broad range of environmental issues, while Cutter-Mackenzie and Smith (2003) emphasize that this knowledge enables stakeholders to ask 'what then?' What these writers share, along with Sturdavant (1993), is a focus on interconnectedness, or, as discussed above, systems thinking. In other words, ecological literacy implies that individuals use their knowledge and understanding of ecological concepts to relate to their lives and lifestyles. Orr describes this as a "quality of mind that seeks out connections" (1992. p. 92), and takes an holistic perspective on issues facing humanity. But as described in Section 2.4.1, this quality of mind is not nurtured in most educational institutions. Nor is another component of ecological literacy, an "attitude of care or stewardship" (Orr, 1992, p. 92).

This attitude constitutes the 'heart' component of the "head, hands and heart" formula proposed by Sipos, Battisti and Grimm (2008). Fromm (1964) and Wilson (1984) use the term biophilia, but the affection required of an ecologically literate citizen may best be embodied in the words of Senegalese environmentalist Baba Douin: "In the end, we will conserve only what we love, we will love only what we understand, we will understand only what we are taught" (as cited in Giller & Malmqvist, 2004, p. 244). Working backwards through this string of cause and effect as expressed here, caring results from understanding, and understanding results from learning. While this may be an oversimplification, and may or may not be supported by the international literature, the ultimate goal expressed by Baba Douin – conservation – represents a form of *taking action for the environment*. On this point there is considerable agreement in the literature (Barker & Rogers, 2004; Bolstad, 2003; Breiting & Mogensen, 1999; Jensen & Schnack, 1997).

Orr is clear that ecologically literate persons have "the practical competence required to act on the basis of knowledge and feeling" (1992, p. 92). Instead of the hierarchy described by Baba Dioun, Orr paints a picture of two feet on which an active person stands. To extend the metaphor, this image fits well with that of EEfS as grounded in science (feet on the Earth) but focused on the higher goal of sustainability (reaching for the stars) as shown earlier in Figure 2.1. Combining Orr's image with that of EEfS gives a fuller picture of the compatibility between ecological literacy and EEfS (see Figure 2.2).


Figure 2.2 The compatibility between ecological literacy and EEfS

Whether an action involves pedaling a bicycle or marching in protest, that action requires two feet, both metaphorically and literally. (The act of writing a submission, however, requires only hands, but still qualifies as an action for the environment.)

What constitutes action is often misunderstood (Jensen and Schnack, 1997; McLean, 2003). According to the action competence approach in environmental education, for an activity to qualify as an action, it must fulfill two criteria: 1) it must be solution-oriented; 2) the actors must be involved in choosing what to do (Jensen & Schnack, 1997). Within this approach, two types of actions are described. Direct actions are those that contribute directly to addressing an environmental issue, such as riding a bicycle instead of driving a car to reduce carbon emissions. Indirect actions are those that aim at influencing others to take action, such as joining a protest march (Jensen & Schnack, 1997):

> The notion of action could, for example, include an emphasis on learners presenting material on environmental and sustainability issues to wider community audiences. The issue of action has profound implications for the role of schools in society. (Chapman & Eames, 2007, p. 17)

Either type of action is sufficient for developing in students the practical competence required of ecological literacy. Taking action, like permaculture in this inquiry, serves as both vehicle and destination. In other words, students need to practice acting in order to become active citizens. But as important as it is for students to develop action competence, this does not diminish the role of activities and active learning in EEfS. Experiential learning has been recognized as central to EE from its beginnings (Daudi & Heimlich, 2002), and remains key to the type of education advocated by Orr (1992) for the transition to a sustainable future.

By many accounts that transition is both urgent and essential (Blumstein & Saylan, 2007; Capra, 2005). The shift will require "a modification of the skills, aptitudes, abilities, and curriculum by which we learned how to industrialize the Earth" (Orr, 1994, p. 109). Like Einstein and many others, Orr believes that problems cannot be solved with the same type of thinking that caused them. The required paradigm shift will not be easy, but failing to change – and doing so rapidly – will result in environmental, economic and social devastation (Brown, 2008; Lovelock, 2006). In Capra's (2008) words, "in the coming decades, the survival of humanity will depend on our ecological literacy" (p. 1).

### *2.2.4 Section Summary*

This section provided a brief history of EE with special emphasis on EEfS and ecological literacy. EEfS was chosen as the preferred approach to sustainability education in this thesis because it remains rooted in the traditional EE practices of nature study and conservation education but aims to cultivate sustainable behaviour changes in learners. Ecological literacy consists of knowledge about ecology and other sciences, an attitude of care for the environment, and the tendency to take sustainable actions. Within the realm of ecological knowledge, two special types of knowledge are central to ecological literacy: systems thinking and the recognition of ecological limits and possibilities. Cultivating ecological literacy involves using certain pedagogical approaches including: affective experiences; taking action for the environment; emphasizing interrelationships; and, experiential learning. These are considered key principles for nurturing ecological literacy. Further key principles – those important for improving scientific literacy - are developed through a review of literature on science education in the following section.

## 2.3 Science Education

Like EE, science education has evolved as a field, albeit over a longer period of time. Many of the advances in science education in the 20th Century were influenced by the interest in developing technologies for war and for economic competitiveness. These drivers of science education have produced a system of education that serves primarily the minority of students who will go onto a career in science to the detriment of the majority of other students. In response to this, many science education researchers advocate different approaches to science education, of which scientific literacy is identified as the predominant one.

### *2.3.1 Trends in Science Education*

A century ago, it was war that began to elevate science in the curriculum. World War I marked a realization among many European nations that succeeding wars would be more dependent on superior technology than superior strategy. Such technology would rely on scientists and engineers, and therefore, school science education in Europe began to shift toward the production of such persons. But it was World War II that drove this point home internationally (Osborne, 2003).

World War II is seen as a landmark in terms of an international change in curricular emphasis in education (Drori, 2004; Osborne, 2003; Solomon, 2003). Prior to the war, a classical European model of education emphasized humanistic subjects and classical languages. After the war, a shift occurred toward science and mathematics, modern languages, the arts, and humanities in a modern curriculum. Since the late 1940s, nations have been expanding their efforts not only in science education, but also in mathematics and technology education (Drori, 2004). During re-industrialization after WWII, the primary focus of science was to generate new knowledge "and subsequently for science education to produce the scientists who would be the driving force of that knowledge production" (Lindsay, 2011, p. 9). This approach to science education emphasized the learning of scientific theories, principles, and facts (DeBoer, 1991). Millar (as cited in Lindsay, 2011, p. 10) suggested that most schools continue to teach science as if to prepare future science researchers. Acknowledging Cohen (1952), Osborne (2003) emphasizes that when science education takes on the role of pre-professional training, instead of a general science approach, it becomes foundationalist: "emphasizing what appears to be a set of basic concepts and unrelated, miscellaneous information" (p. 41). This narrow approach, he argues, is ineffective for many learners because it does not meet their needs or interests. It has been unattractive to students who vote with their feet, and walk right out of science classes when they are no longer required to enrol (Osborne, 2003).

Aikenhead (2003) notes that curriculum change happens in response to, and within, changing social realities. Of course war is a powerful social reality for those even indirectly involved, but Aikenhead (2003) acknowledges that other social realities may have influenced changes in science education, including:

> The Pugwash movement (science for social responsibility), the environmental movement, women's movement, the post-Sputnik science curriculum reforms… research into science instruction and student learning, decreasing enrolment in physical science, and a nagging persistence, by a minority of science educators, to present science to students in a more humanistic way. (p. 59)

Many of these social realities have influenced movements aiming to make science education more socially relevant. One of the earliest was the Scientific Humanism movement in the United Kingdom during the 1930s (Solomon, 2003). But this movement and others, such as the general science movement in the 1930s and 1950s, were largely ignored (Osborne, 2003). Of particular relevance to this inquiry, the term scientific literacy first came to prominence in the 1950s (Lindsay, 2011; Millar, 2008). Aikenhead

(2003) comments that these early reform movements failed to meet their objective of making science relevant to the majority of students by humanizing the curriculum.

The 1970s saw international efforts to promote science and technology as essential to productive national economies, and 1980 was declared The Year of Science for Development (Drori, 2004). Sterling (2001) notes that from the 1980s, the Organisation for Economic Cooperation and Development (OECD) and World Bank produced reports that encouraged education reform toward a neo-liberal agenda. During this time, Osborne (2003) submits that "those engaged in formulating policy and curricula for school science simply chose to meet the needs of a minority because the culture in which they were situated valued them more highly" (p. 39). That is, policy and curricula continued to be designed to promote and support careers in science and technology, and ignored learning needs of the majority of students. But by the 1980s, many reformers believed that "social conditions had changed sufficiently to support a fundamental change to the science curriculum" (Aikenhead, 2003, p. 59). As described in Section 2.5.3, the 1980s were a pivotal time for science education in New Zealand.

The fundamental change suggested by Aikenhead (2003) is a shift from a science education for the minority to one for the majority (Carr & Hartnett, 1996; Dillon, 2009; Gallagher, 1971; Solomon, 2003). The argument for such a change centers on a perceptual "mismatch between the type of science perceived by society, and the type which is currently perpetuated in schools and by policy makers in science education" (Lindsay, 2011, p. 3). The two perceptions of science education are represented in Roberts' (2007) description of two 'visions' of scientific literacy (SL):

> Vision I gives meaning to SL by looking inward at the canon of orthodox natural science, that is, the products and processes of science itself. At the extreme, this approach envisions literacy (or, perhaps, through knowledgeability) *within science*…Vision II derives its meaning from the character of situations with a scientific component, situations that students are likely to encounter as citizens. At the extreme, this vision can be called *literacy* (again, read *through knowledgeability) about science-related situations* [*emphases original*] in which considerations other than science have an important place at the table. (p. 730)

While this inquiry adopts a perspective consistent with Vision II, it has been suggested that science education has remained stuck in Vision I (Gough, 2004), seeing little change in the two decades after Fensham (1985) noted these prominent tendencies in school science education:

a. it involves the rote recall of a large number of facts, concepts and algorithms that are not obviously socially useful;

b. it involves too little familiarity with many of the concepts to enable their scientific usefulness to be experienced;

c. it involves concepts that have been defined at high levels of generality among scientists without their levels of abstraction being adequately acknowledged in the school context, and hence their consequential limitations in real situations is not adequately indicated;

d. it involves an essentially abstract system of scientific knowledge, using examples of objects and events to illustrate how the system is, rather than those aspects of science of factual phenomena that enables some use or control of them to occur;

e. it involves life experiences and social applications only as exemplary rather than as the essence of the science learning;

f. the role of practical activity in its pedagogy is associated with the belief that this activity enhances the conceptual learning rather than being a source for the learning of essential skills;

g. its content gives a high priority, even in biology, to the quantitative, and in chemistry this priority is probably greater than it is for many practicing chemists;

h. it leaves to the continued study of these disciplines at the tertiary level the balance, meaning and significance that is lacking in (a) to (g). (p. 418)

For children who are not drawn to science by personal interest or who may not be good at memorization or calculations, the tendencies included in this list may contribute to the high attrition rate for science classes beyond the compulsory years. The emphasis of science education as pre-professional training – Roberts' (2007) Vision I – is critiqued in the following section.

### *2.3.2 Science Education as Pre-Professional Training*

There has been widespread belief that the persistence of Vision I (Roberts, 2007) has been driven by a desire for economic development (Bell, Jones & Carr, 1995; Codd, 1999; Drori, 2004; Osborne, 2003). In this view, science education is seen as essential to establishing a work force prepared to compete in a global economy. Various international organizations are directly – UNESCO and the International Institute for Educational Planning (IIEP) – and indirectly – IMF and The World Bank – involved in promoting neo-liberal science education through a model of 'science education for development.' Despite its claim as a neutral policy, this model of science education carries significant value judgments as it asserts itself to be a "technical solution to a national problem, phrased in terms of efficiency, compatibility, and resource allocation" (Drori, 2004, p. 26). Drori (2004) identifies the five-fold vision of science education for development as: (a) national, (b) systematically planned, (c) realist, (d) development-oriented / economic-centered, and (e) utilitarian.

As a result, and despite mixed findings from researchers looking for links between science education and economic development (Drori, 2004), the success of science education is often judged by its ability to improve the economic competitiveness of a nation. This judgment has driven recent reform initiatives that include an "unremitting emphasis on inspection and accountability" (Sterling, 2001, p. 21) enforced through rigorous standardized exams (Drori, 2004). Osborne (2003) points out the fundamental flaw with this approach: "having decided to make what is important measurable, an inevitable consequence is that only the measurable becomes important" (p. 44). Gough (2004) includes the global trend in standardized curriculum documents as one of several explanations for the stagnation of science education since the mid-1980s.

Gilbert (2004) suggests the trends in science education have resulted in a perceived connection between educational performance in the sciences and innovation and productivity in the industrial sector. Drori (2004) quotes Norman Augustine, President and CEO of Lockheed Martin, the world's largest defense contractor: "More and more we see that competition in the international marketplace is in reality a 'Battle of the Classrooms'" (p. 24). Hodson (2004) claims that multinational corporations have "created and sustained a discourse that serves their immediate and future needs, and have extended this discourse to schools and the education system" (p. 209). From this perspective, the aims of science education appear to be the production of a "flexible, 'just-in-time' and compliant workforce" (Hodson, 2004, p. 209), or science education as pre-professional training.

Gilbert (2004) claims that these trends are particularly strong in English-speaking OECD nations, and are reinforced by international testing programs that encourage comparing one country to another. This is despite experts in the field identifying the problems associated with such testing (Gilbert, 2004). Sterling (2001) notes, "Internationally, since the 1996 Delors' report on 'Education for the 21st Century', which favoured a holistic and humanistic emphasis on education, this orientation has largely been ignored in favour of managerialism" (p. 77). As seen above, and discussed in the New Zealand context below, ignoring expert opinions and stakeholder input is a trend associated with a free-market approach to education reform. A significant risk of such reform efforts in science education is the potential for the alienation of a segment of the student population from science and, consequently, lower scientific literacy among the general population. The list of prominent tendencies in school science education (Fensham, 1985; Gough, 2004) presented in the previous section includes an emphasis on the quantitative, levels of abstraction and the rote recall of facts. Malcolm (2003) describes this as a reductionist version of scientific literacy. For the most part it lacks a context and relevance for many students, and it includes "life experiences and social applications only as exemplary rather than as the essence of the science learning" (Fensham, 1985, p. 418). An alternative approach to science education, Roberts' (2007) Vision II, is described in the following section.

### *2.3.3 Scientific Literacy*

While the term scientific literacy first appeared in the 1950s (Lindsay, 2011; Millar, 2008), it has gained wider acceptance internationally and in New Zealand over the last two decades since the publication of *Science for All Americans* (AAAS, 1989; Rutherford

& Ahlgren, 1991; Saunders, 2010). Hodson (2004) uses slogans to identify the shifting emphases of science education over the last four decades: ‘Learning by Doing’; ‘Process, not Product’; ‘Science for All’; ‘Less is More’; ‘Children Making Sense of the World’; and ‘Science as a Way of Knowing’ (p. 203). Additionally, Aikenhead (2003) recognizes: ‘Science for Public Understanding’; ‘Citizen Science’; and ‘Functional Scientific Literacy’. But from the early 1990s onwards, much of the debate has centered on the notion of scientific literacy and how to reach it (Hodson, 2004; Millar, 2008). While scientific literacy shares characteristics with ecological literacy, one major difference exists regarding the question: Literacy according to whom? While Orr and Capra appear to be driving the bus of ecological literacy, science literacy appears to be more of a competition between multiple cabbies jockeying for a fare. As Hodson (2004) illustrates:

> While some see scientific literacy as the capacity to read newspapers and magazine articles about scientific and technological matters with a reasonable level of understanding, others see it as being in possession [of] the knowledge, skills and attitudes essential to a career as a professional scientist, engineer or technician. While some argue for a broadening of the knowledge base of the science curriculum to include greater consideration of the interactions among science, technology and society (the STS emphasis), others urge curriculum decision makers to concentrate on the knowledge and skills deemed (by some) to be essential to continued economic growth and effective competition within the global marketplace. (p. 203)

Hodson offers a wider perspective on Roberts’ (2007) two visions for scientific literacy introduced in Section 2.3.1, albeit in reverse order. As discussed above, Drori (2004) recognizes the group endorsing Vision I as the more powerful voice in the debate, resulting in a policy model of “science education for development” (p. 25).

Hodson (2004), among others (Apple, 1993; Bencze, 2001), identifies the trends that have arisen from the economic argument as dangerous to both individuals and society as a whole. He expresses concern over the daily barrage of language in schools that promotes economic globalization, and “identifies technology with unfettered ‘progress’, work with money and excellence with competition and ‘winning at any cost’” (Hodson, 2004, p. 209). Bowers (1996) calls these the 'myths of modernity' that lead to many social and environmental problems. Hodson (2004) believes that one key to addressing the problems of environmental degradation, poverty, injustice, terrorism, and war is an increase in science literacy among all of humanity. But it needs to be a different kind of science literacy than that which is often expressed in the international literature as largely reductionist (Malcolm, 2003). In addition to the international literature, Malcolm recognizes a reductionist definition of science in outcomes statements from English-speaking OECD nations that are “heavily positivist and mechanistic, centred on the ‘basics’ from physics, chemistry, biology and geology” (2003, p. 22).

In the words of Fensham (2002), it is “time to change drivers for scientific literacy” (p. 9). Millar and Osborne (1998) identified the failure of the abstract, academic science contained in the National Curriculum in England and Wales to meet the needs of both current and future societies. They endorsed scientific literacy as the “primary and explicit aim of the 5-16 science curriculum” (Millar & Osborne, 1998, p. 13). In their report, *Beyond 2000: Science Education for the Future*, Millar and Osborne (1988) recognize that the content of the science curriculum in England and Wales remained essentially unchanged since the 1960s. Three years after its publication, the UK Deans of Science Committee broadly agreed with their findings:

> We are acutely aware that the style of specialist school science curriculum has not changed in many years. We thus have to recognise that an approach that worked satisfactorily in the past no longer does so in the changed social and communications environment of today. (cited in Osborne, 2003, p. 45)

This admission of failure is significant not only in and of itself, but also because, as discussed in Section 2.5.3, the New Zealand government adopted the curriculum policies of England and Wales in 1989 (Bell, Jones & Carr, 1995).

Millar and Osborne (1998) emphasize that scientific literacy should not only allow students to understand newspaper articles and TV programs about science, but also to express opinions about critical social and ethical issues, as well as form the basis for potential work-related retraining at any time in their careers. In other words, scientific literacy needs to be socially compassionate and environmentally sensitive, as expressed by the American Association for the Advancement of Science (AAAS) in *Science for All Americans* (AAAS, 1989; Rutherford & Ahlgren, 1991). In a description similar to that which Orr offered for ecological literacy, scientific literacy would nurture “the kind of intelligent respect for nature that should inform decisions on the uses of technology” (AAAS, 1989, p. 12). And in a warning similar to Capra’s, without sufficient scientific literacy, “we are in danger of recklessly destroying our life-support system” (AAAS, 1989, p. 12). In this view, scientifically literate citizens can “use the habits of mind and knowledge of science, mathematics, and technology they have acquired to think about and make sense of many of the ideas, claims, and events that they encounter in everyday life” (AAAS, 1993, p. 322).

Similarly, the OECD provides the following definition for scientific literacy:

> Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity. (OECD, 2003, p. 133)

Upon examination, this definition contains two distinct components. The first half addresses the importance of both knowledge about science and the processes by which scientific knowledge is accumulated. The OECD (2003) insists that the two are bound together. In other words, “the processes are only scientific when they are used in relation to the subject matter of science” (OECD, 2003, p. 133). By contrast, ecological literacy seeks to apply ecological knowledge beyond the subject matter to ecology. For example, concepts such as diversity, interdependence and dynamic equilibrium can be applied to the design of robust and resilient human social and economic systems. This is not a criticism of the above definition, but rather an acknowledgement of one limitation of scientific literacy in regards to my inquiry.

The second half of the definition of scientific literacy addresses the importance of the relationship between human beings and the environment. This emphasis is echoed by the description of scientific literacy provided by the AAAS (1989), and aligns with the aims of ecological literacy. Scientific literacy shares with ecological literacy an emphasis on using scientific knowledge to inform decision-making, particularly concerning the environment. Additionally, and of significance, they share a recognition of the limitations of science (Jenkins, 1994; Norris & Philips, 2003; Orr, 1992). In other words, they both recognize the importance of 'keeping it real' regarding what scientific advances may be possible and what may not. As highlighted in Section 2.2.3, the recognition of ecological limits and possibilities is a special type of knowledge associated with ecological literacy. In coming decades it appears likely to become increasingly important for scientifically and ecologically literate citizens to understand and make decisions about a number of critical socio-scientific issues involving science and the environment such as: the increased use of genetically-modified crops to feed a growing human population; proposals for geo-engineering to moderate against climate change; and, various energy technologies gaining momentum thanks to technological advances such as hydrogen fuel cells, hydraulic fracturing, and the conversion of tar sands into oil. Scientific illiteracy could result in voters and consumers being misled by politicians and corporations with agendas that include private profits over environmental protection.

I submit that scientific literacy is essential to democracy in a world bombarded with advances in technology and worsening environmental conditions (Brown, 2008). In this sense, scientific literacy and ecological literacy go hand-in-hand to promote a citizenry that can make political and economic decisions *and then act on those decisions* based on good scientific understanding of current issues. But, as the title of this thesis makes clear, the aim of this inquiry is ecological literacy, which expands on scientific literacy by emphasizing systems thinking and taking action. While ecology is recognized as a subset of science, I suggest that scientific literacy is a subset of ecological literacy as shown in Figure 2.3.

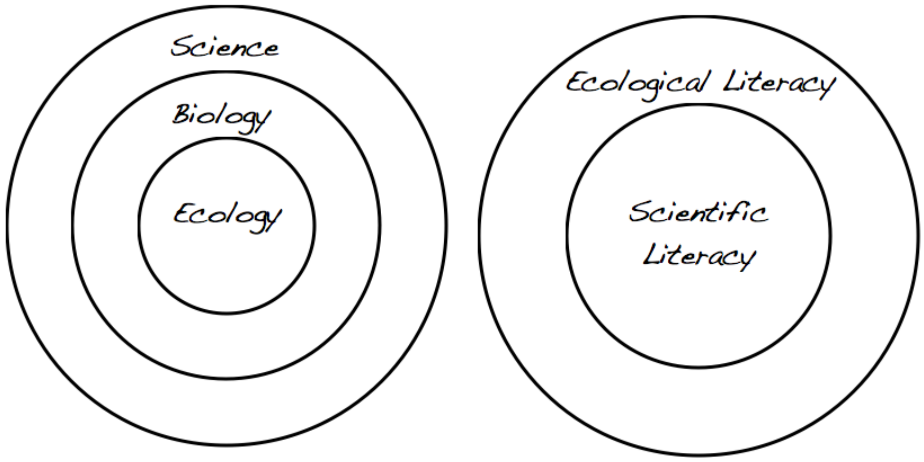


Figure 2.3 Scientific literacy nests within ecological literacy

In the remaining chapters of this thesis, scientific literacy is not mentioned often by name, but the reader can assume its presence within ecological literacy in the same way one can assume the presence of a yolk within an egg without having to see it. I have presented the synergies between the two and made the argument that scientific literacy can support ecological literacy. In this sense, another image emerges of scientific literacy boosting ecological literacy toward its lofty goals as seen in Figure 2.4.


Figure 2.4 Scientific literacy boosts ecological literacy

From this perspective, advances in scientific literacy will support advances in ecological literacy. This does not negate the mutualistic relationship (Gough, 2002) between environmental and science education, because EEfS pedagogies have been argued to enhance science education (Steele, 2011), and thus improve scientific literacy (Hodson, 2003). As implied by the term mutualism, positive feedback loops would constantly be in motion during the successful conjoining of EEfS in a science classroom, as in this study.

Nonetheless, certain key principles relating to the teaching and learning of science to promote scientific literacy have been identified in the literature. These key principles are: student-centered teaching and learning; making science relevant to students; the local application of science in the community; and, a duplicate from the key principles of ecological literacy, experiential learning opportunities.

Within the context of scientific literacy, student-centered, or student-oriented (Aikenhead, 1992), teaching and learning often falls under the large umbrella of constructivism (Labudde, 2008; Sjoberg, 2008). Aikenhead (1992) suggests a shift from knowledge transmittal to knowledge construction. It should be noted that while scientific literacy is a goal, and constructivism is a theory on learning, the key principles identified above involve teaching strategies that seek to capitalize on the understandings of knowledge construction by learners to promote scientific literacy. In other words, if scientific literacy is the destination and constructivist learning is the vehicle, then certain constructivist pedagogies serve as the road. Constructivist pedagogies honor learners' previous knowledge of subjects while seeking to build (construct) new knowledge (Sjoberg, 2008; Taber, 2006). Constructivism is discussed in more detail in Section 2.5.3 in the context of science education in New Zealand.

An adjunct to student-centered teaching and learning is making science relevant to students. In other words, "What does it mean for me and my world?" Relevance can mean importance, usefulness and meaningfulness for learners (Levitt, 2001), and is said to influence students' perceptions of whether certain learning satisfies their personal needs and goals, as well as potential career goals (Keller, 1983). Aikenhead (1992) argues that contemporary science in intertwined with society, and suggests it is the social context that makes science relevant for most students because it allows them to apply science content to their everyday lives. Some studies have shown that increased relevance improved student interest in learning science (Matthews, 2004; Ramsden, 1998). Relevance has the potential to draw students from the periphery of science learning closer to the center. Making science relevant can involve providing a real world context for classroom learning. Aikenhead (1992) identifies contexts that are meaningful to students as essential to student-oriented science education. This can be done by introducing global issues, or scientific advances in other nations, which are likely to impact somehow on students' lives. This strategy lends itself especially well to the science behind many environmental problems and the proposed sustainable solutions (Tilbury, 1995).

Another way of making science relevant to students is by highlighting examples of science being practiced in their own communities. The local application of science could take the form of visiting a water purification plant, a waste treatment plant, or local businesses that use certain technologies or have laboratory facilities on site. These could be valuable field trips that provide a local context for science, but in each case a professional scientist or engineer is involved. For students not seeking such careers the relevance may be weak. Another strategy for highlighting the application of science in the community is to emphasize the science behind local environmental problems and the proposed sustainable solutions. While professional scientists are often involved in these issues, so too are many citizen scientists. As explained in Sections 3.3 and 3.4, this is where local practicing permaculturists can demonstrate their knowledge of science to design and build low-energy homes and low-energy, low-water, low-chemical food production systems.

The three key principles for promoting scientific literacy described thus far – student-centered teaching and learning; making science relevant to students; and, the local application of science – can all be enfolded into the fourth key principle: experiential learning opportunities. Together, these are reflected in what Aikenhead (2010) identifies as relevant content, processes and contexts. The literature provides many advocates for employing experiential instructional strategies to promote scientific literacy (Harty, Kloosterman & Matkin, 1989; Mabie & Baker, 1996; Meichtry, 1992). For instance, Roth and Roychoudhury (1993) found that experiential learning opportunities improved science process skills among secondary students.

### *2.3.4 Section Summary*

This section provided a brief history of science education with special emphasis on scientific literacy. While science education has traditionally catered for students likely to pursue a career in science, advocates for scientific literacy promote a form of science teaching and learning that promotes relevance and engages all students in science. Key components for promoting scientific literacy that are important in teaching and learning are: student-centered teaching and learning; making science relevant; local application of science; and experiential learning. These principles add to the initial four key principles of EEfS summarized in Section 2.2.4 with one duplication, experiential learning. This section also described scientific literacy as a subset of ecological literacy (Figure 2.3) and as a friend that provides a helpful boost toward the learning sustainable behaviors (Figure 2.4). While in the field of science, ecology is nested within science, in the field of education, scientific literacy is nested within ecological literacy. It is an aim of this inquiry to identify ways in which the promotion of scientific literacy in students can also address some of the barriers to ecological literacy described in the following section.

## 2.4 Challenges to Ecological Literacy

Nearly four decades have passed since the *Belgrade Charter* (UNESCO-UNEP) was published, yet many of the changes called for in 1975 have not occurred (Blumstein & Saylan, 2007; Brown, 2008). While successful school-based EE programs exist throughout the world, such programs are the exception, particularly when it comes to state-funded, mainstream secondary schooling. New Zealand is no different (Bolstad, 2003). For the most part, education systems have failed to develop ecologically literate citizens who behave with a holistic understanding of natural laws (Blumstein & Saylan, 2007; Orr, 1994; Sterling, 2001). On the contrary, it has been argued that education is in direct conflict with sustainability when modern economies significantly impact the planet's life support systems (Sipos, Battisti & Grimm, 2008). Sterling (2001) argues that the current educational paradigm "sustains unsustainability" (p. 14). Similarly, Orr (1994, claims:

> The truth is that without significant precautions, education can equip people merely to be more effective vandals of the Earth. If one listens carefully, it may even be possible to hear the Creation groan every year in late May when another batch of smart, degree-holding, but ecologically illiterate *Homo sapiens* who are eager to succeed are launched into the biosphere. (p. 5)

It has been argued that the 'significant precautions' so badly needed include an immediate and broad-scale push toward combating ecological illiteracy. Brown (2008) refers time and again to mobilizing at 'wartime speed' to address the challenges facing humanity.

Sterling (2001) notes that mainstream education is slow to change. Considering this, I argue that tapping into existing systems and structures will be essential for a rapid transition to a sustainable world. Waters (2005) recognizes that the publicly funded school system “is our last best hope for teaching real democrative values that can withstand the insidious voices of those who would have us believe that life is all about personal fulfillment and personal consumption” (p. 54). The problem, however, is that traditional education has failed to instill the type of holistic understanding and appreciation of limits embodied by ecological literacy (Blumstein & Saylan, 2007; Orr, 1994). Environmental education researchers are interested in why this is so. One reason suggested by Sterling (2001) is the fundamental tension between a mechanistic worldview and an 'organicist' worldview. A mechanistic worldview can also be described as reductionism.

### *2.4.1 Reductionism*

One obstacle to a shift toward a more holistic, ecological worldview is the dominant Western view of science, which is often described as reductionist (Capra, 1982, 1997; Flannery, 2005; Tudge, 2008). In order to make sense of a complex world, scientists tend to ‘reduce’ it, that is divide it into smaller and smaller units which can be measured and tested. Reductionist science has contributed to a reductionist worldview identified as ‘modernism’ (Huckle, 1996; Selby; 2000) that has been blamed for many of the environmental problems facing humanity. Other terms for describing a reductionist perspective include ‘mechanistic’ and ‘Cartesian’ (Capra, 1982). Flannery (2005) claims this type of thinking is gaining ground across the world. Malcolm (2003) maintains that reductionism and dualism are set deeply in the Western science curriculum despite considerable critique from the science community. Sterling (2001) proposes the following paradox: while proponents of the globalization of education believe they are at the forefront of change, they are, in fact, behind the times by: continuing to embrace a mechanistic view of teaching and learning; ignoring sustainability issues; and failing to recognize the ascension of ecological thinking.

One reason reductionism/modernism may be in the ascendant is because current education practices tend to replicate the dominant paradigm (Sterling, 1996, 2001). The transmissive approach to education involves the direct delivery of facts, skills and values – determined by a small group of experts – from teachers to pupils. In this sense, education is about "social reproduction," which "inculcates the preferred message, agenda, ideology, or consumer preference" (Jickling & Wals, 2008, p. 7). Referring to previous research, Sipos, Battisti and Grimm insist that the "explicit mission of contemporary school reform is to prepare students to perpetuate" ecologically and socially exploitive economies (2008, p. 70). However, as the Parliamentary Commissioner for the Environment warns: "It is important not to 'transmit' unsustainable practices from one generation to the next" (2004, p. 44).

At the same time, the *Guidelines for Environmental Education in New Zealand Schools* assert, "simply raising awareness of these issues is insufficient to bring about change" (Ministry of Education, 1999, p. 8). Jensen and Schnack (1997) agree that knowledge alone does not necessarily bring about behaviour change. Sterling (2001) emphasizes that not only does a simplistic/deterministic approach to EE not work, but that too much information about environmental crises can actually disempower learners by inducing high levels of awareness but low levels of understanding. Reductionism, not only in science education but also in environmental education, leads to a superficially informed society where individuals know but do not act (Blumstein & Saylan, 2007).

Jensen and Schnack (1997) address the anxiety and worry that exist in young people surrounding environmental problems, and express the need for a new way of teaching "from which pupils acquire the courage, commitment and desire to get involved in the social interests concerning these subjects" (p. 164). They indicate that traditional science-based EE leads to knowledge about environmental issues, but not to action competence. This knowledge-based approach – even if it includes activities and investigations – tends to overwhelm students with feelings of powerlessness (Hillcoat, Forge, Fien & Baker, 1995). When people feel powerless to change the existing system they fall into the habits of that system, even when those habits are patently unsustainable. The failure of environmental education, suggest Blumstein and Saylan, (2007), is indicated by the disconnect between learning and personal responsibility to take action. Sterling (2001) recognizes that this situation can lead to 'breakdown', instead of 'breakthrough'.

Holmgren (2002), co-founder of the permaculture concept, considers that most formal science education is reductionist, and Orr (2005b) concedes that indoor laboratories and classrooms are perfect locations to reduce the world to morsels of information. Meadows (2005) warns that we can never understand our world in the way reductionist science promises.

Reductionism may be expressed in the science classroom by both what is included and what is not included in the curriculum. Capra (2008) recognizes that seeing interconnections is difficult for us because such a view has not traditionally been emphasized in a science where, "we have been told things need to be measured and weighed. But relationships cannot be measured and weighed; relationships need to be mapped" (p. 2). He identifies two main reasons why most people are challenged by systems thinking. "One is that systems are nonlinear – they're networks – while our whole scientific tradition is based on linear thinking" (Capra, 2005, pp. 19-20). Capra also argues that our culture is materialist in both its values and worldview (2005). Under these circumstances, the role of the citizen is reduced to that of consumer, and the message of consumerism suggests a limitless supply of consumables (Bowers, 1996; Perkins, 2004).

Blumstein and Saylan (2007) place over-consumption at the heart of the environmental crisis. Citizens of most OECD nations are told by businesses and governments alike that it is their duty to spend money to support the economy (Perkins, 2004), but at what cost? Kasser (2002) examines the diverse and wide-ranging effects of consumerism in *The High Price of Materialism.* Of particular significance, he reports an inverse relationship between materialistic values and interest in environmental issues. Orr laments: "We may talk about how everything is ecologically connected, but the terrible simplifiers are working overtime to take it all apart" (2002, p. 31). Clover argues that the strongest educational process functioning during the 20th century was "the informal process of learning to consume" (cited in Chapman & Pearce, 2001, p. 392). Bowers (1996) points to evidence suggesting the advertising messages of consumerism far outweigh those of school-based environmental education when it comes to influencing behavior in young people. Likewise, Waters (2005) presents a case that our culture may indeed value young people more as consumers than as students, while Ableman (2005) claims the industrialization of education results in a reductionist system that treats children as consumers, feeding them disconnected bits of information. Not only does this reductionist treatment of learners work against the nurturing of systems thinkers (Capra, 2005, 2008; Orr, 1992), it would also appear to work against some of the most basic elements of scientific literacy, such as an understanding of carrying capacity or non-renewable resources.

Osborne (2003) calls on research that indicates many science teachers promote the value of science study as a pathway to a career, instead of its overall value within a culture. This reduces science education to a means to an economic end and perpetuates the model of education to serve a minority of learners who will pursue science careers (Osborne, 2003). Other authors note that the rational, positivist approach to science education creates an illusion that it is objective, consistent and value-free (Bencze & Hodson, 1999; Hodson, 2003). Pedretti, Bencze, Hewitt, Romkey and Jivraj (2008) found that science teachers were reluctant to include socio-scientific and environmental issues for fear that it would devalue the curriculum. Other reasons for science teachers not including EE pedagogies in their classrooms have been identified, such as low environmental and sustainability pedagogical content knowledge (PCK), an overcrowded curriculum, low confidence in taking children out of the classroom, a lack of resources and preparation time, and a lack of personal commitment to sustainability education (Kim & Fortner, 2006; McDonald & Dominguez, 2010; Samuel, 1993). As discussed in Section 2.3.1, Gough (2004) asserts that science education still functions in much the way it had in the 1980s (as described by Fensham, 1985) and before, the characteristics of which pose threats to scientific and ecological literacy, and would appear to contribute to attrition in school science. Given the international support for scientific literacy (Harlen, 2001; Millar, 2008; OECD, 2007) and the argument for holism in environmental education (Barker & Rogers, 2004; Blumstein & Saylan, 2007; Williams, 2008), the question of why education remains more transmissive and reductionist than transformative and holistic deserves consideration. This question is addressed in the following section.

### *2.4.2 Economic Rationalism*

The education systems of many countries are heavily influenced by economic rationalism, also known as New Right Ideology (Billot, 2003; Chapman, 2011; Giles & Alderson, 2008). In New Zealand, economic rationalism has influenced a shift toward a "reductionist model of accountability" (Codd, 1999, p. 45) applied to schools from the mid-1980s. One element of the resulting "culture of distrust" has been "the establishment of agencies to review, audit, and control the performance of educational institutions and to set standards for teaching and learning" (Codd, 1999, p. 49). Holt (2005) calls this the "curriculum straightjacket" (p. 57), and claims standards, while alluring, are in fact "educational poison" (p. 59). Ableman (2005) observes that schools have become like factories, manufacturing test scores and grades as their primary function. Sterling (2001) uses the same factory analogy.

White (2003) calls on research that reveals that despite high scores on traditional tests, student learning is often shallow, and that students could "hold beliefs about the natural world that were at odds with the scientific explanations that they had been taught" (p. 171). Similarly, Balgopal and Wallace (2009) recognize a type of student who can succeed in traditional science classes but fails to approach adequate levels of ecological literacy. White (2003) recalls studies that indicate, "although students' interest in science itself remained high, each year spent studying it decreased liking science as a school subject" (p. 171). Similar findings are reported in New Zealand by Bolstad and Hipkins (2008) and in a review of international science education literature by Tytler, Osborne, Williams, Tytler, and Cripps-Clark (2008). This pattern of disengagement with science learning, argues White (2003), leads to a positive feedback loop where fewer students pursue science in university and become science teachers. Some of those who do find themselves teaching secondary science are under qualified and resort to a textbook based approach to teaching, which further discourages another generation of students. White (2003) argues that "poor teaching leads to even fewer students enjoying science, and the spiral accelerates downwards" (p. 172). Among the reasons given for students' disengagement with science learning after the primary/secondary transition are an increase in transmissive teaching styles and the perception among students that the science curriculum lacks relevance (Tytler et al., 2008).

Both Codd (1999) and Holt (2005) recognize the competition between schools that results under strict educational management strategies, while Codd (1999) goes on to acknowledge reduced levels of participation among professional educators in the process of forming policy. This despite, as Holt (2005) claims, there is no research supporting a managerial approach to education. Yet 10 years after Codd's critique of New Zealand education policies, in which he condemns "the assumption that surveillance is the best way to maximize performance" (1999, p. 49), assessment remains a powerful influence.

A 2006 baseline assessment of EE in formal education in New Zealand (Bolstad et al., 2008) indicates that schools are constrained in their curriculum design by assessment accountability as well as by other pressures. This is consistent with Sterling's (2001) argument that managerialism inhibits innovation. Assessment and accountability put significant pressure on schools and teachers. This is particularly true of the senior secondary curriculum where EE struggles for legitimacy (Bolstad, 2005; Bolstad et al., 2008). Challenges to incorporating sustainability education into secondary schools are discussed further in Section 2.5.2 with a focus on New Zealand.

No matter how one feels about standardized testing, it is a tool that will remain in use for the foreseeable future. As such, the challenge in education reform is "to make the case that the programs we are advocating will make the material required by standards come alive, and will increase the likelihood that children will learn it" (Evans, 2005, p. 254). As described in Chapter 1, this inquiry seeks to identify potential synergies between junior secondary science, *The New Zealand Curriculum*, EEfS and permaculture with the goal of student learning expressed as improved ecological and scientific literacy. If a permaculture approach for junior secondary science has any chance at achieving these goals, it must mesh well with the existing conditions in junior secondary science classrooms in New Zealand.

Economic rationalism has significantly influenced New Zealand's enthusiasm for the 'knowledge economy', where "communications technology, scientific information and engineering skills," will account for a significant portion of future economic wealth (Chapman & Pearce, 2001, p. 428). Chapman and Pearce (2001) question how this represents any significant change in forms of production, how investment in education will be influenced, and the resulting effects on the natural world. The commodification of knowledge exposes the fundamental assumptions that a knowledge economy relies heavily on constant innovation and speed in the pursuit of profit. As such, little room is left to consider ethics and environmental consequences. As the gap between rich and poor widens and environmental deterioration continues, it is likely that the knowledge economy, "like any other economy based on exploitation and constant growth, is a one-way ticket to human oblivion" (Chapman & Pearce, 2001, p. 434).

While not synonymous, economic rationalism, neo-liberalism and globalization are cut from the same cloth. Jickling and Wals (2008) indicate that powerful institutions such as the World Bank influence education policy and international research toward neo-liberalism. As such, education becomes more about preparing worker/consumers for the global marketplace and less about providing young people with the best education possible (Jickling & Wals, 2008). Chapman (2011) suggests that the neo-liberal project, which relies on market competition, is inherently exploitative. Holmgren (2002) notes the erosion of innovation in educational institutions since the 1980s due to economic rationalism. In the name of economic efficiency, he posits, narrowly defined, short-term benchmarks are given priority, resulting in the loss of creativity in society. Sterling (2001) identifies the participation of New Zealand, along with the other English-speaking nations, in such an approach to education.

Jickling and Wals (2008) insist that globalization and neo-liberalism influence *all* education, and fear that EE is being pushed in a neo-liberalist direction by a drive to replace EE with education for sustainable development (ESD). They note that many such trends in education are policy-driven instead of innovation-driven. According to Porritt (2007), among politicians, "Levels of ecological illiteracy remain so deep as to beggar belief after 40 years of accumulating evidence that all is not well with our dominant model of progress" (p. 191). In New Zealand, economists such as Rod Oram (Oram, 2011) and Wayne Cartwright (Sustainable Aotearoa New Zealand, 2009) echo this sentiment and advocate for more sustainable economic models.

### *2.4.3 Section Summary*

Traditional education systems have failed to develop an ecologically literate citizenry that recognizes unsustainable practices and takes action on and for sustainable practices (Blumstein & Saylan, 2007; Orr, 1994). It has been argued that a barrier to the type of holistic worldview represented by ecological literacy is contrasted by the dominant Western worldview that is often described as reductionist (Capra, 1982, 1997, 2005, 2008; Flannery, 2005; Holmgren, 2002; Sterling, 2001; Tudge, 2008). This section described a number of reductionist conditions that appear to exist in the education systems as well as the economies and consumerist cultures of many of the world's wealthy nations including New Zealand. Of particular relevance to this inquiry are the ways that reductionism can express itself in a science classroom by what material is included or not, and how that material is presented to students. In many ways these expressions are the polar opposite of the holistic perspectives on learners, learning, and that which should be learned expressed by scientific literacy and ecological literacy. What appears to be a driver of reductionism in schools in many countries including New Zealand is often called 'economic rationalism' (Billot, 2003; Chapman, 2011; Codd, 1999; Giles & Alderson, 2008), which results in a managerial model of accountability that often inhibits educational innovation (Bolstad et al., 2008; Sterling, 2001). Some pressures on New Zealand schools, and specifically secondary schools, that effect both science education and EE are discussed in the following section.

## 2.5 The New Zealand Context

As an OECD nation, New Zealand has much in common with other OECD nations, particularly those with English as a primary language. Although New Zealanders are recognized as hardy, creative problem-solvers, due to its small population New Zealand only rarely leads the world in innovation. Regarding environmental education and science education, New Zealand has been influenced by developments in the UK, Canada, the US and Australia. While the EE movement in New Zealand appears to be more of a follower on the international scale, science education in New Zealand has played more of a leadership role. Both EE and science education are discussed in the following sections after a brief overview of environmental problems in New Zealand.

### *2.5.1 Environmental Problems in New Zealand*

The *Guidelines for Environmental Education in New Zealand Schools* (Ministry of Education, 1999) contains a page and a half of environmental issues that it divides into school, local, national and global levels. Although this document is outdated, it remains the most recent EE text published by the Ministry of Education. A list of national environmental priorities came from the Government's *Environment 2010 Strategy* (Ministry for the Environment, 1995), which included: managing land and water resources; protecting clean air and biodiversity; controlling pests, weeds and diseases; maintaining fisheries; managing the impacts of energy, transport, and hazardous substances; restoring the ozone layer; and reducing the risks of climate change. A more recent accounting includes issues relating to air, land, fresh water, oceans, biodiversity and the atmosphere, as well as household consumption, transport, energy and waste (Ministry for the Environment, 2007).

Of particular importance to New Zealand, especially in reference to this study, are the issues of climate change and peak oil, although it can be argued that the latter is not an environmental problem. Peak oil is recognized as the point of maximum annual oil production after which yearly extraction drops off year by year (Campbell & Laherrere, 1998; Connor, 2009; Deffeyes, 2003; Hubbert 1956; Simmons, 2005). As an agricultural nation, and one surrounded by water, New Zealand is especially vulnerable to volatile precipitation (drought and flood) and rising sea level (IPCC, 2007). At the same time, New Zealand imports more oil than it produces domestically (Ministry of Economic Development, 2011) but relies heavily on personal automobile transport. Transport accounted for 38% of total energy demand in 2011, more than any other single sector: industrial, commercial, residential or agricultural (Ministry of Economic Development, 2012). Additionally, large sectors of the economy are based on shipping agricultural and forest products long distances, and tourists flying equally long distances to spend their vacations and dollars here. The issues around carbon emissions and the price and availability of carbon-based fuels are not limited to the environmental realm, but also have significant economic and social implications. Therefore they may be described as 'sustainability problems' or more accurately as unsustainable practices that could have significant impacts on all aspects of contemporary life in New Zealand (and the rest of the world, especially OECD nations). But like many other OECD nations, New Zealand has not embraced an environmental or sustainability focus in its education system (Chapman, 2011; Chapman & Eames, 2007) as described in the following section.

### *2.5.2 Environmental Education in New Zealand*

As with most other nations, EE in New Zealand has evolved over the last four decades. Although there was no government policy on EE through the 1970s and 1980s, grassroots advocates were at work networking and lobbying (Eames, Cowie & Bolstad, 2008), and some EE was happening in schools (Bolstad, Eames & Robertson, 2008). Early on – between 1976 and 1978 – the Department of Education, the Commission on the Environment, and various universities held meetings on EE (Bolstad et al., 2008). In 1981 the Department of Education hosted a conference on "environmental education across the curriculum," followed in 1984 by the formation of the New Zealand Association for Environmental Education (Bolstad et al., 2008, p. 36). By 1988, "the environment" was included in a draft *Curriculum Statement* (Chapman & Eames, 2007).

The 1990s saw a dramatic increase in activity surrounding EE, starting in 1991 with an international conference on the subject hosted by the New Zealand Natural Heritage Foundation (NZNHF). NZNHF continued to play a significant role by developing an EE curriculum for schools that provided them with "tools and infrastructure to make things work in their own environment and their own community" (Bolstad et al., 2008, p. 37). This "eco-school" approach involved entire school communities and was trialed in several schools (Bolstad et al., 2008). It appears likely that this program influenced the later development of the Enviroschools program.

In 1992, the Earth Summit influenced New Zealand along with other countries – through *Agenda 21* – to develop and implement EE policies (Bolstad, 2003). However, Chapman (2011) has questioned the integrity with which the government followed through on its obligations from the Earth Summit by framing EE in such a way as to not interfere with the priorities of a conservative education agenda. He is unequivocal in his assertion that, "environmental educators need to be acutely aware that government policy is often in opposition to the agenda of environmental concern" (Chapman, 2011, p. 200). Between 1991 and 1993, what was called "Science and the Environment" in the draft of the New Zealand Curriculum Framework became simply "Science" in the New Zealand

Curriculum. Instead of a stand-alone learning area, the environment was included in a number of the essential learning areas, especially social studies, science and technology (Bolstad et al., 2008).

A whole-school approach to EE was fostered in 1993 by the formation of the Enviroschools program by a taskforce consisting of Hamilton City Council, Environment Waikato, the Department of Conservation, the University of Waikato, and interested teachers (Bolstad et al., 2008). The whole-school approach was embraced because it addresses both the explicit and implicit messages that children receive. The Hamilton City Council (2001) recognized that "children learn informally through the messages and meanings hidden within the physical surroundings, operational practices and organisational principles of a school" (p. 7). From three initial Enviroschools, the program has grown significantly over the years to include hundreds of schools.

The Ministry of Education commissioned the writing of an EE guidelines document in 1994 and 1995. Although the draft was finished in 1995, it was not released for another four years. In the meantime, the Ministry for the Environment released a number of documents relating to EE that included: *Environment 2010 Strategy: A Statement of the Government's Strategy on the Environment* (1995); *Learning to Care for Our Environment: Perspectives on Environmental Education* (1996); and *Learning to Care for Our Environment: A National Strategy for Environmental Education* (1998).

In 1999 with pressure from both the EE community and the Ministry for the Environment (Eames et al., 2008), the Ministry of Education published the *Guidelines for Environmental Education in New Zealand Schools*, in which a formal definition of environmental education was provided:

> Environmental education is a multi-disciplinary approach to learning that develops the knowledge, awareness, attitudes, values and skills that will enable individuals and the community to contribute towards maintaining and improving the quality of the environment. (Ministry of Education, 1999, p. 9)

Perhaps more useful for teachers than the definition itself, were the three dimensions of EE that the *Guidelines* contained: *in, about,* and *for* (Barker & Rogers, 2004). Of these, however, Barker and Rogers (2004) argue that education *for* the environment that leads to taking action for the environment is essential for authentic EE. This is a significant note with regards to this inquiry as it identifies a major challenge in taking action in what is already considered by many teachers an over-crowded curriculum (Bolstad et al., 2008; Chapman & Eames, 2007; Eames et al., 2008). Teachers have cited insufficient time and resources to make it possible to plan actions for the environment (Bolstad et al., 2008).

Alongside the three dimensions of EE, the *Guidelines* include four key concepts – interdependence, sustainability, biodiversity, and personal and social responsibility for action – and five aims: awareness and sensitivity to the environment; knowledge and understanding of the environment; attitudes and values toward the environment; skills involved in problem solving; participation and action in addressing environmental issues (Ministry of Education, 1999).

In pursuit of these aims, the *Guidelines* endorsed a multidisciplinary holistic approach to teaching and learning (Ministry of Education, 1999). In support of the *Guidelines*, the Ministry of Education funded two professional development programs between 1999 and 2002: Environmental Education Professional Development; and Professional Development for Sustainable School Organic Gardens (Eames et al., 2008).

The Ministry of Education followed up these programs in 2002 by commissioning a study to assess the status of EE in New Zealand schools that found:

> While many teachers and schools expressed enthusiasm about environmental education, the focus of teachers' environmental education programmes, where these existed, tended to be education 'about' the environment, with attention to encouraging students' care and respect for the environment. (Bolstad et al., 2008, p. 43)

As discussed in Section 2.2.2, too much education *about* the environment – if it focuses on environmental problems – can overwhelm students and leave them feeling powerless (Jensen & Schnack, 1997; Uzzell, Rutland & Whistance, 1995).

The year 2002 was also when the Enviroschools Program became available nationwide. The whole-school approach embraced by Enviroschools is the preferred approach for EE (Department of the Environment, Water, Heritage and the Arts, 2008; Davis & Cooke, 2007; McKeown & Hopkins, 2007; Ministry of Education, 1999), but is challenging for secondary schools because of a number of pressures (Bolstad et al., 2008; Chapman & Eames, 2007; Eames et al., 2008). Pressures on teachers include what is perceived as an overcrowded curriculum (Bolstad et al., 2008; Chapman & Eames, 2007; Eames et al., 2008; Jenkins, 2009) and insufficient time and resources to plan and take action for the environment (Bolstad et al., 2008). Additionally, it is possible that many New Zealand teachers have low levels of ecological literacy, as was found among Australian teachers (Cutter-MacKenzie & Smith, 2003). These challenges to incorporating sustainability issues in secondary schools informed this study and motivated the creative approaches within the intervention.

In 2004, the Parliamentary Commissioner for the Environment (PCE) released *See Change: Learning and Education for Sustainability* (2004). The document included a list of assumptions inherent in EfS that are also basic to permaculture and the promotion of more democratic societies. Among others, the assumptions include:

- there are ecological limits that constrain resource use and the ability of the environment to absorb the impacts of human-induced wastes;
- humans can use technologies to enhance their ability to exist within these limits; however, technologies also act as a double-edged sword;
- sustainability should be achieved through democratic processes; and
- development should be human-centred.

The first two assumptions align closely with ecological literacy and permaculture, while the last two relate to the Science for All (SFA) movement and scientific literacy, which aim to democratize science education and enhance the role of a scientifically literate citizenry in a critical democracy.

Currently, *The New Zealand Curriculum* (Ministry of Education, 2007) represents a shift toward a more democratic approach to education in New Zealand (Chapman, 2011). Compared to the former *New Zealand Curriculum Framework* (Ministry of Education, 1993), it is less prescriptive, and empowers schools to make educational decisions that are most appropriate for their students and communities (Chapman, 2011; Chapman & Eames, 2007). As long as each school remains true to the principles, values, key competencies and achievement objectives set out in the document, they have considerable freedom in tailoring a curriculum that could easily embrace an emphasis on the environment and sustainability. The principles, values, and key competencies of the *Curriculum* appear to encourage such an emphasis. Among the values is "ecological sustainability, which includes care for the environment" (Ministry of Education, 2007, p. 10). Among the Principles is "future focus," which includes such issues as "sustainability, citizenship, enterprise and globalisation" (Ministry of Education, 2007, p. 9). And among key competencies is "participating and contributing," which again mentions sustainability, but this time in reference to contributing to "social, cultural, physical and economic environments" (Ministry of Education, 2007, p. 13). In order to support the future focus of the *Curriculum*, the Ministry of Education set in motion a process to revise the *Guidelines for Environmental Education in New Zealand Schools* (Chapman & Eames, 2007). Part of that process included a position paper written by two leading EE researchers in New Zealand released in 2007 (Chapman & Eames, 2007). However, due to a change in government in 2008 the Guidelines were not revised. Additionally, national funding for Enviroschools was cut and the Ministry of Education placed an emphasis on numeracy and literacy. Although these developments challenge sustainability education in New Zealand, they also offer the opportunity for creativity in the exploration of different approaches. This study represents one such approach by combining the challenges facing EE with the challenges facing science education to improve both. Science education in New Zealand is discussed in the following section.

### *2.5.3 Science Education in New Zealand*

During the first three decades following World War II the educational changes that occurred in many other developed nations described in Section 2.3.1 were slower to come to New Zealand. During that time, New Zealand was transitioning from "being a British farm to a post-industrial, independent trading nation" (Bell et al., 1995, p. 5). Although there was a national science curriculum as early as the 1950s, by the 1970s and 1980s many New Zealanders grew increasingly dissatisfied with the curriculum, and called for a change that reflected the nation's need for more skilled citizens in the fields of science and technology (Bell et al., 1995). Chapman (2011) links rising petroleum prices in the 1970s and the resultant decrease in trade with Britain to a national interest in an education system that would prepare students for changing economic conditions that appeared to be on the horizon. By the mid-1980s, the school curriculum had become a topic of wide public debate as well as lobbying in parliament (Bell et al., 1995).

The year 1984 marked the convergence of this debate with the election of a fourth Labour government and the ensuing shift in education policy toward an economic ideology variously described as neo-liberalism, market-liberalism, marketisation, economic rationalism (Codd, 1999), free-market, New Right (Bell et al., 1995), or "busnocratic rationality" (Marshall, 1994, cited in Peters & Marshall, 1996, p. x). Central to the notion of the latter, according to Peters and Marshall (1996), are: "The concepts and stances taken in promoting skills, as opposed to knowledge; information and information retrieval, as opposed to knowledge and understanding; and the view that it is the consumers, especially industry, that define and determines quality, as opposed to providers" (p. 33). From the mid-1980s onward, Codd (1999) recognizes the role of the economy as dominant in the formation of state policy, while Peters and Marshall (1996) identify a focus on maximizing the economic power of both the individual and the state.

In 1984, incoming Minister of Education, Russell Marshall (1987), initiated a review of school curriculum that was ultimately released in 1987 as *The Curriculum Review* (Department of Education, 1987). With considerable consultation and input, the *Review* expressed the widely held public concern for education. Of note, the *Review* expressed the concerns that the needs of the learner should be at the heart of schooling. This learner-centred emphasis received wide support from the education community in New Zealand (Bell et al., 1995; Peters & Marshall, 1996), and is now recognized as drawing from constructivist approaches and conceptual change theories of the time (Malcolm, 2003). A year later, and based on the recommendations of *The Curriculum Review*, a Draft National Curriculum Statement (Department of Education, 1988) was published.

Chapman (2011) calls this a "ground-breaking document" (p. 196) because it provided an overview of the entire curriculum, it encouraged interdisciplinary strategies, and the curriculum areas identified values, attitudes and skills in addition to knowledge. One of the eight "Curriculum Aspects", or subject areas, was called "Science, Technology, and the Environment" (Department of Education, 1988, p. 9). Three years later the "Learning Area" heading had changed slightly to "Science and Environment" (Ministry of Education, 1991, p. 12), but in another two years, in the final *Curriculum Framework* (Ministry of Education, 1993), the environment was no longer partnered with science. Instead it was identified as being part of a number of different curriculum areas including science, social science and technology (Chapman & Eames, 2007).

As noted above, the *Review* received support from the education community for its focus on the learner, but it, and the resulting Draft National Curriculum Statement, were criticized by an emerging neo-liberal ideology that promoted a free-market approach to education reform (Bell et al., 1995; Chapman, 2011). Particularly vocal, despite no direct involvement in education, was the New Zealand Treasury (Bell et al., 1995; Peters & Marshall, 1996). In this case, the neo-liberals were criticizing the liberals for being more liberal than neo. Boston (1991) argues that the theoretical foundation of New Right restructuring efforts in New Zealand had three pillars: "Public choice theory; managerialism (or New Public Management); and the new economics of organizations, including principal-agency theory and transactional analysis" (as cited in Codd, 1999 p. 46). Codd (1999) identifies these theories as playing large roles in policy advice coming from the New Zealand Treasury.

It is significant and perhaps unfortunate that the peak of the decades-long national debate on education corresponded with the major social and economic changes being established by the 1984 Labour Government. As will be seen, economic rationalism essentially hijacked the debate and thwarted what may have been significant and meaningful education reform. In many ways, *The Curriculum Review* and the Draft National Curriculum Statement were ahead of their times (Chapman, 2011). One example was the combining of science, technology and the environment mentioned above. A decade and a half later, Hodson (2004) proposed that the interactions between science, technology and society (the STS emphasis) be broadened to include EE. In this way, STS became STSE, as New Zealand curriculum designers had intended much earlier – and as Canada (STSE) and Israel (STES) have also done (Aikenhead, 2003).

Alongside the overarching *Curriculum Review*, a revision of the science curriculum for 11 through 14 year-old students was underway, and a new draft science syllabus was written between 1985 and 1989 (Bell et al., 1995). In the draft syllabus, the underlying theoretical approach was a constructivist perspective on learning that was developed in the early 1980s by researchers at the University of Waikato (Bell et al., 1995). Constructivist thought is credited to Jean Piaget, who developed his ideas from biological concepts including adaptation and self-regulation (Sjoberg, 2008). Although there are many definitions of constructivism (Labudde, 2008), there are shared ideas that form the core of constructivist learning theory. Primarily, these ideas are: that knowledge is actively constructed by learners instead of being passively absorbed from an outside source; and, that learners enter learning forums with existing ideas about various phenomena (Sjoberg, 2008; Taber, 2006). From this perspective, knowledge itself is a human construct, and learning is a continuous and permanent process (Labudde, 2008).

Constructivist and other progressive approaches proposed during the 1980s for science education in New Zealand included the following:

- a 'Science for All' approach to the aims and goals of science education, including the emphasis on equity and accessibility of science for girls and Māori for those students who wished to do so (both Māori and English are official languages of New Zealand);

- the teaching and learning of science in contexts that have meaning and relevance for students;

- new additional teaching and learning experiences and activities, for example, concept mapping, creative writing, brainstorming;

- earth sciences as an area of science along with biology, chemistry, astronomy, and physics;

- teacher development as a part of curriculum development;

- broadening the notion of practical work;
- the inclusion of thinking skills in the list of scientific and learning skills to be learnt. (Bell et al., 1995, p. 11)

These approaches – based on perspectives of learning rather than simply content – were supported widely by science teachers and others involved in the field of education. The constructivist view differed from the behaviourist and hierarchical views embodied in the previous syllabus released by the Department of Education in 1978. In this way, the draft syllabus presented its scientific knowledge, skills and attitudes in broad terms in order to allow each school to design its own curriculum to address local needs, while remaining within the scope of the national curriculum (Bell, 1995).

As with the *Review*, the *Draft National Curriculum Statement* (Department of Education, 1988) received widespread support from the education community – the New Zealand Science Teachers' Association, the Ministerial Task Group reviewing science and technology education, and two teacher unions – for its focus on a constructivist approach to learning instead of simply on content. But the document was also criticized. On the one hand, criticism came in from some teachers nervous about the less rigid approach to teaching and learning, in light of the new accountability efforts being proposed by the new government based on free-market ideologies. On the other hand, conservative supporters of the neo-liberal agenda criticized the draft for not including rigid and specified content, clear learning outcomes, or labour market and economic analyses. In the end, the latter group carried more influence and the syllabus was never ratified (Bell et al., 1995).

The above examples illustrate how New Zealand curriculum designers in the 1980s were at the leading edge of a trend in science education. The constructivist view of learning embraced in the draft syllabus has been recognized as the dominant model for the teaching and learning of science from the 1980s onward (Hodson, 2004; Labudde, 2008). Hodson (2004) cites Fensham as recognizing constructivism as a 'new orthodoxy' of science education in many parts of the world. For instance, Malcolm (2003) links learner-centred pedagogy in South Africa to constructivist approaches (and conceptual change theories) that dominated science education during the final two decades of the century.

Additionally, as discussed above, the draft syllabus presented scientific knowledge, skills and attitudes in broad terms and allowed schools to design their own curriculum to address local needs while remaining within the scope of the national curriculum (Bell, 1995). Even a cursory review of the latest revision of the New Zealand school curriculum (Ministry of Education, 2007) reveals that this approach is embraced.

The 'Science for All' (SFA) approach embraced by the draft syllabus represented a significant step toward the democratization of science education. Implicit in SFA is putting the learner at the center (Malcolm, 2003). It seeks to make science education more accessible to groups of learners who may not have previously been engaged in science learning, such as girls and ethnic minorities (Fensham, 1985). SFA recognizes that how science is taught is equally important to what is taught, and encourages teachers to consider: any special characteristics of the subject matter; the backgrounds of the students in their classroom; and, the conditions surrounding the teaching and learning of science (AAAS, 1989; Science for All Expert Group, 2010). The wider international acceptance that scientific literacy achieved after the 1989 publication of *Science for All Americans* (AAAS, 1989; Rutherford & Ahlgren, 1991; Saunders, 2010) would also have supported the SFA approach taken by the draft syllabus writers in New Zealand.

However, as described above and documented by Chapman (2011), the development of a national curriculum is inherently political. While it is important to acknowledge how politics influences teaching and learning in schools, it is not the purpose of this section to dwell on the political. Backgrounded by the changes that took place in the 1980s, *Science in the New Zealand Curriculum* (Ministry of Education, 1993) helped provoke discussions on why and how science was taught in New Zealand schools (Hipkins, 2009). Many of those discussions can be revisited with the current version of *The New Zealand Curriculum* (Ministry of Education, 2007), which includes "a new vision, a revised values statement, key competencies instead of essential skills, a set of eight design principles, and new guidance about the 'how' of pedagogy and assessment" (Hipkins, 2009, p, 1). Bull, Joyce and Hipkins (2007) question the role of science in the overall curriculum and suggest that contexts and content should be considered as an essential pair. Of particular relevance to this inquiry, they link learning about ecosystems in primary school to the development of systems thinking skills, what they also call "joined-up" thinking. By learning how elements of a system relate to one another, it is likely that students would also learn how those elements relate to themselves. This could go a long way toward improving the perceived relevance of science for some students, and potentially their engagement with it. Similarly, Saunders (2010) recognizes shifts towards a focus on scientific literacy by pointing to the science essence statement in *The New Zealand Curriculum*: "students explore how both the natural physical world and science itself work so that they can participate as critical, informed and responsible citizens in a society in which science plays a significant role" (Ministry of Education, 2007, p. 17).

It appears that this focus has served some New Zealand students well when compared to other OECD nations. The PISA results from 2006 show that the best 15-year-old science students in New Zealand are among the best in the world (Telford & Caygill, 2007). However, there is also a "long tail" of underachievement among science students here (Telford & Caygill, 2007). Also revealed in PISA 2006 was that fewer New Zealand 15-year-olds considered it important to do well in science compared with mathematics and English (Caygill, 2008). Two more aspects of PISA 2006 appear to hold special significance to the present inquiry. Each one addresses aspects of the research question and sub-questions regarding student's attitudes toward science and the environment.

Regarding students' attitudes toward science, it appears that students who reported higher engagement with science generally achieved higher in science than students who reported low engagement (Caygill, 2008). (Engagement was measured by students' self-reporting on enjoyment, interest and motivation.) Related to this, Crooks, Smith and Flockton (2008) have noted a decrease in New Zealand students' attitudes toward learning science paired with a decline in understanding of some conceptual areas of primary-level science. Considering these findings, it would appear that attempts to engage students in science are needed even to arrest the apparent slippage. Regarding science education, I suggest that the most realistic aim of this inquiry is to engage students in science by making it more relevant, local, experiential and solution-oriented using permaculture design and interacting with practicing permaculturists in the community. An argument along the lines of the transitive property suggests that by engaging students more in school science their attitudes about learning science will improve and then their achievement will improve.

Regarding students' attitudes toward the environment, PISA 2006 provides some interesting and potentially worrisome results. The data shows a positive correlation between the mean scientific literacy of students and their awareness of environmental issues (Caygill, 2008). This correlation appears to indicate a certain level of success in New Zealand schools teaching *about* the environment. Awareness is important, but as described in Section 2.2, it is only a part of the EEfS equation. When it came to concern for the environment, there was no correlation with student achievement in scientific literacy (Caygill, 2008). And when it came to optimism about the environment, researchers found a negative relationship with achievement in scientific literacy (Caygill, 2008). These findings appear to support what some authors see as the danger of disempowering learners by overwhelming them with too much information *about* the environment without enough experiences *in* and *for* the environment (Blumstein & Saylan, 2007; Hillcoat, Forge, Fien & Baker, 1995; Jensen and Schnack, 1997; Sterling, 2001). Regarding sustainability education, I submit that a more holistic approach to learning *about*, *in* and *for* the environment is needed to respond to the situation presented by the PISA 2006 results. Recognizing that integrating sustainability education into secondary schools is difficult, I see science as an appropriate learning area to target. From an ecological perspective, science education and sustainability education at the junior secondary level can enter into a mutualistic relationship where each benefits from the other. This type of mutually-beneficial relationship at this schooling level has been promoted by Gough (2004):

> Science education needs environmental education to reassert itself in the curriculum by making science seem appropriate to a wider range of students and making it more culturally and socially relevant. Environmental education needs science education to underpin the achievement of its objectives and to provide it with a legitimate space in the curriculum to meet its goals because they are very unlikely to be achieved from the margins. (p. 237)

Although Gough is an Australian researcher, she has described a combined approach that lends itself beautifully to the latest version of *The New Zealand Curriculum* (Ministry of Education, 2007) that represents a change in national education policy. Although it provides structure and requirements like the previous curriculum framework, it offers schools considerable freedom in how to meet the national standards. Significant elements in the new curriculum that relate to scientific literacy are a focus on the future and an emphasis on sustainability, citizenship and community. These emphases provide an opportunity for progressive reform in some areas such as junior secondary science. It is the purpose of this thesis to argue that the science learning area in years 9 and 10 in New Zealand secondary schools can be enhanced using a permaculture approach to teaching and learning, which simultaneously supports the national standards, engages students in science, and encourages students to develop higher levels of ecological literacy. To these ends, the approach aims to be transformative, constructive and participatory (Sterling, 2001).

### *2.5.4 Section Summary*

New Zealand is a unique country in many ways and faces certain environmental challenges that are particularly pronounced here, such as the protection of endemic species and the management of pollutants associated with a large and intensifying agricultural sector. But New Zealand also faces international issues such as climate change, ozone depletion and resource availability. Although resource availability – particularly non-renewable resources – is more of an economic issue, through the wider lens of sustainability it can become a social issue when resource scarcity results in rapidly rising or volatile prices. Of particular concern for New Zealand, especially in reference to this study, are the issues of climate change and peak oil. In short, the predicted effects of climate change include an increasing incidence of weather extremes (IPCC, 2007) including drought and sever storms, neither of which is amenable to agriculture. At the same time, New Zealand relies on imported oil to ship agricultural products long distances as well as to provide most domestic transportation (Ministry for the Environment, 2007). Given the vulnerabilities exposed by these challenges to sustainability, one may expect an education system that helps prepare young people for the future they are likely to inherit, but for the most part this has not been the case in New Zealand (Chapman, 2011; Chapman & Eames, 2007).

Like many other OECD nations, New Zealand has a decades long history of EE and a number of high quality examples. For the most part, EE/EfS has been embraced by many primary schools through the Enviroschools program started in 1993, which takes a whole school approach to EE (Bolstad et al., 2008). Despite some success in primary schools, a whole school approach poses challenges for secondary schools for a number of reasons including the perception of an already overcrowded curriculum (Bolstad et al., 2008; Chapman & Eames, 2007; Eames et al., 2008; Jenkins, 2009) and insufficient time and resources (Bolstad et al., 2008). However, it is my belief, as well as that of other researchers (Gough, 2004; Greuenwald, 2004; Hart, 2007; Hodson, 2003; Steele, 2011) that sustainability education can be successfully integrated into junior secondary science in such a way that enhances the teaching and learning of science.

Science education in New Zealand and across the globe took on a greater significance after World War II, and has been evolving ever since. The 1980s were a time of particularly rapid change. Although progressive reforms were suggested by researchers and endorsed by many educationists, the government in New Zealand and many other nations adopted reforms that favored higher levels of assessment, accountability, and more prescriptive curricula. These reforms were heavily influenced by economic interests and the push to be competitive in a globalized economy. Although the political nature of curriculum development was addressed in some detail in this section, the current state of science education in New Zealand appears to be one in which scientific literacy and constructivism are embraced and our high performing students are among the world's best (Telford & Caygill, 2007). However, research indicates declining engagement in science (Caygill, 2008) and decreasing attitudes toward learning science (Crooks, Smith & Flockton, 2008) among New Zealand students. Research also indicates an inverse relationship between New Zealand students' achievement in scientific literacy and their optimism regarding environmental issues (Caygill, 2008). Considering all of this, there appears to be a need for carefully-researched, well-grounded, creative, and holistic approaches to teaching and learning that can engage students in science while cultivating higher levels of scientific and ecological literacy. A permaculture approach for junior secondary science attempts to do just that. The vision for such an approach is presented in Chapter 3.

## 2.6 Chapter Summary

This chapter offered the history and current status of environmental education and science education internationally and in New Zealand, including some challenges facing each. Careful consideration was paid to ecological literacy and scientific literacy, and the relationship between them. It was argued that scientific literacy can be considered a subset of ecological literacy and that by combing key principles of each, educators have the opportunity to enhance both in their students. The partnership between scientific and ecological literacy is consistent with current thinking on EEfS as an approach to sustainability education: one that is rooted in the traditional EE practices of nature study and conservation education but aimed at encouraging sustainable behaviours in learners. Key aspects of ecological and scientific literacy were identified from the literature and then expressed as pedagogical practices aimed at cultivating those qualities. These key principles for teaching and learning aimed at improving ecological and scientific literacy are: affective experiences; experiential learning; taking action for the environment; emphasizing interrelationships; student-centred teaching and learning; making science relevant; and, the local application of science.

Having identified these key principles for nurturing ecological and scientific literacy, the chapter went on to identify some barriers to doing just that. First and foremost, there appears to be agreement from a broad range of authors that the type of holistic worldview represented by ecological literacy is contrasted by the dominant Western worldview often described as reductionist (Capra, 1982, 1997, 2005, 2008; Flannery, 2005; Holmgren, 2002; Sterling, 2001; Tudge, 2008). A number of reductionist conditions appear to exist in the education systems, economies, and consumerist cultures of many of the world's wealthy nations including New Zealand. Of particular relevance to this inquiry are the ways that reductionism can express itself in science classrooms by what material is included or not, and how that material is presented. What appears to be a driver of reductionism in schools in many countries including New Zealand is often called 'economic rationalism' (Billot, 2003; Chapman, 2011; Codd, 1999; Giles & Alderson, 2008), which results in a managerial model of accountability that often inhibits educational innovation (Bolstad et al., 2008; Sterling, 2001).

The final section of this chapter examined some of the barriers to ecological and scientific literacy in New Zealand schools, and some potential opportunities to overcome them within the context of local and global environmental issues. Of the many challenges to sustainability in New Zealand, two were identified as particularly relevant to this inquiry for their holistic natures, their global and local relevance, and their frequent appearances in the news in recent years: climate change and peak oil. But before thinking about how these two issues could be combined with the seven key pedagogical practices discussed above, a clearer picture of EE and science education in New Zealand would be necessary to optimize the potential impacts.

New Zealand has a decades long history of EE and a number of high quality programmes such as Enviroschools, which takes a whole school approach to EE (Bolstad et al., 2008). Despite success in some primary schools, a whole school approach poses challenges for secondary schools for a number of reasons including the perception of an already overcrowded curriculum (Bolstad et al., 2008; Chapman & Eames, 2007; Eames et al., 2008; Jenkins, 2009) and insufficient time and resources (Bolstad et al., 2008). These are significant challenges to overcome, but it appears that opportunities may exist to address them within the context of national trends showing student disengagement with science (Caygill, 2008), decreasing attitudes toward learning science (Crooks, Smith & Flockton, 2008), and an apparent disconnect between New Zealand students' scientific literacy and optimism regarding environmental issues (Telford & Caygill, 2007).

As described briefly in Chapter 1, permaculturists see solutions in problems, and from a permaculture perspective I envision a potential way to address the dual challenges introduced in Section 1.2: the difficulty of incorporating sustainability education in secondary schools (Bolstad, 2003; Cowie & Eames, 2004; Eames, Cowie & Bolstad, 2008; Gough, 2002; Steele, 2011); and, concerns about students' attitudes toward and engagement in learning science (Caygill, 2008; Crooks, Smith & Flockton, 2008; Tytler, Osborne, Williams, Tytler, & Cripps-Clark, 2008; White, 2003). A permaculture approach to science education aims to turn these two problems into one solution. Additionally, this approach strives to be transformative. It aims to facilitate the transformation of students' ideas and opinions about the environment, sustainability and science, and it aims to transform science teachers' ideas and opinions about the environment, sustainability and their teaching practice. Transformation and transformative learning are discussed in the next chapter followed by a discussion on permaculture. Chapter 3 concludes with an outline of the vision for a permaculture approach for junior secondary science.

# CHAPTER THREE - TRANSFORMATION AND PERMACULTURE

## 3.1 Chapter Outline

The previous chapter provided a review of literature on ecological and scientific literacy, including the New Zealand context. This chapter reviews the relevant literature on transformative learning and permaculture. The first section examines transformative learning theory and the stages of transformation. These are followed by an argument for how this adult learning theory may be applied to adolescents and what pedagogies and potential catalysts can be employed to enhance transformative learning in this age group. Permaculture, within this context, represents a way of sustainable thinking that can serve as a desired outcome of transformative learning. Section 3.3 presents the history of permaculture along with its ethical underpinnings, its emphasis on design, some criticisms, and examples of ways permaculture has been used in schools. Section 3.4 addresses aspects of sub-question 1 of this inquiry: What are the characteristics of a permaculture approach to junior secondary science? It describes five ways in which permaculture, as a distinct philosophy and movement, could be used in a New Zealand junior secondary science classroom to cultivate ecological and scientific literacy. In so doing, it addresses the relationship between permaculture and ecological literacy as implied in the title of this thesis. The chapter concludes with a summary and a review of the eight key principles that informed the intervention design (Chapter 5).

## 3.2 Transformation

Warnings have been issued about the environmental destructiveness and unsustainability of contemporary consumer lifestyles (Brown, 2008; Lovelock, 2006; United Nations, 2012). This is reported to be especially true of wealthy OECD nations such as New Zealand (Sustainable Aotearoa New Zealand, 2009; World Wildlife Fund, 2012). Some authors argue that the transition to sustainable societies and lifestyles will require major efforts at every level (Brown, 2008; Heinberg, 2011; Lovelock, 2006; Macy & Johnstone, 2012), and education will play a vital role (Cutter-Mackenzie & Smith, 2003; Littledyke, Taylor & Eames, 2009). Bolstad (2003) acknowledges arguments that such a transformation cannot result from the traditional form of schooling that appears largely to replicate existing social structures. Other authors go so far as to claim that many times education works in direct conflict with the vision of a sustainable future (Blumstein & Saylan, 2007; Orr, 1994; Sipos, Battisti & Grimm, 2008; Sterling, 2001). In New Zealand, the Parliamentary Commissioner for the Environment (PCE) has stated the formal education system "helps to reproduce the society/culture that people live in and maintains existing systems and structures of power" (2004, p. 40). In other words, the suggestion is that unsustainable cultures transmit unsustainable behaviors from generation to generation. However, education need not only be transmissive (PCE, 2004; Sterling, 2001). Many authors suggest that education has the potential to be part of a transformation to a sustainable world (Capra, 2008; Cutter-Mackenzie & Smith, 2003; Littledyke, Taylor & Eames, 2009; Sterling, 2001; UNCED, 1992). Shaull promotes a vision for education where it can become "'the practice of freedom,' the means by which men and women deal critically and creatively with reality and discover how to participate in the transformation of their world" (1970, p. 15).

Such a transformation is what Macy and Johnstone (2012) call 'The Great Turning,' a shift from an unsustainable industrial society to a sustainable ecological society. Milne, Ball and Gray (2005) submit that to make such a transition, business and industry will require an ecologically literate work force. Whether this entails hiring qualified applicants or (re-) educating existing employees, they emphasize the need to think beyond eco-efficiency, in other words, beyond a weak model of sustainability. As an alternative to eco-efficiency, McDonough and Braungart endorse the concept of eco-effectiveness in their manifesto, *Cradle to Cradle* (2002). The title of the book represents the type of transformation in thinking needed to move from a failed history of opportunistic design to a future of ecologically inspired design. Sterling (2001) identifies this as third order change: 'seeing things differently'. But how does such change occur? The next section explores transformative learning and potential ways to nurture it.

### *3.2.1 Transformative Learning*

Learning is considered a relatively permanent change in human capability or disposition not ascribable merely to growth (Gagne & Medsker, 1996). It can be simple, or it can be transformative. Simple learning merely elaborates the learner's existing paradigm, ways of thinking, feeling, or doing, relative to a topic (Robertson, 1996). Transformational learning involves meaning-making that can result in changes to one's frame of reference (Mezirow, 1990; 2000). It involves “critical self-reflection, which results in the reformulation of a meaning perspective to allow a more inclusive, discriminating, and integrative understanding of one’s experience” (Mezirow, 1990, p. xvi). Kegan (2000) describes this as an epistemological change or a new way of knowing. Central to the theory is the critical examination of one's basic assumptions, and entering into a “special form of dialogue” which requires one to strive “to be open and objective in presenting and assessing reasons and reviewing the evidence and arguments for and against the problematic assertion to arrive at a consensus” (Mezirow, 1995, p. 53).

In the context of this study, transformative learning focuses primarily on environmental sustainability, but the theory is not exclusive to this realm. In fact, transformative learning can involve any number of perspective transformations unrelated to environmental sustainability. For example, a person having experienced a heart attack may change their diet and exercise habits as a result. For the purposes of the present inquiry, however, the focus lies on what Rathzel and Uzzell (2009) call 'transformative sustainability,' the type of transformation advocated by O'Sullivan (2002, 2003), Sipos, Battisti and Grimm (2008), and Sterling (2001), who calls it 'sustainable education.'

A note of caution, however, is required when discussing this type of transformative learning. Sterling (2001, 2005), for instance, advocates for the transformation of the entire educational system. While one may be in agreement with his position, it is clear that such a vision is beyond the scale of this inquiry, which addresses only the inner two spheres of his nesting systems of education: teaching methods and the learning experience (Sterling, 2005).

O'Sullivan (2002) calls his approach to transformative learning ‘integral transformative learning’, which emphasizes the integrated, thorough, and essential nature of transformation. For him, “Transformative learning involves experiencing a deep, structural shift in the basic premises of thought, feelings, and actions” (O'Sullivan, 2002, p. 11). This view of learning is similar to what Freire (1998) argues is the ultimate purpose of education: the transformation of both the individual and society:

> Something much richer than the simple repetition of a lesson or of something already given. For us, to learn is to construct, to reconstruct, to observe with a view to changing—none of which can be done without being open to risk, to the adventure of the spirit. (p. 67)

However, many potential learners may avoid taking this risk and adventure. Some research indicates reluctance in individuals to engage with and learn more about topics such as environmental issues and energy concerns when they feel uninformed about them (Shepherd & Kay, 2011). In other words, "ignorance…may, ironically, breed more ignorance" (Shepherd & Kay, 2011, p. 1). Other research indicates that when faced with complex social or scientific issues, people who hold strong opinions are apt to engage bias when considering empirical evidence (Lord, Ross & Lepper, 1979; Munro, 2010). Roberts (1996) warns that facilitating transformative learning experiences in adults may have unintended adverse effects, such as hampered performance or reluctance to further education.

When considering these barriers to transformative learning, it is not hard to understand why individuals and society have not made the wholesale transition advocated by Orr (1992), Capra (2008), Brown (2008) and others. O'Sullivan (2003, p. 327) expresses the urgency and monumentality of the task:

> From the perspective of "transformative learning", the fundamental educational task of our times is to make the choice for a sustainable planetary habitat of interdependent life forms over and against the pathos of the global competitive marketplace.

This requires a change in worldview from one that is reductionist, mechanistic, and quantitative to one that is holistic, organicist and qualitative. To achieve this monumental task requires that educators equip learners with all the knowledge and skills they require. In pursuit of this, it is critical to understand the stages of transformative learning, as described next.

### 3.2.2 Stages of Transformation

Mezirow (2000) identifies 10 stages of transformative learning: a disorienting dilemma; self-examination with feelings of fear, anger, guilt, or shame; a critical assessment of assumption; recognition that one's discontent and the process of transformation are shared; exploration of options for new roles, relationships and actions; planning a course of action; acquiring knowledge and skills for implementing one's plans; provisional trying of new roles; building competence and self-confidence in new roles and relationships; a reintegration into one's life on the basis of conditions dictated by one's new perspective.

The first stages are similar to what Kubler-Ross (1969) identifies as the stages of grief in her study of the terminally ill: denial, anger, bargaining, depression and acceptance. Later Kubler-Ross (2005) identifies these stages in individuals undergoing other forms of major loss such as divorce, the death of a loved one or job loss. Each of these forms of loss appears to qualify as a disorienting dilemma, the first stage in a transformative learning process (Mezirow, 2000). O'Sullivan (2002) uses the term cognitive crisis to describe the catalyst for change, and Schugurensky (2002) suggests, "transformations may occur incrementally, without necessarily experiencing a disorienting dilemma" (p. 72). No matter which language is used to describe it, a transformative learning process is often facilitated by an unplanned change in a learner's life, be it sudden or gradual. The importance of transformation is to work through the initial stages of fear, anger, sadness or denial, and to come out the other end with an altered perspective on the world or oneself.

The 10 stages of transformative learning (Mezirow, 2000) can be summarized as: a disorienting dilemma "sets in motion a self-examination of one's underlying assumptions, followed by sharing these thoughts with others, which leads to exploring new roles, relationships, and actions, a trying on of new roles" (Merriam, 2006, p. 24), and ultimately, the adoption of one's new perspective into their life and lifestyle (Mezirow, 1991). The phases do not necessarily occur in this order, and learners may occupy multiple phases simultaneously (Roberts, 2006).

O’Sullivan (2002) takes a critical cultural view of transformative learning that sits well with a study such as this dealing with issues of sustainability. He identifies three “simultaneous moments” inherent to transformative criticism: “the critique of the dominant culture’s formative appropriateness; a vision of what an alternative to the dominant form might look like; and, some concrete indications of the practical exigencies of how a culture could abandon those aspects of its present forms that are functionally inappropriate while, at the same time, points to a process of change that can create a new cultural form that is functionally appropriate” (p. 3). For the purposes of this study, ecological literacy and permaculture address all of these moments save for, perhaps, the process of change. In other words, ecological literacy is the aim, and permaculture can serve as an example of a functionally appropriate cultural form, but reaching that aim and adopting that form are the challenges for which transformative learning theory has been included in the theoretical framework.

O'Sullivan (2002) identifies three modes in integral transformative learning: “education for survival; education for critical understanding; and, education for integral creativity” (p. 4). In the context of this study, I have distilled transformative learning into three fundamental stages: 1) a disorienting dilemma (Mezirow, 2000) or cognitive crisis (O'Sullivan, 2002); 2) looking for and trying out alternative ways of knowing; 3) changing one's frame of reference by adopting an alternative worldview. Milbrath (1994, p. 117) defines worldviews as “epistemological structures for interpreting reality that ground their picture of 'reality' in their own construction.” A change of worldview, or “new ways of thinking and patterns of behaviour” (Chapman & Eames, 2007, p. 13), is central to education for sustainability (Parliamentary Commissioner for the Environment, 2004; Spring, 2004), and ecological literacy (Capra, 2008; Orr, 1992, 1994). These three stages provide an overall structure for the design of the intervention (see Chapter 5) and are described henceforth as the *transformative chronology*. This chronology is the last of the eight key principles of the intervention, the other seven having been introduced in Chapter 2. But a transformative chronology is not the only application of transformative learning theory in this inquiry. Certain transformative pedagogies are described in Section 3.2.4, while an argument for the application of an adult learning theory to junior secondary students is made immediately below.

### *3.2.3 Expanding Transformative Learning*

While transformative learning theory is rooted in the field of adult education (Mezirow, 1990, 1991), it has been applied to adolescent learning (Goulah, 2007), and appears appropriate when viewed alongside the work of Vygotsky (1978, 1997). Adults, according to Piaget's theory of cognitive development, are said to inhabit the fourth and final developmental stage - the formal operational stage - that commences at age eleven or twelve and extends into adulthood (Piaget & Inhelder, 1969). Vygotsky's social development theory focuses on the socio-cultural contexts in which learners interact in shared experiences (Crawford, 1996). Social development theory (Vygotsky, 1978) submits that children working at any stage of cognitive development may be able to operate at a higher cognitive level by working with a so-called More Knowledgeable Other (MKO), which can take the form of peers or adults in the community. The difference between a student's ability to learn independently and with a MKO is known as the Zone of Proximal Development (ZPD) (Vygotsky, 1978). The students in this study were likely in the early formal operational stage or in transition from the concrete operational stage (Piaget & Inhelder, 1969).

The argument, then, is that the use of socio-cultural learning and MKOs can make aspects of transformative learning more accessible to adolescents who may not otherwise experience such learning on their own. Approaches that include group work and engaging with a community of adults - 'Facilitating Shared Learning' – are among the pedagogies encouraged in *The New Zealand Curriculum* (Ministry of Education, 2007). Social constructivism is also called inter-subjectivist strategy, or communicative learning by van der Veen (2000), who argues that it can precipitate transformative learning in individuals. “Communicative learning thrives on and facilitates individual transformative learning” (van der Veen, 2000, pp. 15-16). Goulah (2007) does, however, acknowledge that students' social construction should be scaffolded (also see Bruner, 1986).

If education has an obligation to prepare students for the world they are likely to inhabit, it appears that traditional transmissive pedagogies are inadequate. International experts present considerable evidence that the future will likely be defined by environmental degradation and increased competition for limited resources (Brown, 2008; Heinberg, 2007; Holmgren, 2009; Klare, 2012; Vitousek, Mooney, Lubchenco & Melillo, 1997). But how do we prepare students for these future scenarios without overwhelming them? The next section discusses some pedagogies that may help gently cultivate transformative learning.

### *3.2.4 Transformative Pedagogies*

Orr (1992) insists, "*the way education occurs is as important as its content* [original italics]" (p. 91), and draws on the writings of John Dewey, Alfred North Whitehead and Paulo Freire, among others, to argue:

> Real learning is participatory and experiential, not just didactic. The flow can be two ways between teachers, who best function as facilitators, and students who are expected to be active agents in defining what is learned and how. (Orr, 1992, p. 91)

Transformative learning includes all of what Orr espouses here and elsewhere as sound educational pedagogy. Transformative methodology can include participatory teaching and learning styles, experiential education, and constructivist approaches that draw on the everyday lives of learners, and encourage them to understand what they already know in more comprehensive ways (Littledyke, 2009; Rathzel & Uzzell, 2009; Sipos, Battisti & Grimm, 2008; Sterling, 2001). Transformative learning environments require the teacher to become a facilitator of learning, acknowledging students as active participants (Rathzel & Uzzell, 2009). Transformative education employs constructivist approaches that are engaging, meaningful and participative, because in order for change to be sustainable, it must be owned by the participants (Sterling, 2001). The ultimate change, it should be made clear, for both ecological literacy and transformative learning theory is a change in the way people live their lives (Mezirow, 1991, 2000; Orr, 1992; O'Sullivan, 2003: Sipos, Battisti & Grimm, 2008). A balanced approach of head (cognitive domain), hands (psychomotor domain) and heart (affective domain) in teaching and learning sets the stage for potential transformation of the 'behavioral domain' (Kuk, 1993; Loup & Koller, 2005; Sipos, Battisti & Grimm, 2008).

The preoccupation with change in human behaviors, taking actions for the environment, and practical competence "can only be derived from the experience of doing" (Orr, 1992, p. 92). In other words, experiential education is essential for a transformative learning process that cultivates ecological literacy. Dewey (1916) was a strong advocate of experiential education nearly a century ago, especially regarding a more democratic education system. As discussed in Sections 2.3.3 and 2.5.3, scientific literacy and Science For All (SFA) are attempts to democratize science education. They, too, endorse experiential learning, and seek to engage a greater number of students in learning science. From this perspective, they seek to change (transform) some students' attitudes toward learning science from negative to positive. Although this level of transformation is small compared with that discussed above, I would suggest that the cumulative effect of many small changes in perspective can lead to a larger change in perspective such as a sustainable worldview. Central to this argument is that greater levels of scientific literacy may lead to greater levels of ecological literacy. As discussed in Section 2.5.3, there appears to be a positive correlation between engagement in learning science and achievement in scientific literacy among 15-year-old students in New Zealand (Caygill, 2008). From this perspective, the goal of engaging more students in learning science should be a high priority among all science educators.

But engaging students in learning science by making it more experiential relies on teachers engaging with more experiential pedagogies. For some teachers this may require a change (transformation) in their philosophy on teaching. As described in the first two paragraphs of this section, transformative pedagogies include not only experiential learning but also affective experiences, and student-centered teaching and learning. While science education in New Zealand is meant to address constructivist learning, given the pressures on teachers described in Section 2.5.2, the question arises as to what extent teachers go to embrace such pedagogies given that lecturing is so much quicker and easier. Cultivating a learning ecology in a science classroom that promotes a transformation in some students' attitudes toward learning science and a transformation in some students' attitudes toward the environment appears to require either a teacher who already embraces most of which has been discussed in Chapters 2 and 3, or a teacher who is willing to change their own perspective on the teaching and learning of science.

Given the trends in, and challenges to, science education and sustainability education discussed in Chapter 2, it appears that many science teachers are not effectively applying the transformative pedagogies discussed above. Therefore, I submit that another key transformation for the advancement of ecological and scientific literacy among students is that of many science teachers. While this inquiry primarily focuses on students, the transformative pedagogies discussed above can only be implemented by a teacher. Research sub-question 2 addresses this to a certain extent: How does a permaculture approach to junior secondary science impact on the teaching and learning of science? As far as I am aware, this approach has never been studied before, and any changes in the teacher's perspective (or lack thereof) would be important to the overall inquiry. Findings related to the impact of a permaculture approach are discussed in Chapters 6, 7 and 8, while the potential for sparking transformational learning in students is discussed in the next section.

### *3.2.5 Igniting Transformation*

Before learners embark on transformative learning, they need to perceive a need to change. 'If it ain't broke, don't fix it' is a fair argument coming from someone who does not perceive any need to change. "Successful transformative learning seems to depend ultimately on the individual's motivation to learn" (van der Veen, 2000, p. 19). In this sense, transformative learning relates to humanistic education (Sterling, 2001), which "sees transformative learning as a form of self-realisation" (van der Veen, 2000, p. 19). Skillful educators must be in a position not only to answer the age-old question, 'Why do I need to learn this?' but to proactively avoid that question ever being asked by designing into their transformative learning experiences sufficient and clear relevance. That relevance could include a disorienting dilemma or cognitive crisis.

Transformative sustainability involves questioning the fundamental basis of the dominant Western mechanistic worldview. The prospect of challenging the very foundations of modern Western culture is so massive in and of itself to be disorienting. The process of discovering flaws in the dominant paradigm is likely incremental, and there may be no discernible single trigger for transformation (Schugurensky, 2002), but at some point there accumulates enough evidence to convince one of the need for change. Using the language of general systems theory, O'Sullivan (2002) argues that 'adaptive positive feedback' occurs "when we can no longer interpret experience in terms of old assumptions" (p. 3). This tipping point could conceivably be interpreted as a disorienting dilemma, or, in other words, the straw that broke the camel's back. But it may be impossible to separate the last straw from the cumulative effects of all the other straws. A broken axel is a dilemma for both car and driver, but no mechanic would say it was just the last bump that caused it. Rather, it was years of rust, corrosion and micro-cracks in the steel. The year 2011 witnessed two dramatic tipping points, or watershed moments, in the form of the Arab Spring and the Occupy Wall Street movement. I submit that each of these can be interpreted as mass examples of transformative learning among those who have become sufficiently dissatisfied with the status quo.

Kegan (2000) emphasizes the role of contradiction, paradox, and oppositeness in transformative learning. These contribute to what O'Sullivan (2002) calls a cognitive crisis. As emphasized throughout this inquiry, an ecological worldview is diametrically opposed to the dominant Western mechanistic worldview. As such, it considers the latter to be inadequate for explaining how the world works, as O'Sullivan (2002) explains:

> Transformative learning processes are counted as the *creative* [original italics] function of cognitive crisis. Creativity occurs within a cognitive system when old habitual modes of interpretation become dysfunctional, demanding a shifting of ground or viewpoint. The breakdown, or crisis, motivates the system to self-organize in more inclusive ways of knowing, embracing, and integrating data of which it had been previously unconscious. (p. 4)

Permaculture, as explained in the next section, is one such creative response. Dysfunctional interpretation is discussed presently with a critique of globalized consumption.

The dominant modern worldview is based on the assumption of continual economic growth (Berry & Swimme, 1992; Rifkin, 1991; Sale, 1991; Schumacher, 1974). This paradigm manifests on a micro scale as consumerism and on a macro scale as globalization. These two have fed each other for decades in a positive feedback loop that economists cheer and environmentalists curse. The frame of reference that sees the planet as a global marketplace provides only a narrow economic perspective of the Earth, and significantly hinders progress toward sustainable societies (O'Sullivan, 2002).

An underlying assumption of consumerism and globalization is that of cheap, abundant energy without consequences (Holmgren, 2009; Hopkins, 2008; Kunstler, 2006). This assumption is fundamental to Western lifestyles but an increasing body of evidence continually challenges it. Not only does scientific evidence suggest the burning of fossil fuels has significant consequences for climate stability (Gore, 2006; IEA, 2011; IPCC, 2007; Stern, 2006), but there is a growing number of warnings that scarcity of energy resources may lead to rapidly increasing prices (Alexander, 2011; Heinberg, 2004, 2007, 2011; Klare, 2012; IEA, 2010; Nashawi, Malallah & Al-Bisharah, 2010). Of particular concern is the prospect of reaching the maximum production limit of oil supplies known as peak oil (Campbell & Laherrere, 1998; Connor, 2009; Deffeyes, 2003; Hubbert 1956; Simmons, 2005). Both climate change and peak oil appear with increasing frequency in the news media and, whether one *believes* them or not, they influence political and economic policy.

Using the two related issues of climate change and peak oil as a starting point could potentially serve as a disorienting dilemma for adolescents who may not necessarily be interested in the environment per se. This is because, while being environment and science based, both climate change and peak oil have significant social and economic implications, which may appear more relevant to some adolescents. In other words, what may be most disorienting to young people are the prospects of higher prices for consumer goods, less travel, and a restricted job market in the future. As described in the previous chapter, of primary concern to this inquiry is making science and environmental issues relevant and meaningful to learners. The role of a disorienting dilemma is to sow the seeds of relevance and potentially inspire learning and change. While the aims of this study include developing students' systems thinking skills, I suggest that a more reductionist catalyst (climate change and peak oil) may have greater potential for facilitating transformation than a holistic catalyst (the entire environmental crisis). If, after all, students already possessed an ecological worldview, there would be no need for the transformation toward one.

Carefully planned, the issues of climate change and peak oil can be utilized as the ignition of a secondary science unit structured as a transformational learning process using permaculture as both beacon and handrail. Such an approach may suit secondary science in New Zealand because researchers have found that science teachers desire more stimulus materials “that challenge students' ideas and that encourage discussion, speculation, and ongoing exploration by groups of students working together” (Hipkins & Neill, 2006, p. 18). The potential of an end to cheap energy or a greater frequency of weather extremes could provide a powerful context for students at a time when most New Zealand science teachers report “aspects of teaching in context are neither prioritized nor often used” (Hipkins & Neill, 2006, p. 60).

A socio-dialogic approach appears to be warranted for use in the context of climate change/peak oil because “Communicative learning comes to the fore in more complex and dynamic situations where the existing body of knowledge raises doubts and controversies” (van der Veen, 2000, p. 15). Such an approach would benefit New Zealand science classrooms in two ways. First, it addresses the disconnect exposed by the *Green at 15* report (OECD, 2009) between academic performance and “awareness of, concern about, and level of optimism regarding environmental issues, as well as students' sense of responsibility in relation to sustainable development” (Bolstad & Hipkins, 2008, p. 11). Second, Mezirow's “special form of dialogue” (1995, p. 53) has the potential to address many of the assertions made by Hipkins and Neill (2006) regarding the impact of the National Certificate of Educational Achievement (NCEA) on science teaching. They submit: “Students need time to learn to *think more critically* [original emphasis] and independently, making connections to other parts of their learning and/or application to related issues and contexts” (p. 59). Additionally, they recommend a shift from cognition toward meta-cognition and the need for “more student-directed learning if students are to aspire to achieve at merit and excellence levels” (Hipkins & Neill, 2006, p. 59). These recommendations to improve student performance on NCEA are in strict alignment with what Sterling (2001) proposes as an ecological view of transformative education that emphasizes: “critical and creative inquiry; active learning styles; appreciative and cooperative inquiry; and a wide range of methods and tools” (p. 59). Fostering such beneficial relationships, as identified in Section 3.3, is at the heart of permaculture.

### 3.2.6 Section Summary

This section provided some background on transformative learning theory (Mezirow, 1990; 2000) while highlighting the stages of transformation. A transformative chronology was developed based on these stages and became the eighth and final key principle for the design of the intervention described in Chapter 5. An argument was made for expanding transformative learning theory from adults to adolescents by including social development theory (Vygotsky, 1978), and a proposal for igniting transformation was also described. Additionally, transformative pedagogies were identified as key principles for the intervention design (Chapter 5). These key principles – experiential learning, student-centered teaching and learning, and affective experiences – were already identified as important components for cultivating scientific and ecological literacy in Chapter 2. That they are also important transformative pedagogies reinforces the robustness of the intervention design, and satisfies one of the design principles of permaculture: each function of a system should be fulfilled by multiple elements (Mollison, 1988; 1991; Nuttall & Millington, 2008). Also known as redundancy, it is common practice in qualitative research (triangulation) and in permaculture. The former is discussed in Chapter 4 while the latter is discussed in the following section.

## 3.3 Permaculture

"Permaculture is a creative design response to a world of declining energy and resource availability" (Holmgren, 2002, p. xvi). It emerged as a concept in the mid 1970s through the work of Bill Mollison and David Holmgren. Mollison, sick of protesting *against* environmental degradation, was determined to develop a positive, solution-oriented approach *for* environmental protection (Mollison, 1991). After coining the term 'permaculture,' he and Holmgren published *Permaculture One* (Mollison & Holmgren, 1978), launching a worldwide movement. According to Holmgren (2002), permaculture is based on the following assumptions:

> The environmental crisis is real and of a magnitude that will certainly transform modern global industrial society beyond recognition. In the process, the well-being and even survival of the world's expanding population is directly threatened.

> The ongoing and future impacts of global industrial society and human numbers on the world's wondrous biodiversity are assumed to be far greater than the massive changes of the last few hundred years.
>
> Humans, although unusual within the natural world, are subject to the same scientific (energy) laws that govern the material universe, including the evolution of life.
>
> The tapping of fossil fuels during the industrial era was seen as the primary cause of the spectacular explosion in human numbers, technology, and every other novel feature of modern society.
>
> Despite the inevitably unique nature of future realities, the inevitable depletion of fossil fuels within a few generations will see a return to the general patterns observable in nature and pre-industrial societies dependent on renewable energy and resources. (pp. xv-xvi)

These assumptions, particularly the first three, are closely aligned with the assumptions that underlie EEfS and are implicit in sustainability (PCE, 2004). The last two assumptions have influenced the resilience movement, exemplified by rapid growth in the number of Transition Towns worldwide following the oil price spike of 2008. Transition Towns concern themselves largely with the effects of climate change and peak oil on local communities (Hopkins, 2008), as described in Section 3.3.4 below.

The word permaculture is formed from the words permanent and agriculture. This represents the original emphasis on perennial crops over annuals. Another emphasis is mimicking nature in diverse food systems as alternatives to monocultures:

> Permaculture is based on the observation of natural systems, the wisdom contained in traditional farming systems, and modern scientific and technological knowledge. Although based on good ecological models, permaculture creates a *cultivated* [*original emphasis*] ecology, which is designed to produce more human and animal food than is generally found in nature. (Mollison, 1991, p. 1)

This fecundity implies that permaculture is not just sustainable, but regenerative. As described below, permaculture has progressed beyond the agricultural focus of this definition, but as Mollison emphasizes in the last sentence, feeding people will always be fundamental for maintaining civil society.

Modern, or 'design permaculture' has evolved to address more than its original agricultural applications (Whitefield, 2009). It is seen as a philosophy and lifestyle ethic as much as a design tool. As Bell (2005) suggests, "Permaculture is a way of thinking" (p. 20). The design principles are broad enough to apply to many cultural systems such as legal, financial, and business (Hopkins, 2008). The original vision of "permanent (sustainable) agriculture has evolved to one of permanent (sustainable) culture" (Holmgren, 2002). On humanity's hopeful path toward a sustainable culture, permaculture offers strategies to heal damage already inflicted on the planet. Lillington (2009) quotes David Suzuki, one of the most recognized environmentalists in the world:

> What permaculturists are doing is the most important activity that any group is doing on the planet. We don't know what details of a truly sustainable future are going to be like, but we need options, we need people experimenting in all kinds of ways and permaculturists are one of the critical gangs that are doing that. (p. 9)

As suggested by Suzuki, the work of permaculturists is critical, although they are but one of the groups doing this type of work. Permaculture is one of many ecological design systems in practice today, but offers some advantages over others in that it is time-tested, world-wide in practice, and, as argued by Morrow (2006), the most comprehensive. It is a system of science and ethics, but the ethics always come first.

### *3.3.1 Ethics*

The ethical underpinnings of permaculture are introduced at the beginning of every course, and book on the topic (Holmgren, 2002; Mollison, 1988; Morrow, 2006). The permaculture ethics are generally expressed as: care for the Earth; care for people; and, share surplus resources. However, variations of the third ethic include: return the surplus; fair share; "contribution of surplus time, money, and energy" (Mollison, 1991, p. 3); and, "set limits to consumption and reproduction, and redistribute surplus" (Holmgren, 2002,

p. 1). Many permaculturists feel ethically bound to share their ideas and enthusiasm for permaculture, and are active in various education efforts involving permaculture.

I submit that the ethical commitment of permaculturists to care for the planet and share their commitment with others makes them ideal candidates as ambassadors for sustainability and, as outlined below, citizen scientists. Such an ethically bound person may be more willing to take time to visit a science class at a local school or host a site visit on their property. A commitment to the Earth, to people, and to sharing puts permaculturists in the position to help make science more relevant, more local, more experiential, and more hopeful for students worldwide. They can do this by sharing their experiences with the applied sciences of sustainable practices and the use of ecological design.

### *3.3.2 Ecological Design*

Design is “the conscious and intuitive effort to impose meaningful order” (Papanek, 1984, as cited in Holmgren 2002, p. 14), and where permaculturists put their ethics and principles into practice (Goldring, 2007). Permaculture design is based on observing and mimicking natural systems (Allen, 2002; Baxter, 2008; Bell, 2005; Holmgren 2002; Mollison, 1988, 1991; Whitefield, 2009). A number of design principles have been developed to guide permaculturists (Holmgren 2002; Mollison, 1988; 1991), but Holmgren (2002) emphasizes that systems thinking is an essential companion to these principles. “From a systems ecology perspective, ‘design by nature’ is not simply a metaphor but a result of the forces of self-organisation which can be observed everywhere in the living and wider universe” (Holmgren 2002, p. 14). In other words, permaculture is more systemic than systematic. Permaculture is not the principles. It is not a formula to memorize, or a recipe to follow: “To practice permaculture well is not necessarily to store a vast quantity of facts. It is better to understand underlying patterns” (Bell, 2005, p. 63). After many years of thinking about permaculture, I describe it as a system of design that seeks to recognize and maximize beneficial relationships while minimizing or eliminating harmful relationships. I embrace an approach to permaculture not as a set of principles to memorize and apply, but rather as a way of seeing that gives equal value to the links between elements of a system as to the elements themselves.

While formal permaculture principles were not used in the design of the intervention, a form of ecological design thinking was used that implicitly included them.

Like other ecological design strategies, permaculture relies on an understanding of ecological principles such as diversity and interdependence (Baxter, 2008), and strives to maximize networks of beneficial relationships (Whitefield, 2009) in order to reduce risks within systems (Allen, 2002; Bell, 2005). Such an approach to design can be applied to biological and non-biological systems. The commonly recognized permaculture interpretation of an orchard is a food forest, where a chemically managed monoculture is replaced by an organic polyculture complete with diverse ground cover and, potentially, domesticated animal inhabitants. In this context, a permaculturist uses design strategies gleaned from nature as well as specific science knowledge. This science knowledge could include an understanding of: leguminous plants and their role in fixing nitrogen; soil porosity and permeability; soil chemistry; and, predator – prey relationships among resident insects. Permaculturists also engage in the *practice* of science, for example by experimenting with new plant guilds – complementary plantings (usually of three) of mutually beneficial species – such as the 'Three Sisters' (originated by the Hopi tribe of North America): corn, beans, and squash.

A permaculture interpretation of a home is a structure that is not consumptive and polluting, but one that functions more like a tree: consisting of natural materials and gaining its energy directly from the sun. In this context, the design inspiration may be biological but the science knowledge is astronomical and physical. For example, in order to design and build a home that heats itself in winter but does not overheat in summer it is critical to understand the different sun angles and directions at various times of year. Additionally, a passive solar home requires a balance of incoming solar energy, thermal mass, and insulation. Attaining this balance requires knowledge of physics and particularly thermodynamics. Additionally, some permaculturists dabble in electricity in the form of renewable energy systems. For example, Mike Lawley from Egmont, New Zealand rewires old Smartdrive washing machine motors to make generators for micro-hydro electrical systems (EcoInnovation, 2007). It is easy to imagine that a large amount of science knowledge and experimentation went into the development of his generators.

Time-tested, comprehensive, and science-based, it appears as though permaculture could be integrated into school science as a way to increase science knowledge, systems thinking, and students' inclination to act. Additionally, practicing permaculturists could serve as local examples of citizen scientists practicing science outside of a laboratory with no test tubes or white coats. That said, permaculture is not without its critics.

### *3.3.3 Criticism*

Newman, Beatley and Boyer (2009) criticize permaculture co-founder David Holmgren's suggestion that permaculture can and should be practiced in the suburbs. First, they suggest that this may actually promote urban sprawl that would likely "destroy and consume more natural resources as lower-density communities spread out, and could easily result in more battles over existing resources" (p. 54). Second, they argue that permaculture in the suburbs would distract from "seeking region-wide solutions to these issues of energy, water, waste, and food production in favor of individualized approaches, which may not be equitable" (p. 43). Holmgren (2002) admits that permaculture has suffered at times from over-promotion, and that some efforts have "proved, at least in retrospect, naïve, misguided and counterproductive" (p. xxiii). He cites "lack of finance, information and skill" (p. xxiii), and, at times "superficial and cynical use" (p. xxiii) of permaculture as identifiable problems on certain projects. Finally, Holmgren (2002) recognizes the early, rapid growth of the permaculture movement as a potential cause of problems because at that time the ideas and principles were not fully developed.

Downton (2009) criticizes Mollison for his attempt to attract people into the fold by promoting permaculture as 'common sense.' Downton's argument revolves around a contention that many things in science are "counter-intuitive and non-commonsensical" (p. 135). He accuses Mollison of intellectual dishonesty because "no system of total human settlement design…can afford to lack scientific rigour" (p. 135). It appears that Downton may have interpreted Mollison's attempt at demystifying permaculture for neophytes (many of whom likely have low scientific literacy) as a pronouncement that the design system is 100% based on common sense, some, but not all of which, may correspond with science. Permaculture is a system of science and ethics, some, but not all of which may be considered common sense. But isn't common sense, after all, in the eye of the beholder? For example, is it common sense to bring a reusable shopping bag to the market when plastic bags are provided for free? One person may argue that reducing unnecessary consumption is common sense, while another may argue that taking advantage of a free service is common sense. So which is it, conservation or convenience? It depends on one's perspective.

But it is exactly the shift in perspective from consumptive convenience to productive conservation with which permaculture education concerns itself. The use of the term 'common sense' by Mollison and others is often used as an educational technique rather than a landscape design strategy. That said, however, much of permaculture *is* considered common sense by those concerned with thrift, energy and resource conservation, and/or living lightly on the planet: "Permaculture is common sense, but the thing that separates it from other methods of providing human needs is design. The design is based on observations we have made of patterns of natural ecosystems and how they function" (Nugent & Boniface, 2005, p. 11). Patterning design on natural systems can reduce the amount of work required (Bell, 2005), which could appeal to many individuals as a common sense solution to busy lives. Although prophets like Leopold (1949) and Carson (1962) urged ecological perspectives decades ago, contemporary Western culture still does not pattern itself on natural systems. On the contrary, authors argue that Western culture is patently un-ecological because of its obsession with continual growth (Heinberg, 2004; Meadows, Meadows, Randers & Behrens, 1972; Redclift, 1991). The cognitive crisis that likely draws many people toward permaculture is a realization of the complete unsustainability of the convenience/consumer/growth culture that has enmeshed their entire lives. Modernity, as explained by Holmgren (2002) "has tended to scramble any systemic common sense or intuition" (p. 127). The recent sub-prime mortgage crisis is a good example of the breakdown of common sense in the face of modern fiscal policy. Critics of borrowers who have recently lost their homes to foreclosure accuse them of lacking common sense when they signed up for adjustable rate mortgages on houses they couldn't afford. Before the crash of 2008, however, common sense seemed to dictate that one buy the biggest house possible because the way the market was rising one could always turn around and sell it at a profit.

Just as there is a difference between chemistry and chemistry education, there is a difference between the practice of permaculture and permaculture education. Choosing to use the term 'common sense' can, in fact, be considered a good design strategy for education because it provides an un-intimidating invitation for learners to enter a new field of study. In true permaculture spirit, then, this leads to mutually beneficial relationships between teachers and learners that may not have been established had permaculture remained simply a long, unfamiliar, and intimidating word. Keeping it simple does not equate to keeping it unscientific. Ultimately, a scientifically and ecologically literate population may consider all science, even that which may have previously appeared counter-intuitive, as common sense.

Not a criticism per se, but a common misunderstanding of permaculture is that it is a messy form of gardening. This reductionist view misses the holistic thinking and design embodied by permaculture. Permaculture is not untidy gardening and the intervention described in Chapter 5 is not a gardening unit. While gardening has been incorporated into schools in Australia (Nuttall & Millington, 2008) and the US (Stone & Barlow, 2005), with regional enthusiasm, it has also been criticized. Flanagan (2010) argues that no evidence exists that school gardens improve student performance on California state standards for mathematics and English, and therefore takes time away from what she considers more important learning. If performance on standards-based exams is all that matters in education, Flanagan may have some traction for her argument, but that argument is fundamentally at odds with transformative learning and environmental education. The polarity of the situation is illustrated by an interview she shares with the CEO of a cluster of 15 charter schools in Los Angeles in which the litmus test for an adequate education is whether pupils can read Shakespeare and laugh at the appropriate times. When contrasted against a backdrop of the predicted environmental, economic, and social challenges that those very students may face in their lifetimes, *The Taming of the Shrew*, while arguably hysterical, may not be argued as essential learning for the twenty-first century. On the other hand, an argument for permaculture – whether in the form of a school garden or a holistic approach to the teaching and learning of science – may become stronger and stronger as humanity experiences increasing volatility of the climate, energy and food prices, and financial markets (Heinberg, 2011; Holmgren, 2009).

### *3.3.4 Permaculture Since the Oil Price Spike and Market Crash of 2008*

Although climate change has received political and public attention for decades (Gore, 2006; McKibben, 1989), peak oil has been lesser publicized, especially before the spike in crude prices in 2008 (Heinberg, 2011). Record oil prices in July of 2008 were followed in October by a crash of world financial markets from which the global economy still suffers. Although the global financial crisis caused oil prices to plummet by the end of 2008, the shock may have served as a wake up call for many people who had previously bought into a paradigm of cheap, abundant energy, and debt-based growth. The disorienting dilemmas presented by many of the events of 2008 may have prompted individuals to seek alternative perspectives in the Transition Town movement that started to gain popularity worldwide with the publication of *The Transition Handbook* by Rob Hopkins (2008). As a permaculture teacher, Hopkins (2008) drew on his experience and knowledge of permaculture to design what he envisioned as a community approach to addressing the dual challenges to climate change and peak oil. In this respect, Transition Towns is permaculture's most overt expression of concern about the carbon-based globalized economy. It appears as if Hopkins' timing could not have been better to capture those suddenly jarred by what a glimpse of the future might look like: record food prices and record prices at the petrol pump. From the latter half of 2008, the Transition Movement experienced sudden growth worldwide and in New Zealand, which went from zero to nearly 60 recognized Transitions Towns (Transition Towns New Zealand Aotearoa, 2012).

Permaculture is a creative response to the predicted impacts of both climate change and peak oil, among other environmental, economic and social issues (Holmgren, 2002, 2009; Hopkins, 2008; Whitefield, 2009). However, it appears to me that the focus over the last half-decade has shifted from prevention to adaptation. This shift, I suggest, has galvanized around recent revelations about the potential proximity of peak oil (Alexander, 2011; IEA, 2010; Nashawi, Malallah & Al-Bisharah, 2010) and the dramatic failure of the Copenhagen summit on climate change in December 2009. Ultimately it may be hoped that permaculture can be part of a global transition to sustainability that will result in the reduction of both fossil fuel use *and* carbon dioxide levels in the atmosphere, but as of yet its contributions have been limited to helping individuals and communities develop levels of local self-sufficiency, or, using the language of the Transition Movement, 'resilience.' Calls for re-localization reach far beyond the permaculture movement (Kingsolver, 2007; Pollan, 2006; 2008), but their increasing frequency may draw more individuals and communities toward permaculture as a safeguard against volatile external forces that can dramatically affect the prices of food, energy, and commodities such as copper pipe, and even employment levels when local jobs are controlled by corporations headquartered far away. In a recent report from the United Nations (United Nations, 2012), the concept of resilience to change (along with mitigation and adaptation) plays a significant role throughout the document. Malcolm Bowman, a storm surge researcher in New York, described resilience in the context of the flooding of New York City by Hurricane Sandy in late October 2012 as "adapting and responding to events as they happen" (National Public Radio, 2012).

The classic permaculture design element that embodies resilience is the swale. Swales are linear earthworks that run perpendicular to slope. They are built high on the landscape to harness the potential energy of water and to facilitate infiltration. Swales facilitate the storage of water in soil pore space or in dams high in a watershed where it can be gravity fed to lower areas as needed. In this manner, the swale addresses both the predicted increase in variability of rainfall events (more droughts, more torrents) and potential increases in energy prices (the cost of running water pumps). When native forests are removed and soils are compacted (as is the case in much of New Zealand), rainstorms cause greater flooding and dry periods cause harsher droughts. This cycle of extremes is hard on the land and on people, and increases the need to use energy to pump water uphill for irrigation purposes. By contrast, a system of swales and high dams literally re-hydrates the landscape and provides gravity-fed irrigation. It uses free services provided by nature to moderate climatic extremes over which the landowner has essentially no control.

Used metaphorically, *thinking like a swale* can represent the retention of wealth in a community through the use of a local currency or the retention of heat in a passive solar home through the use of thermal mass and insulation. On a small suburban section, thinking like a swale could mean installing a water tank to collect roof runoff or adding water-retaining organic matter to a vegetable garden. These examples indicate varying levels of buffering against climate, energy, and financial volatility that appears to define much of the current practice of permaculture as resilience. Caution should be exercised, however, when considering engaging schools and teachers from this perspective. Although the concept of resilience may resonate strongly with someone experiencing a transformative learning experience related to concerns over the possible volatility in weather patterns and future energy and food prices, it does not necessarily resonate with teachers and school principals who concern themselves primarily with student learning. Schools should not be viewed as potential farms or orchards due to their vast expanses of grass. While vegetable gardens and fruit trees can and should be a part of all schools that can sustain them, the focus of those installations should be on student learning, not community resilience. The next section explores some ways permaculture has been used in schools and the scant research surrounding it.

### *3.3.5 Permaculture in Schools*

At times, permaculture projects in schools have taken the form of gardens. For instance, Praetorius (2006) describes using a school permaculture garden in an effort to reinforce values of sustainability, stewardship, and resourcefulness. Lewis, Mansfield, and Baudains (2008) used planting a community permaculture garden in their study of values in education for sustainability, but nothing in their description indicates how or why it qualifies as a permaculture garden. The authors describe the garden as organic and note that children were encouraged to engage in whole systems thinking while working there, but these alone do not differentiate a permaculture garden from any other organic garden. Harb (2011) describes installing a permaculture garden at the University of Massachusetts (US) in 2010 complete with details of what makes it a permaculture garden: sheet mulch, bio-diverse, human-scale, low-energy input, and reused materials. In 2012 this project won the National Association of Student Personnel Administrators' (NAPSA) Silver Excellence Award in Careers, Academic Support, Service Learning and Community Service division ("Student Permaculture Garden", 2012). At another American university, Gunderson and O'Day (2008) describe a permaculture project that embraces the permaculture ethics and systems-based ecological design as an innovative way of teaching sustainability in higher education.

Although school gardens have a long history (Nuttall & Millington, 2008), there has been little rigorous research on their effects on learning (Ozer, 2007). A survey of California fourth-grade teachers working in schools with gardens reported on teachers' perceptions that the gardens enhanced academic performance, physical activity, language arts, and healthy eating habits (Graham & Zidenberg-Cherr, 2005). A pre-post panel study of sixth-grade students in California found that school gardening may increase vegetable consumption by children (Ratcliffe, Merrigan, Rogers & Goldberg, 2011). Regarding student learning, a study prepared for the Royal Horticultural Society in London (Passy, Morris, & Reed, 2010) on student involvement in school gardening (not necessarily organic) reported outcomes including improved science knowledge, literacy, numeracy, and oracy skills. As important and useful as this research is, it has only peripheral relevance to this inquiry, which does not involve school gardens or health education.

Research relating to more holistic permaculture approaches to schooling has not been identified, and the presence of permaculture in secondary schools appears limited to niche offerings in some Australian high schools (Permaculture Australia, 2011), and in New Zealand as a topic within the Level III certificate in Production Horticulture (New Zealand Qualifications Authority, 2006). These peripheral elective offerings may appeal to a small number of students and focus on teaching skills. While there is nothing wrong with these programs, this inquiry focuses on how to expose all children to permaculture ideas, practices, and ways of thinking in a mainstream, compulsory science class. The aims are neither to teach gardening nor to teach permaculture, but to teach science by engaging permaculture on multiple levels. As detailed in the next section, permaculture has the potential to outgrow its heretofore-limited garden role in schools due, in part, to its high level of compatibility with EEfS, scientific literacy, ecological literacy, and *The New Zealand Curriculum* (Ministry of Education, 2007).

### 3.3.6 Section Summary

Permaculture is an ecological design system based on science and ethics. This section addressed each of these aspects of permaculture, along with some criticisms, recent trends (post 2008), and some ways in which permaculture – in the form of vegetable gardens – has been integrated into schools. Throughout the section, a positive relationship between permaculture and ecological literacy was emphasized. For example, practicing permaculturists abide by a code of ethics that include: care for the Earth; care for people; and, share any surplus. An attitude of care for the environment motivates permaculturists to take sustainable actions. Caring and acting are two components of ecological literacy along with scientific knowledge and systems thinking skills. Permaculturists use their understandings of science and the interconnectedness of things to design and build sustainable human buildings and organic food systems. Not only do permaculturists exhibit all of the components of ecological literacy, but they are also likely to share their knowledge and enthusiasm as part of their ethical code. Although permaculture has been around since the 1970s, there appears to have been a sudden rush of interest following the oil price spike and market crash of 2008. This has come primarily in the form of the Transition Movement and what is often referred to as personal and community *resilience* to external forces of potential extreme weather events, energy price volatility, and economic and financial uncertainty. While these developments may have swelled the ranks of permaculturists who could potentially approach their local schools, I suggest their approach should be different than the one heretofore embraced, which almost exclusively has been in the form of organic vegetable gardens. I'm not suggesting that there is anything negative about teaching children organic gardening, but I would argue that this represents the reductionist application of a holistic belief system, and that it may not recognize some of the perceived pressures on teachers and students (particularly at the secondary level) that may keep them inside their classrooms and outside of school gardens no matter how well-intentioned their development. This inquiry takes a broader view of permaculture by encompassing a wide range of design elements that could affect the development of ecological literacy in students. The holistic application of permaculture takes place on both the meta-cognitive and practical levels. The following section describes five ways that I have identified in which permaculture – as a unique design philosophy and movement – could be used as an approach to junior secondary science.

## 3.4 A Permaculture Approach to Junior Secondary Science

While many environmental, sustainability, and science educators have sought and continue to seek ways to improve ecological and scientific literacy, this inquiry aims to do so in ways heretofore untested. First and foremost, this inquiry provides a unique approach to the dual challenges of increasing attrition in school science and the difficulty of including sustainability education in secondary schools. The intervention design described in Chapter 5 is based on the belief that the teaching and learning of science can be improved by the careful and appropriate integration of sustainability education. This view runs contrary to the popular perception of teachers that EE/EEfS competes in an already overcrowded curriculum (Bolstad et al., 2008; Chapman & Eames, 2007; Eames et al., 2008). From a permaculture perspective, junior secondary science and EEfS can enter into a mutually beneficial relationship described as mutualistic or synergistic. Ultimately, such a relationship can also become regenerative by potentially inspiring students to learn more in the fields of science and sustainability, to apply their learning in their day-to-day lives, and to share their experiences and enthusiasm as advocates for a sustainable future.

Such lofty goals can only be achieved upon a solid foundation of relevant education research and through the creative application of a coherent and complementary design strategy. Chapter 2 provided a foundation in the fields of environmental/sustainability education and science education, and this chapter – to this point – has provided the building blocks for an intervention design involving transformative learning and permaculture. It should also be noted that such an integrated approach to school science is compatible with *The New Zealand Curriculum* (Ministry of Education, 2007), especially in addressing some aspects of the *Curriculum's* Vision, Principles, Values, and Key Competencies. Specifically, these include active involvement and connection (p. 8), future focus (p. 9), ecological sustainability (p. 10), and participating and contributing (p. 13). Specific to the study of science is the opportunity that a permaculture approach provides to embrace the Nature of Science as "the overarching, unifying strand" (p. 28) for the study of science. Specific to year 10 students, this approach can provide the type of "responsive curriculum" (p. 41) called for by the Ministry of Education (2007) to allow for "positive relationships with adults, opportunities for students to be involved in the community, and authentic learning experiences" (p. 41). Considering the potential synergies presented thus far in this thesis, my role as a curriculum designer is not unlike the job of a permaculture designer: to recognize and maximize beneficial relationships within a system for maximum effectiveness and productivity. In the case of curriculum design, the effectiveness and productivity relate to the time that students spend studying science and their advancements in scientific and ecological literacy. In all cases, the design is holistic and adaptive.

Permaculture is relevant to this inquiry for three primary reasons. First, it is grounded in science, and particularly ecology. Second, it has a worldwide (and New Zealand-wide) network of citizen practitioners who can serve as MKOs for pupils with regards to the science of sustainability. Third, it offers creative responses to the predicted future impacts of environmental problems and resource scarcity.

Permaculture is *applied* ecological design (Holmgren, 2002; Mollison, 1991; Morrow, 2006). It seeks to recognize and maximize beneficial relationships like those observed in nature (Bell, 2005; Jacke & Toensmeier, 2005; Whitefield, 2009). Understanding and mimicking these relationships can be highlighted in biology, chemistry and physics. Examples include: companion planting in organic agriculture; cation exchange capacity in soils; and, thermal transfer between a greenhouse and a dwelling. The following sections describe the ways in which permaculture design, the transformative nature of permaculture, permaculture techniques, permaculture practitioners, and permaculture properties could be used to enhance the teaching and learning of science while cultivating systems thinking skills and exposing students to sustainable living practices. These are the five ways that I have identified in which permaculture – as a distinct design philosophy and movement – could be used as an approach to junior secondary science.

### *3.4.1 Permaculture Design as Means Not End*

While a description of permaculture as ecological design filled Section 3.3.2 above, this section explains many of the ways that permaculture design could be used in this inquiry. Design and design thinking play substantial roles in most permaculture education programs that seek to teach them as distinct skills, as Holmgren (2002) notes:

> A large part of the thinking revolution involves the emergence of design as a universal skill alongside those of literacy and numeracy. It is not so much that we are just beginning to design; rather, we are becoming more conscious of the power of our individual and collective design processes and how to improve them. Design is fundamental to humanity and nature. (p. 14)

As much as I agree with Holmgren's words, I would argue that a permaculture approach to junior secondary science should not include the teaching of design or, for that matter, the overt teaching of permaculture. It should involve teaching science in permaculture ways. Based on the dual challenges this inquiry seeks to address, and the substantial body of literature around each one, an appropriate design decision for teacher buy-in does not include the suggestion of adding anything extra to the curriculum. Instead, the role that permaculture design should play in this inquiry is limited to a meta-level where it is used in the design of the overall investigation – including the methodology and analysis – and of particular importance, the intervention.

For example, Section 3.4 described how this inquiry is based on the recognition of potential mutually beneficial relationships between science education, EEfS, permaculture, and *The New Zealand Curriculum* (Ministry of Education, 2007). Permaculture design often involves thinking outside of the square, looking to nature for inspiration, and seeing problems as potential solutions (Mollison, 1988; 1991; Nuttall & Millington, 2008). Given the two problems, or challenges, of increasing attrition in school science and the difficulty of including sustainability education at the secondary level, I identified a potential solution and worked toward it. But I did not use the formal permaculture design principles to do so. Instead, I used the habits of mind inherent to ecological design thinking. Just as there are scientific habits of mind, there are permaculture habits of mind that come from looking at the world through a lens of solution-oriented eco-design. This perspective also influenced the choice of methodology and methods for the study, as well as data analysis, discussions, and conclusions. The presence of permaculture thinking can be felt in Chapters 4 through 9.

While the aim of this inquiry is neither to teach permaculture nor design, a desired outcome is that students develop certain habits of mind associated with ecological design thinking. Integral to these habits of mind is systems thinking. For example, while designing the intervention described in Chapter 5, I had to recognize the interrelationships between elements such as: the teacher, the *New Zealand Curriculum*, the classroom, the school grounds, the ethos of the school, local permaculturists, access to audio visual equipment, and vehicle availability for student transport. Additionally, any intervention would be designed around the key principles gleaned from the literature on ecological and scientific literacy, and transformative learning: affective experiences; local application of science; making science relevant; student-centred teaching and learning; taking action for the environment; experiential learning; emphasizing interrelationships; and, transformative chronology. Designers, I would argue, are not born but nurtured. A designing mind can be cultivated through design education. And an ecological design mind can be cultivated through ecological design education. But a science classroom is not the place for overt design education. It is the place for science education. However, a holistic view of science and science education allows for teaching and learning activities that cultivate systems thinking in students that could lay important groundwork for ecological design education when they are older. Should they find themselves seeking out such training later in life they may be influenced by a transformative learning experience, such as one of those described in the next section.

### *3.4.2 The Transformative Nature of Permaculture*

As described in Section 3.3, permaculture arose in the 1970s as a creative response to the environmental crises of the day (Mollison, 1991). Co-founder Bill Mollison describes the experience of making the transition from a logger to a protester to a permaculturist in the Australian documentary series, *Global Gardener* (Russell & Gailey, 1991). What Mollison describes appears to have been a transformative learning process in which he had a disorienting dilemma and experienced sadness and anger before retreating into nature to seek refuge from the destructiveness of humanity. It was through his careful observation of natural ecosystems that he began to formulate his thoughts around permaculture. Ultimately, he emerged from the experience with a new frame of reference that became – in cooperation with David Holmgren – the concept of permaculture (Russell & Gailey, 1991). Dawborn and Smith (2011) recognize the personal and cultural transformational value of permaculture, and Johnson (2010) describes the transformational learning experiences of students taking a permaculture design course at Indiana University. One student reported that the course had dramatically changed her life, making her more aware of resource use, and helping her identify behavior changes that she could make to shrink her ecological footprint (Johnson, 2010).

In my years as an educator and permaculture practitioner, I have observed many students and colleagues go through similar transformative learning experiences. The big difference between them and Mollison, of course, is that they did not invent permaculture but rather discovered permaculture as a new frame of reference. Based on these observations, I believe it is possible to design and scaffold transformative learning experiences that mimic Mollison’s in some ways. Chapter 5 details the design and description of the intervention, which includes the distilled three stage transformative learning process described in Section 3.2.2: 1) a disorienting dilemma (Mezirow, 2000) or cognitive crisis (O'Sullivan, 2002); 2) looking for and trying out alternative ways of knowing; 3) changing one's frame of reference by adopting an alternative worldview. Recognizing the nature of transformative learning, Mollison’s personal story of transformation, and the transformation of some of my former students and colleagues toward a permaculture perspective, I worked with the teacher to re-order the science units as shown in Section 5.1.1. Beyond this approach and the one presented in the previous section – both of which can be described as meta-curricular approaches to incorporating permaculture into junior secondary science – the final three strategies described below are those that would be readily apparent to students in (and outside) the science classroom.

### *3.4.3 Permaculture Techniques*

With the goals of harnessing energy flows and recycling waste products on site, permaculturists use a range of science-based techniques when designing and managing their properties or homes. Many of these techniques can be explained and explored in ways that are easily accessible to junior secondary students. Learning about some of these techniques can help make science more relevant, hands-on and hopeful for students, especially those who may feel under-engaged or alienated from science. For example, instead of planting monocultural orchards of the same fruit tree, permaculturists create food forests as described in Section 3.3.2. Such a cultivated ecology can be used to help students learn about science concepts such as biodiversity, materials cycling, and predator/prey relationships. At the same time, students are exposed to sustainability ideas such as organic horticulture and ‘food miles’. By contrasting the energy and chemical inputs between an orchard and a food forest, students can be asked to recognize multiple perspectives on the growing of fruit.

Another example of a common permaculture technique is the no-dig garden. Permaculturists recognize that most natural ecosystems have loose, friable soils while most conventional farms have compacted soils. Soil compaction can result from heavy machinery, too many large hoofed animals, or even too much human foot traffic. Compacted soils are less favorable to most vegetable plants, and reduce the infiltration of water, which increases the chances of runoff and erosion during rainstorms and decreases the amount of water stored in the earth available to hydrate plants in between rain events. A no-dig garden demonstrates an applied understanding of porosity and permeability, the water cycle, root function, and the soil food web. These science concepts can be shared with students in ways that are hands-on, relevant, and solution oriented. And they can be shared by local, citizen scientists, sometimes known as ‘permies.’

### *3.4.4 Permaculture Practitioners*

Those who actively practice permaculture can be described as systems thinkers, change agents, and citizen scientists. In these respects they can serve as MKOs for students who meet them. Many permaculturists also actively engage in design work based on a foundation of ecological literacy. Orr (2002) insists, in the spirit of Buckminster Fuller, that what is required of our world is no less than an ecological design revolution. He suggests that in the coming decades all nations will have to:

> Improve energy efficiency by a factor of 5-10; rapidly develop renewable sources of energy; reduce the amount of materials per unit of output by a factor of 5-10; preserve biological diversity now being lost everywhere; restore degraded ecosystems; redesign transportation systems and urban areas; institute sustainable practices of agriculture and forestry; redistribute resources fairly within and between generations; and, develop more accurate indicators of prosperity, wellbeing, health, and security. (Orr, 2002, p. 23)

All of these goals fall within the scope of contemporary permaculture, as shown in Figure 3.1. The Permaculture Flower provides an overview of the movement's broad scope that includes: energy efficiency; renewable energy; appropriate technology; protecting biological diversity; holistic land management; transportation issues; organic agriculture; forest gardening; intergenerational and intragenerational equity; ethical investment; local currencies; holistic medicine; and, peace (Holmgren, 2002).

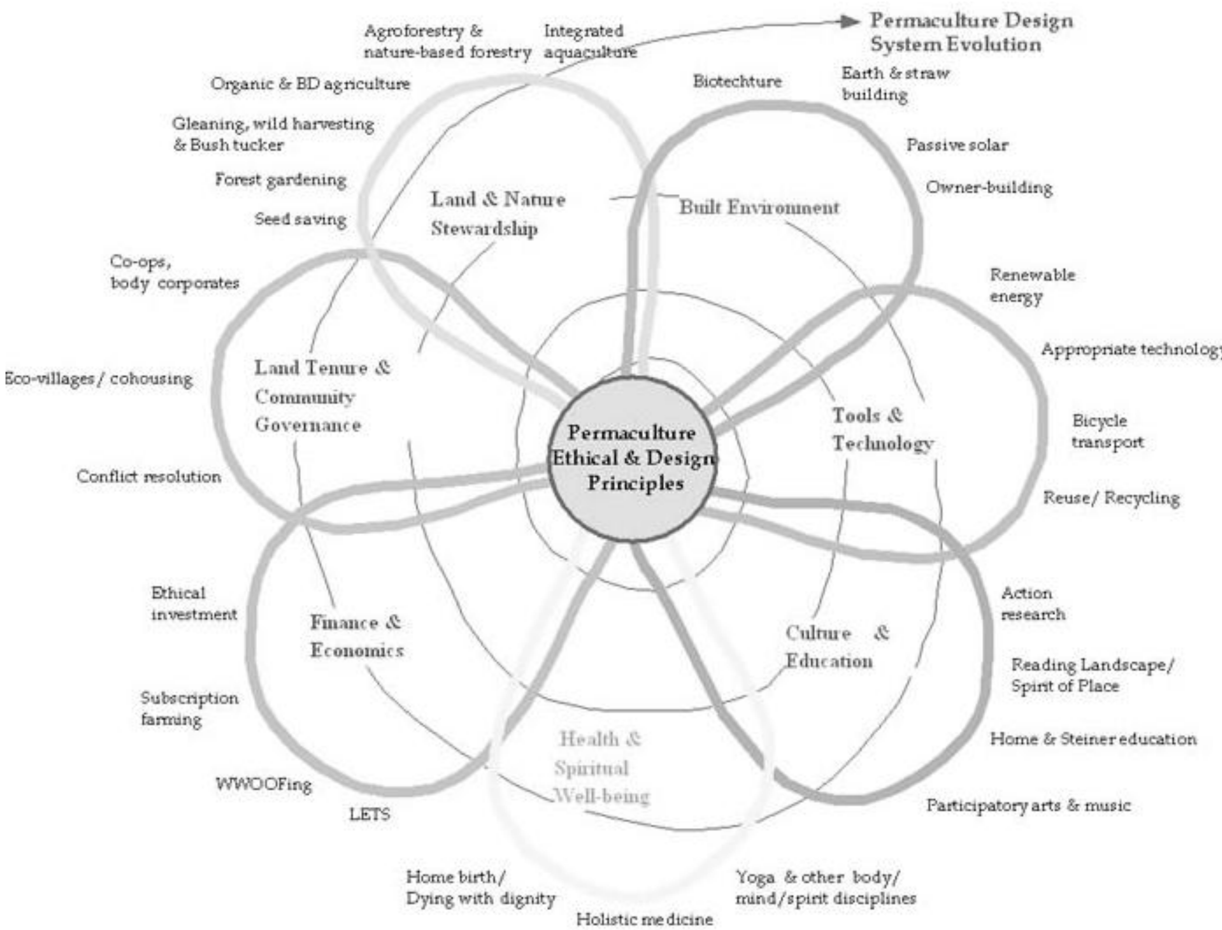


Figure 3.1 Permaculture flower (Holmgren, 2002)

"Permaculture provides a new design language for observation and action that empowers people to co-design homes, neighborhoods, and communities full of truly abundant food, energy, habitat, water, income…and yields enough to share" (Johnson, cited in Goldring, 2007, p. 17). This description of permaculture compares favorably with the education and design agendas of ecological literacy. Orr (1994) endorses educating a "citizen constituency that supports change and is competent to do the local work of rebuilding households, farms, institutions, communities, corporations, and economies" (p. 109) that do not reduce the planet's ability to sustain life. The fact is that this citizen constituency already exists, albeit in small but growing numbers. Permaculture practitioners give a local, human face to the concept of sustainability, which can help to demystify it for students and teachers alike.

As MKOs, permaculturists can role model all aspects of ecological literacy: science knowledge and ecological thinking; an attitude of care towards the environment; and, an active approach to environmental problem solving. In defining a permaculturist, I would work backward, for the most part, through this list. Permaculturists care, and they care enough to act. A permaculturist is defined by their actions – by what they do - just as a doctor or lawyer or farmer. A permaculturist is a *practitioner* of permaculture as a doctor is a practitioner of medicine. To be sure, permaculture design requires considerable thinking, and permaculture practice requires mindfulness, but at the end of the day these thoughts and ideas and feelings and plans require physical manifestations. Someone who merely takes a 10-day permaculture design course is not necessarily a permaculturist. It is only when he or she takes what was learned and applies it do they earn the title. At times in this thesis I use the term *self-identified permaculturist* to identify those individuals who voluntarily and publicly devote themselves to the practice of science and ethics.

It is the practice of science that places permaculturists in the position to enter into educational partnerships with science teachers. Permaculturists can demonstrate their knowledge and practice of science in their homes and on their properties. Some examples of scientific knowledge can be found in the lists offered by Orr (1994) and Klemow (1991) in Section 2.2.3. These may include carrying capacity, overshoot, thermodynamics, trophic levels, energetics, succession, and evolution (Orr, 1994). Many permaculturists practice science on their properties by making observations, collecting data, and conducting simple controlled experiments. For example, I spend time nearly everyday observing my gardens, fruit trees, and chooks for signs of change. I also collect temperature data on the thermal performance of my renovated villa, and often experiment with different cultivars, different applications of compost and compost tea, and weed control methods. These examples of scientific thinking are coupled with an overall perspective of ecological, or systems, thinking. While it may be difficult for students to recognize systems thinking in an MKO, it may be they would recognize and appreciate a permaculturist's knowledge and practice of science, their attitude of care, and their actions for the environment. While an exchange between science students and a self-identified permaculturist could take place in a classroom, a much better location might be on the permaculturist's home turf.

### *3.4.5 Permaculture Properties*

House-proud is an understatement when describing many permaculturists' attitudes toward their homes and properties. Hundreds, and in many cases thousands, of hours are spent developing highly sustainable homesteads both rural and urban. These properties are the physical manifestations of ecological literacy. Unsurprisingly, Orr (2002) advocates seeing "our houses, buildings, farms, businesses, energy technologies, transportation, landscapes, and communities in much the same way that we regard classrooms" (p. 31). Holmgren's Permaculture Flower (Figure 3.1) addresses everything on Orr's list and more. When Holmgren (2002) writes, "The landscape is the textbook" (p. 16), he indicates that the landscape encompasses not only the physical land, but also the cultural terrain. In order to establish effective approaches to holistic education, Orr insists that students must be invited into the conversation: "The goal is to honestly discuss the relationship between the concepts and skills that students will need to master in the coming century in order to protect and enhance life" (Orr, 2002, p. 140). As discussed throughout this section, a permaculture approach to science education is honest, future-focused, and directed not only at protecting life (sustainability), but also enhancing life (regenerative design). A permaculture property offers a venue not only for the honest discussion to take place, but also to demonstrate the crucial concepts and skills in real contexts.

Making science relevant to learners is central to cultivating scientific literacy (Bentley, Ebert & Ebert, 2007; Hodson, 2008). Carefully planned field trips to permaculture properties could help demonstrate relevancy, but also provide experiential learning opportunities and place science in a local context. With a little more planning and emphasis, these three key principles (identified in Chapter 2) could be joined by two more: emphasizing interrelationships and student-centered pedagogies. In this respect, fully five of the eight key principles identified from the literature on ecological literacy, scientific literacy, and transformative learning could be integrated into one carefully planned field trip to a permaculture property. While the first three key principles may be described as low-hanging fruit and the latter two as higher-hanging fruit, they are all fruit that can feed high quality teaching and learning, and nourish ecological and scientific literacy in students. A mature permaculture property is the product of ecological literacy and applied ecological design. Such properties, and their stewards, or guardians (*kaitiaki)*, can serve as important landmarks and guides for students along their learning journeys through school and beyond. While a field trip is likely to have immediate impacts on students in numerous ways, my observations during years of teaching have been that some of those experiences continue to inform the way young people make sense of the world for months and years afterward.

## 3.5 Chapter Summary

This chapter completed the framework by which the goal of improving ecological literacy in junior secondary science students can be approached through the use of transformative learning theory and by the holistic application of permaculture. The first section introduced transformative learning theory and identified certain pedagogies that may enhance transformation. Permaculture, within this context, represents a way of sustainable thinking that can serve as a desired outcome of transformative learning. The next section introduced permaculture, responded to some criticisms, and described ways in which permaculture has been used in schools. The final section described part of what makes this inquiry unique – as a *permaculture* approach – by describing five ways in which this distinct movement and design philosophy was used in the overall inquiry and specifically in the intervention design, which are: permaculture design as means not end; the transformative nature of permaculture; permaculture techniques; permaculture practitioners; and, permaculture properties. These five fingers of permaculture's hand in the investigation are joined by eight key principles for pedagogies aimed at enhancing ecological and scientific literacy, and encouraging transformative learning presented in Chapter 2 and Section 3.2.4. Together these address sub-question 1 of this inquiry: What are the characteristics of a permaculture approach to junior secondary science? The key principles discussed in Section 3.2.4 were: student-centered teaching and learning; affective learning experiences; experiential learning; and a transformative chronology. The key principles discussed in Chapter 2 were: affective experiences; experiential learning; taking action for the environment; emphasizing interrelationships; student-centered teaching and learning; making science relevant; and, the local application of science. While these principles and approaches are highlighted in the design of the intervention described in Chapter 5, the next chapter discusses the methodology and methods employed in this inquiry.

# CHAPTER FOUR - METHODOLOGY

## 4.1 Chapter Outline

This chapter describes the methodology and the methods selected for collecting and analyzing data in this investigation. After an introduction to the common methodologies used in science education research, the chapter includes a discussion of data collection in naturalistic settings. Specific to this study, a discussion follows that addresses the methods and protocols used, and their appropriateness. These include questionnaires, interviews, and observations. Next is a description of the research design, followed by a section on steps taken to ensure the trustworthiness and dependability of the inquiry. The chapter concludes with a discussion of ethical considerations.

## 4.2 The Research Questions

Research is driven by a quest for new knowledge. The first steps of that quest involve the formulation of questions that accompany the researcher for the rest of the journey. Research questions constantly remind the researcher of the central task at hand and dictate the choice of research strategies. For instance, the case study approach to research used in this study is recognized as being valuable for answering ‘how’ and ‘why’ types of questions (Cohen, Manion & Morrison, 2011). Three of the four sub-questions below are ‘how’ questions, and even the main research question could easily be rephrased into a ‘how’ question. Yin (2009) argues that the more specific the questions for a case study the more likely it is for the case to remain focused, and so the sub-questions in this inquiry address specific aspects of the investigation.

All decisions by the researcher should be determined by what will best answer the research questions. This is particularly important when choosing a methodology (Section 4.3) and methods (Section 4.4), and when designing the research (Section 4.6). Before those discussions take place, the research questions are presented here as a reminder to the reader.

The main question that is addressed in this thesis is:

> In what ways can permaculture be used to increase scientific literacy and ecological literacy in junior secondary science in New Zealand?

This question is supported by the following sub-questions:

- What are the characteristics of a permaculture approach to junior secondary science?
- How does a permaculture approach to junior secondary science impact on the teaching and learning of science?
- How does a permaculture approach to junior secondary science impact on students' ecological and scientific literacy?
- How does a permaculture approach to junior secondary science affect students' attitudes toward studying science?

## 4.3 Methodology

Just as permaculturists ascribe to certain ethics and principles, so do researchers. While research ethics are considered in Section 4.9 below, the present discussion centers on research principles common to education and particularly science education. While different researchers embrace different sets of principles, or research paradigms, it is crucial that the principles be consistent from ontology through epistemology and on to methodology (Cohen, Manion, & Morrison, 2011). While mixing methods is a recognized approach to data collection (Yin, 2009), mixing methodologies is not viewed favorably as a way to frame one's research paradigm. Consistency is important as it alerts readers and reviewers to the particular worldview of the researcher. Perspective prejudices perception. In other words, the lens through which a person views the world influences the way he or she makes sense of it. For example, one would perceive the world differently working from a holistic perspective as opposed to a reductionist perspective.

Anderson (1992) identifies two primary perspectives among human beings: objective and subjective. Objectivists contend that human behavior can be explained by universal laws, and that the role of a researcher is that of neutral observer. Objectivists would subscribe to an ontology that is realist, an epistemology that is positivist, and a methodology that is nomothetic (Burrell & Morgan, 1979; Cohen, Manion, & Morrison, 2007). When describing this paradigm, Guba and Lincoln (1989) also use the term realist for its ontology, but choose the term objectivist to describe the epistemology and describe the methodology as experimental and manipulative.

Subjectivists, on the other hand, insist that individuals construct the world through experiences and social interactions. From this perspective, the role of the researcher is to examine how individuals or groups make sense of the world. Subjectivists would subscribe to an ontology that is nominalist, an epistemology that is anti-positivist, and a methodology that is ideographic (Burrell & Morgan, 1979; Cohen et al., 2007). Guba and Lincoln (1989) use the term relativist to describe this ontology.

Methodology is not methods, but a bridge between methods and the ontological and epistemological assumptions that inform one's research. Guba and Lincoln (1989) describe methodology as involving "the researcher utterly—from unconscious worldview to enactment of that worldview via the inquiry process" (p. 183). That said, the methods chosen for an inquiry must be consistent with the methodology. However, it *is* possible for two researchers to use the same methods for data collection while working from different ontologies, epistemologies and methodologies. To repeat, perspective prejudices perception. That is why the reporting of research requires the methodological perspective of the researcher. This section seeks to build the bridge between the theoretical framework constructed in Chapter 3 and the methods described in Section 4.4. But methodology is not simply the bridge, but also the *processes* of designing, building and crossing the bridge. It is both noun and verb. Cohen, Manion and Morrison (2011) describe methodology as the *process* of inquiry rather than simply the inquiry outcome. Guba and Lincoln define methodology as "the overall strategy for resolving the complete set of choices or options available to the inquirer" (1989, p. 183). Whatever the choice of methodology, it must be appropriate to the purpose of the inquiry and based on the questions central to the inquiry (Patton, 1990).

A number of competing paradigms exist within education research. These include positivism, post-positivism, interpretivism and constructivism, and critical theory (Guba & Lincoln, 1994; Robottom & Hart, 1993). The two common theories of learning that echo objectivism and subjectivism are behaviourism and constructivism. Aligned with objectivism, positivism (which aligns with behaviorism) contends that human behavior can be understood as responses to stimuli. In other words, human actions, thoughts and feelings are simply behaviors, and thus can be understood scientifically. Like subjectivism, interpretivism and constructivism focus on the individual learner and how he or she builds their own learning by way of cognitive processing or social interactions (Mutch, 2005). This paradigm is based on a nominalist, or relativist, ontology that insists there "exists multiple socially constructed realities ungoverned by natural laws" (Guba & Lincoln, 1989, p. 84).

Positivist research comes from an objectivist perspective and relies heavily on quantitative data. Anti-positivist, or interpretive, research employs a subjectivist perspective, which can make use of both quantitative and qualitative data. From the positivist perspective, a researcher can, in principle, successfully achieve neutrality (objectivity) throughout the research process. By contrast, qualitative research is not neutral, as the experiences of participants are interpreted by a researcher with his or her own perspective and biases (Preissle, 2006). Subjectivist researchers freely offer their personal position, what Hertz (1997) calls the 'location of self,' and what Denzin and Lincoln (1994) call the 'personal biography.' This biography can include "age, gender, social class, ethnicity and culture, geographic location, life experiences, and current status" (Mutch, 2005, p. 63). Denzin and Lincoln (1994, p. 24) assert: "There are no objective observations, only observations socially situated in the worlds of the observer and the observed." The world of the observer – my world – is described below. The world of the observed – the students and teacher involved in this research – is described in Chapters 5, 6, 7 and 8.

To the positivist and interpretivist approaches, Neuman (1994) adds a third main theoretical grouping: critical research: "a critical process of inquiry that goes beyond surface illusions to uncover the real structures in the material world in order to help people change conditions and build a better world for themselves" (p. 74). In EE/EfS research, a critical approach is possible and in some cases desirable. Critical theory is recognized to hold a strong position in EE/EfS (Huckle, 1993; Huckle, 1998; Wals & Jickling, 2002). An important difference between the empirical and interpretive methodologies and critical theory is that the former attempt to describe the world as it exists, while the latter attempts to understand why it is this way and, by extension, how critique can create a better understanding of how it should be (Huckle, 1993).

While it is conceivable that a critical approach could be employed in research involving science, sustainability, and permaculture, I submit it would be more appropriate in research involving adults as they are in a better position to change their own conditions than students. Or, perhaps, for students involved in higher education as argued by Wals and Jickling (2002). Indeed, permaculture itself is about building a better world. But, neither are adolescents in a strong position to make significant changes in the world, nor is it the task of schools to improve the world through students' activities (Jensen & Schnack, 1997). Therefore, in this particular case an interpretive approach was deemed more appropriate because this study focuses more on a search for meaning than critique and emancipation. While a critical eye was cast toward genetic engineering and deepwater oil production during the intervention, the overall aims of the study – as expressed in the research questions – were to better understand how permaculture could be used in a science classroom to help improve students' ecological and scientific literacy.

For many years, education research has been heavily positivist, relying on quantitative approaches in an effort to attain predictability and reproducibility (Filstead, 1979; Guba & Lincoln, 1994). Realist ontology purports that objective knowledge exists without depending on the knower. This methodology was developed for, and borrowed from, the natural and physical sciences. But this type of education research has been criticized as mechanistic and reductionist (Cohen et al., 2007; Habermas, 1972; 1974). With its roots in science, positivism insists that knowledge is gained only through experimentation and objective observation (Burrell & Morgan, 1979). As such, Roszak (1970; 1972) argues that it serves to distance human beings from nature and from themselves. In other words, it fails to recognize the human experience (Guba & Lincoln, 1989) and each individual's ability to interpret their own experiences for themselves (Cohen et al., 2007). Habermas

(1972; 1974) is particularly critical of the positivist scientific approach, claiming it completely ignores important aspects of the human condition including personal beliefs and values, moral positions, and informed opinions. Anti-positivists insist that social science research be considered differently from science research. They reject the notion of the detached, objective observer and embrace that of an engaged, subjective observer who strives to inhabit the frame of reference held by the subjects of the inquiry. From this perspective, human knowledge is not considered "hard, objective and tangible" but "personal, subjective and unique" (Cohen et al., 2007. p. 7).

Over time, education researchers began adopting methodological approaches developed by anthropologists. These included ethnographic and naturalistic approaches that emphasize description, induction, generation of theory and construction as opposed to prediction, deduction, verification of theory and enumeration (LeCompte & Preissle, 1993). This methodological shift by science education researchers has been particularly well established in New Zealand where naturalistic studies have been taking place for many years and may reflect the country's long interest in constructivist approaches to teaching and learning (See: Bell, 1993; Driver & Bell, 1985; Osborne, Bell & Gilbert, 1983).

Naturalistic research takes place in the natural setting of the participants – in this case their science classroom. Naturalistic inquiry usually involves an interpretivist paradigm. In other words, the researcher seeks to make sense of – interpret – the subjective world of the human participants of the study (Bryman, 2001; Gonzales, Brown & Slate, 2008). Interpretivism maintains the interdependence of the researcher and the subjects of study (Guba & Lincoln, 1989), and emphasizes a social constructivist learning model in which the learning cannot be separated from the social context in which that learning takes place (Resnick, 1991). Additionally, some authors argue that not even attitude can be considered out of context.

> Fundamentally, attitude cannot be separated from its context and the underlying body of influences that determine its real significance. In the case of school science, this points to the need to move away from general quantitative measures of attitude constructs and, instead, to explore the specific issue of students'

> attitudes to school science, and their attitude to studying further courses in science in school (Osborne, Simon, & Collins, 2003, p. 1055).

This weighty quote from *science* education researchers supports the shift from quantitative to qualitative methodologies, and holds particular significance for this study in that it addresses directly students' attitudes to school science, which is one of the research sub-questions.

But interpretive and naturalistic approaches to research have been criticized as having abandoned both the strict objective discipline of the scientific method and the aim of generalization of findings (Cohen et al., 2007). Positivists are uncomfortable with the lack of clear-cut independent and dependent variables. Objectivists suspect that subjective data has the potential to be incomplete and/or misleading (Bernstein, 1974). Maxwell (2005) identifies researcher bias and reactivity as challenges to the validity of qualitative data analysis. This can be a particular concern in case study research (Shaughnessy, Zechmeister & Zechmeister, 2003). (Issues of trustworthiness are discussed in Section 4.8). Further criticism notes the lack of recognition of external forces that can influence participants' attitudes and behaviors. The risk, critics claim, is that interpretive and qualitative research can become stuck within its own "narrowly micro-sociological perspectives" (Cohen et al., 2007, p. 26). Given these criticisms, it would be unlikely to find a positivist who embraces interpretivist research. But the opposite is not also true. Interpretivists do not reject all positivist research: "Interpretivists generally acknowledge that work in the positivist paradigm can provide food for thought" (Hinchey, 2008, p. 29). Similarly, permaculturists recognize that there are valuable contributions from hard science such as research in solar technology and composting toilets while still maintaining a holistic, systems perspective.

There is no one best way to do education research, and no single research paradigm can guarantee certainty in results (Peshkin, 1993). When facing choices between quantitative and qualitative methods, researchers recognize that gains in breadth often result in losses in depth, and vice versa. While qualitative methods allow researchers to dig deep for individual meaning, quantitative methods allow more for transferability and comparison. Quantitative methods are used to probe the extent of an issue while qualitative methods aim to explore its nature. Mixing methods does not simply eliminate the drawbacks while maintaining the advantages, but can provide the unique opportunity for researchers to include a range of appropriate methods to enhance data collection in order to help find the best answers to their research questions (Mutch, 2005; Patton, 1990).

### *4.3.1 Choice of Methodology in this Study*

Researchers and permaculturists, at their best, thoughtfully consider all available perspectives, technologies and methods in the design process. The focus for both is on effectiveness over efficiency. The quality of outcomes is paramount. A robust inquiry must stand up to the scrutiny of reviewers; a robust permaculture system must stand up to the scrutiny of nature. Weaknesses in each will be exposed, and the goal of the designer is to minimize weaknesses in advance. Considering the different possible ways to design research regarding a permaculture approach for a single junior secondary science class, the choice of a qualitative case study based on an interpretivist methodology appears highly valid.

The interpretive paradigm aims to understand the subjective nature of the human experience (Cohen et al., 2011). It is about the individual, not the group. Interpretivism and constructivism "share the goal of understanding the complex world of lived experience from the point of view of those who live it" (Schwandt, 1994, p. 118). With emphasis on honoring the standpoint of individuals, the onus is on the researcher to strive to share frames of reference. Interpretive educational research is specific to a certain place and time. The naturalistic case study I undertook was in one small classroom in one small school in one small town in one small country. Just as every case study is unique (Bassey, 1999), every permaculture property tells its own story. Permaculture principles are applied individually to each piece of land, reflecting the unique character of place within a specific bioregion and climatic zone. Permaculturists pay heed to the sun, the rain, the soil, the wind, the slope, and a host of other living and non-living factors to interpret the individual physical and biological conditions of a specific site. Just as interpretivists reject the positivist notion of a single universal truth, permaculturists understand there is no one-size-fits-all for ecological design.

The interpretivist paradigm in this study provides for rich descriptions and explanations of the teaching and learning processes, and provides better understanding of participant responses (Bryman, 2001) to permaculture pedagogies, the development of students' ecological and scientific literacy, and students' attitudes toward learning science. This methodology also provides the opportunity to explore changes over time and to identify situations that may affect the process (Miles & Huberman, 1994). Finally, it is suited to social constructivism (Vygotsky, 1978, 1997), which focuses on the socio-cultural contexts in which learners interact in shared experiences (Crawford, 1996). This section has endeavored to build the bridge from the theoretical framework in Chapter 3 to the choice of data collection methods described in the following section.

## 4.4 Methods

As described above, methodology bridges the theoretical framework to the methods or tools chosen for an inquiry. Just as an engineer would choose different tools and materials to build a suspension bridge rather than a trestle bridge, a researcher must choose the tools and methods best suited to their methodology. A suspension bridge requires cables and towers in the same way that a positivist methodology requires quantitative data and statistical analysis. In both cases, the latter must be appropriate to support the former. For robust research, the methods selected must provide the types of data that can be analyzed within the research paradigm of the methodological approach. Form follows function.

While positivists prefer methods and tools such as structured observation, experimentation and surveys, interpretivists often choose qualitative methods and data collection tools that include formal interviews, informal conversations, participant observations, field notes and document analysis (Cohen et al., 2007). These methods allow for the examination of the learning context and the meaning that participants make from their experiences. However, as mentioned in the previous section, interpretivists are not as dogmatic in their choice of methods as positivists may be. Interpretivists can and do make use of quantitative methods when appropriate. A combination of qualitative and quantitative approaches to research is often called mixed methods. Mixing methods is appropriate for case study research (Yin, 2009), and lends itself to a permaculture approach because they both rely on diversity for their integrity. Permaculturists seek out new, creative and synergistic combinations of elements of a system. For example, they often use groupings of plants, called guilds, to maximize results. Each plant is chosen to provide functions that complement the others and form a synergy within the guild. A prime example of this is the Hopi "Three Sisters": corn, beans and squash. In the same way, researchers can combine complementary methods to provide more robust results (Mutch, 2005; Patton, 1990). Through triangulation, a mixed methods approach to research, which includes both quantitative and qualitative data collection, can help overcome 'method-boundedness' (Gorard & Taylor, 2004), and has been argued to be appropriate to any research paradigm (Guba & Lincoln, 1989).

As discussed in the previous section, mixing methods can enhance data collection in order to help researchers find the best answers to their research questions (Mutch, 2005; Patton, 1990). This integrated approach seeks to take advantage of the strengths of different methods *and* the symbiotic effects of using them in combination. However, as described in Section 4.3, an interpretive methodology calls primarily for qualitative methods. Those methods include interviews, classroom observations, and case study. They are described below after the description of questionnaires, the one quantitative method employed in this inquiry.

### *4.4.1 Questionnaires*

A questionnaire is a type of survey. Questionnaires are commonly used for collecting quantitative data from a large number of participants in order to be able to generalize results (Hinds, 2000; Mutch, 2005). While this aim is not consistent with the interpretivist paradigm, in the context of mixed methods, questionnaires can provide qualitative data or quantitative data that can contribute to a qualitative interpretation, as well as provide valuable triangulation: through the use of two or more data collection methods (Cohen et al., 2007).

Questionnaires can contain any combination of closed and/or open questions. Closed, or structured, questions restrict respondents to a limited number of ways to answer. Open, or unstructured, questions allow respondents to answer in any way they like. Accordingly, closed questions result in quantitative data, and open questions result in qualitative data (Cohen et al., 2007). In this study, both closed and open questions were used in the preand post-questionnaires, along with a concept mapping exercise and a section on the Structure of the Observed Learning Outcomes (SOLO) Taxonomy (Biggs & Collis, 1982). Whether closed or open, question design is of great importance (Hinds, 2000; Mutch, 2005). That process is described in Section 4.6.2.

Closed questions were included in the questionnaires not with the intention of generalizing the results, but for their potential of quantifying changes in students' beliefs and attitudes. They were also included to collect a large amount of data quickly because the questionnaires were administered during class time. While the small sample size makes quantitative class data indicative only, an individual student's responses to closed questions on both questionnaires contributes to the overall qualitative analysis with the goal of providing a more holistic view of changes that he or she may have undergone during the intervention. Data for closed responses from students was collected using semantic differential (Osgood, Suci & Tannenbaum, 1957) on the pre- and post-questionnaires, and Likert scale (Likert, 1932) on the post-questionnaire only. These decisions are explained below.

Rating scales, such as semantic differential and Likert, can be used to measure both intensity and degrees of response (Oppenheim, 1992). Semantic differential scales are useful in the contexts of evaluation, potency and activity (Osgood et al., 1957). In this study, a semantic differential format was used on both questionnaires to address students' attitudes toward science and the environment, their attitudes toward learning science, and the frequency of the practice of certain sustainable behaviors. A semantic differential format was considered appropriate in this case for its ability to provide a measure of pole polarity and the strength of the belief (Dalgety, Coll, & Jones, 2003; Ostrom, 1989). A seven-point scale was used from left (1 = "strongly disagree") to right (7 = "strongly agree"), with a neutral position (4 = "balanced opinion") in the middle. Paired statements maintained the same polarity in order to minimize potential confusion.

On the post questionnaire, a short Likert scale section was added to probe students' perceptions of their learning experiences relating to the intervention. Ostrom (1989) suggests using a Likert scale for items relating to specific contexts. In other words, the Likert scale was used to gauge students' responses to the context of learning science with an emphasis on the environment, and a focus on permaculture design and visits to local permaculture sites. Dalgety et al. (2003) argue that when referring to specific learning contexts, a Likert scale is the better choice but when investigating less contextualized concepts “beliefs are often less well defined and therefore the continuum style of semantic differential scales are more appropriate” (p. 657). A five-point scale was used from left to right ranging from “strongly disagree” to “strongly agree.” The middle of the scale was labeled “neither agree nor disagree.”

As useful as rating scales can be to researchers, caution must also be taken. When designing rating scales and processing the data, researchers should be aware of unbalanced scales, respondent aversion to extremism, end point descriptors and equal intervals (Cohen et al., 2011). Each of these is addressed briefly in the following paragraph.

In order to balance Likert and semantic differential scales, Friedman and Amoo (1999) advise using the same number of positive and negative categories as I have done. A tendency of some people to avoid the extreme poles on a scale can limit their options on a five-point scale. Schwartz, Knauper, Rippler, Noelle-Neumann and Clark (1991) suggest that a seven-point scale can be more reliable by giving respondents the ability to better choose between the values on the scale. I used a seven-point scale on the semantic differential sections on the pre- and post- questionnaires. On a similar note, Friedman and Amoo (1999) suggest the extremes can be further softened by avoiding extremist language. I used the word ‘strongly’ to label the extremes of all Likert and semantic differential scales. The final note of caution – that of equal intervals – refers to the recognition that the numeric intervals on the scale do not correlate to strength of belief intervals of the respondents. Although Thurston scales can address this problem (Oppenheim, 1999), in this study without sufficient numbers for significant quantitative analysis the decision was made to use the more familiar Likert and semantic differential formats.

A limited number of open questions were included to allow students to provide additional information to support their responses to some of the closed questions. Depending on the response, these could either validate or invalidate a student’s response to the closed question, but they also provided qualitative data that added to the holistic picture of each individual learner in the class. The SOLO Taxonomy sections of both questionnaires progressed from closed to open questions. The use of the SOLO Taxonomy for data collection is discussed in the following section.

#### *4.4.1.1 SOLO Taxonomy*

The Structure of the Observed Learning Outcomes (SOLO) Taxonomy was developed as a tool for measuring learning outcomes that reflect Piaget's stages of cognitive development (Biggs & Collis, 1982). "It is a hierarchical model of increasing structural complexity: increasing consistency, increasing number of organizing dimensions and increasing use of relating principles" (Chan, Tsui, Chan, & Hong, 2002, p. 513). The SOLO Taxonomy consists of five levels: prestructural, unistructural, multistructural, relational and extended abstract (Biggs & Collis, 1982). Learners are asked to respond to a series of questions that are ordered in a hierarchy of complexity that parallels Piaget's stages. The highest level the student achieves indicates their level of competence, and a failure to reply appropriately to the first question represents a prestructural understanding (Biggs, 1999).

A prestructural level (SOLO Level 1) is assigned when it appears that a learner has not understood the point of the question. The response may make no sense, may simply repeat the question, or be left blank. A unistructural level (SOLO Level 2) represents nominal understanding. One obvious piece of information is grasped, but not relationships or connections. A multistructural level (SOLO Level 3) represents the use of two or more discrete pieces of information serially. A relational level (SOLO Level 4) indicates a learner can recognize the relationship of two of more pieces of information to a larger whole. An extended abstract level (SOLO Level 5) is achieved when learners can apply the information in the previous steps as an abstract general principle or a hypothesis beyond the specific subject area addressed in the exercise (Biggs, 1999; Biggs & Collis, 1982; Chan et al., 2002). In the present study, the SOLO Taxonomy was chosen as a way to probe students' increasing abilities to think systemically.

The SOLO Taxonomy has been praised by researchers for its objective criteria for measuring learning outcomes (Lake, 1999; Van Rossum & Schenk, 1984). Some authors argue that SOLO is appropriate for measuring cognitive attainment for students at different levels, in different subject areas, and for different types of assignments (Biggs & Collis, 1982; Hattie & Purdie, 1998). Other authors have found evidence to support these assertions (Chan et al., 2002). However, weaknesses in SOLO have been identified relating to its criteria for categorization and the problem of low inter rater reliability (Chan et al., 2002; Chick, 1998). The second weakness can be addressed by the fact that I was the only rater for this study. The first weakness was addressed in the design of the SOLO exercise for the questionnaires that is described in detail in Section 4.6.2.2.

#### *4.4.1.2 Concept Mapping*

A concept map is a graphic representation of one's conceptual understanding or structural knowledge of a certain subject (Novak & Gowin, 1984). A concept map usually appears as a web of interconnected words, circles and lines that can exhibit conceptualizations of relationships on a topic (Croasdell, Freeman, & Urbaczewski, 2003). Participants in concept mapping connect concept words or phrases with linking words or phrases to form propositions. A proposition is a unit of meaning constructed in cognitive structure.

Concept mapping has been used for instruction and as a learning aid since the 1960s (Hill, 2004; Novak & Gowin, 1984; Stoddart, Abrams, Gasper, & Canaday, 2000), but more recently has been recognized as a research tool for assessing student knowledge (Herl, Baker, & Niemi, 1996; Miller, Koury, Fitzgerald, Hollingsead, Mitchem, Tsai, & Park, 2009; Wallace & Mintzes, 1990). Concept maps have been used in the study of every field of science and at every level of formal education (Stoddart et al., 2000), as well as in environmental education (Heinze-Fry, 1997). Brody (1993) used concept mapping to study students' misconceptions of ecology, and Heinze-Fry (1990) used them to study meaning learning in biology students.

Concept maps have been used to assess science inquiry learning (Stoddart et al., 2000), and to evaluate conceptual change (Miller et al., 2009). Conceptual change includes not only content, but also its organization and interrelatedness (Miller et al., 2009). Concept mapping is promoted over more traditional assessment tools for pre- and post-testing by some authors, who recognize validity problems with the latter due to the difficulty in administering the "test" – for instance in a multiple choice format – before the material has even been taught (Ruiz-Primo & Shavelson, 1996; Stoddart et al., 2000). These authors argue that a pre-test concept map allows participants to express what they *do* know about a topic rather than what may be random guessing on a more structured traditional assessment.

Concept maps can be scored quantitatively and qualitatively (Miller et al., 2009). Novak and Gowin (1984) pioneered quantitative scoring systems, and most subsequent quantitative approaches have evolved from those. These scoring systems consist of tallies of accurate propositions, hierarchy, examples, and crosslinks (Novak & Gowin, 1984). Qualitative scoring systems focus more on content validity than on map counts (Ruiz-Primo, Schultz, & Shavelson, 1997). Qualitative scoring often involves comparing students' maps to an expert map (Coleman, 1998; Herl et al., 1996; McClure, Sonak, & Suen, 1999), but some authors argue that this "fails to provide a qualitative measurement of change that can be used empirically" (Miller et al., 2009, p. 367). An approach designed to address this problem is to develop a scoring rubric protocol (Miller et al., 2009). However, the use of expert maps was carefully considered, and the Executive Board of Permaculture in New Zealand was enlisted to participate in the same concept mapping exercise as on the questionnaires. Board members each completed a map, and then I used those maps along with my own map to develop an expert map. From the expert map, I made a list of sustainable propositions, along with additional concepts not provided on the exercise, and a list of permaculture emphases (Appendix A). Although student maps were not compared directly to the expert map during qualitative analysis, the expert map was used to develop a Concept Map Quality Scoring Rubric and Protocol (CMQSRP), described in Section 4.6.2.1.

### *4.4.2 Interviews*

The interview is a common tool used to collect qualitative data. It can be defined as "a specialized form of communication between people for a specific purpose associated with some agreed subject matter" (Anderson, 1990, p. 222). Kvale (1996) dissects the word itself into *inter* and *view* to emphasize the interchange of views between those involved. I submit it is also a way to bring out the *inner-views* of research participants with greater clarity than questionnaires or observations. The interview is particularly valuable in that it can probe aspects of an inquiry not accessible with other methods (Wellington, 2000), and provides the opportunity to clarify participant responses (Jaeger, 1997). Research interviews are used: to collect information in support of research objectives; to test hypotheses or develop new ones; and, to reinforce other methods (Mutch, 2005). They have also been shown to be valuable tools for investigating children's science learning (Bell, 1995; Bell, Osborne, & Tasker, 1985).

Mutch (2005) groups interviews into three categories - structured, semi-structured and unstructured – while others group them into four: closed quantitative, standardized open-ended, interview guide approach, and informal conversational (Cohen et al., 2007). While each one has advantages and disadvantages, only those for semi-structured interviews – my chosen approach – will be discussed here. Semi-structured, or guided, interviews can include a list of prepared questions but also allow the interviewer to seek additional information with follow-up questions on the spot and/or to clarify prepared questions for respondents who may benefit from re-wording. The main advantage of this style over unstructured interviews is that it provides a consistency of questioning for all respondents, which increases comparability and provides complete data for each participant (Patton, 1980). Its main advantage over structured interviews is that it allows for further exploration of unanticipated issues that may arise that have the potential to provide richer qualitative data (Bryman, 2001; Kvale, 1996). For these reasons, the middle road provided by the semi-structured interview appeared to be the best choice for both the series of three teacher interviews and the student focus group interviews.

Focus group interviews are a special form of group interview. They generally proceed with pre-set questions but allow flexibility depending on the purpose and the group (Mutch, 2005). Focus group interviews rely on the interaction within the group based on the questions provided by the interviewer (Morgan, 1988). Through the interaction of interviewees with one another, data can emerge that may not emerge during one-on-one interviews. The synergy between four participants in one focus group interview is likely to result in a different quality of data than each of those four being interviewed individually (Cohen, et al. 2007). Along with this unique characteristic, focus group interviews tend to produce a lot of data in a short time and can be useful to triangulate with other data (Morgan, 1988). Related to this study, grouping children for an interview can put them more at ease in the interview setting by defusing the power dynamic between the adult interviewer and the young interviewees (Eder & Fingerson, 2003).

As with all methods, focus group interviews have weaknesses and challenges. For instance, the group dynamic may result in some participants dominating while others remain mostly silent. Additionally conflicts may arise, or the line of questioning may be derailed by bored or distracted group members (Cohen et al., 2007). The number of participants can also make group interviews difficult to record and transcribe (Mutch, 2005). Indeed, some authors suggest a second person take on the role of recorder for group interviews (Hinds, 2000). But including a second interviewer was deemed unrealistic in this case of unfunded doctoral research.

While interviews can be enjoyable and interesting for a researcher (Wellington, 2000), they also require a good deal of skill in the preparation and administration. In general, interviewers need to strive for a balanced approach that includes a level of formality and direction, a level of personability and ease (Fontana & Frey, 1998), and a level of neutrality (Patton 1990). While these standards apply to individual as well as group interviews, focus group interviews carry the additional expectations that interviewers ensure that all participants have an opportunity to contribute their thoughts, allowing the synergy of the interactions between the participants to develop while not allowing conversation to stray off topic (Morgan, 1988). Section 4.6 describes the research design for both the semi-structured student focus group interviews and the series of semi-structured teacher interviews.

### *4.4.3 Observation*

Until now, the data collection tools described rely on participant self-reporting. But human beings do not always do what they say they do. Therefore, observations can serve as an important check on the consistency between people's words and actions (Bell, 1993; Robson, 2002). Additionally, observations can reveal information about the participants in a study that may remain hidden by other methods alone (Bell, 1999). Observational data can allow a researcher to enter the world of participants (Patton, 1990), and appear particularly helpful in naturalistic inquiry. Observations can provide data on physical settings, human settings, interactional settings and program settings (Morrison, 1993).

Like interviews, observations can range from structured to unstructured, with semi-structured between the two. Highly structured observation requires the researcher to have worked out in advance the categories that address what he or she is looking for. This is also known as pre-ordinate observation (Cohen, et al., 2007). When employing unstructured observation, a researcher enters a situation simply to observe what is taking place without predetermining what to look for. The semi-structured approach offers a middle road by allowing a researcher to enter a setting with some expectations but also the freedom to collect data in less predetermined and structured ways. A key difference between structured observation and the other two is that the choice of structured is usually made for hypothesis testing, while semi-structured and unstructured observation are more commonly used for hypothesis generation (Cohen, et al., 2007). The advantages and disadvantages of these three approaches are nearly identical to those described in Section 4.4.2 on interviewing. For the same reasons described above – some consistency but also flexibility – a semi-structured approach to observation was chosen for this study. Additionally, it provides valuable triangulation with other methods.

The classroom observations in this study were made in a naturalistic setting – the science classroom – but I did not necessarily take on an insider's role. For the most part – perhaps 90 to 95 percent of the time – I was a researcher taking notes from the back of the classroom or walking among the seated students. Only for five to ten percent of the time did I take on the role of teacher. At these times it was difficult to observe the students and the science teacher. LeCompte and Preissle (1993) recognize that there are varying degrees of participation in observation. My role may best be described as "observer-as-participant" (Cohen et al., 2007), although on a number of occasions I switched roles from complete observer to complete participant, consistent with observations by Swain (2006). Hammersley and Atkinson (1983) suggest that this offers a greater level of detachment than participant-as-observer or full participant, but less objectivity than a complete observer.

Participant observation allows the observer to interact with other participants in the social setting being studied and can build identity and confidence with the group over time (Bryman, 2001; Denscombe, 1998). It also offers valuable insight into classroom culture (Denscombe, 1998). However, participant observation can impact the group being studied by causing them to act differently than usual (Cohen et al., 2007). But these reactivity effects tend to be reduced over longer periods of time (Bryman, 2001) as rapport and relationships are developed (Maxwell, 2005; Thomson & Holland, 2003). Additional advantages to longer exposure of a researcher to participants include "a more holistic view" of the "interrelationships of factors" (Morrison, 1993, p. 88). Over the course of 12 weeks, I believe I recognized both changes in students' behaviors around me and a finer level of detail in their relationships to one another, to the teacher, and to learning science in school.

Perhaps the greatest danger of participant observation is the potential for bias and subjectivity. But this risk can be reduced by using observation data only to support data collected using other methods (Bell, 2005). This was the approach used for the present study. I looked first to interview and questionnaire data to identify trends and themes emerging, and then turned to observation data to confirm or refute them. The multifaceted approach that was taken can be described as a case study, as explained in the following section, with further details provided in Section 4.6, The Research Design.

## 4.5 Case Study Research

The methods described in Section 4.4 were brought together in a case study approach in a single case. Like many aspects of this inquiry, case study research is distinguished for being holistic rather than reductionist (Verschuren, 2003; Yin, 2009). Case study provides rich, contextualized descriptions of a bounded system (Bassey, 2000; Bishop, 1997), although sometimes can also be less bounded (Verschuren, 2003). These data can be used to enhance understanding and develop generalizations (Merriam, 2001; Maxwell, 2005), although the generalizability of case study may be limited (Yin, 2009) or even not generalizable, except for where individual readers identify (Larsson, 2009; Nisbet & Watt, 1984). Some authors argue it is a particularly useful approach for researchers who have little control over events (Hitchcock & Hughes, 1995). However, case study research comes with challenges for reliability and validity, particularly regarding the potential for researcher bias (Verschuren, 2003; Yin, 2009). The trustworthiness of case studies in naturalistic settings relies on credibility, transferability, dependability and confirmability (Lincoln & Guba, 1985). Measures to address trustworthiness are described in Section 4.8. The hallmarks of case study include: clear description of events relating to the case; a chronological narrative of events relating to the case; a blend of description and analysis; a focus on individuals or small groups within the case; an emphasis on specific, illustrative events; a researcher who is integrated into the case; and, a clear effort to show, rather than simply tell, the story of the case in writing (Hitchcock & Hughes, 1995).

Bassey (1999) urges researchers using case study "to be creative and adventurous in their choice of data collection methods" (p. 69), and that research ethics, not traditional views, should act as the governor. "What is important is that the process is conducted in a sufficiently systematic way to ensure that the researcher can work effectively within the ethic of trustworthiness and the ethic of respect for persons" (Bassey, 1999, p. 80). An ethical approach to data collection values participants as the elemental source of all data, and aims to minimize harm to participants, which in educational settings primarily relates to issues of time. From a permaculture perspective, the principles 'use and value renewable resources and services' and 'produce no waste' are important aims. Central to permaculture ethics is the care for people (Holmgren, 2002).

Some authors have been critical of case study research on sustainability in higher education. Corcoran, Walker and Wals (2004) raise concerns that case study research has failed to live up to its potential due to "a lack of theorizing about the research methodology or an understanding about the methodology" (p. 7). Dillon and Reid (2004) suggest that case study methodology "risks misinterpretation and superficiality if assumptions and positions regarding epistemological and ontological dimensions of the case under study are not appraised or attended to" (p. 23). Kyburz-Graber (2004) recognize that case studies sometimes lack rigor because they are used as a method of superficial inquiry. However, they also argue that case study research "can be fully recognized as a scientific method" (p. 58) if criteria are fulfilled that adhere to recognized criteria for validity, reliability and objectivity. These include: a theoretical basis including research questions; triangulation; an audit trail; full documentation; and, reporting the case through an iterative review and revision process. Some researchers (Lotz-Sisitka & Raven, 2004) report to have found that case study methodology is robust for learning about sustainability education in higher education, and others recognize careful case study research "as a challenging and exciting process" (Kyburz-Graber, 2004, p. 63) for gaining knowledge about environmental and sustainability education in formal settings. I agree with this assessment on all levels, not the least of include 'challenging' and 'exciting.'

In this inquiry, case study was used to paint a vivid picture of some students' science and sustainability learning experiences. For various reasons, data for students varied in terms of both quantity and quality. Those with the richest palettes were selected, and their cases were used to help develop a thesis with the potential to represent other participants. With a novice researcher such as myself entering an unfamiliar setting, and with little control over what happened in the classroom, the best research strategy was case study. Additionally, the best approach to data collection included a diversity of methods over an extended period of time. Robust, stable ecosystems rely on diversity and develop over long timeframes in a process of succession. I would argue the same is true for robust research. The design for a cultivated research ecology is explained in the following section.

## 4.6 The Research Design

Intention is the first signal of design (McDonough & Braungart, 1998). As suggested immediately above, the *intention* of this research design is to be robust in the same manner as a natural ecosystem. As permaculture draws lessons from nature to design cultivated ecologies, the same principles can be applied to cultivating research ecologies. The design principles for both include diversity, redundancy, longevity, negative feedback, and evolution. Permaculture and naturalistic research design are dynamic. Flick (2009) recognizes the cyclic and interactive nature of qualitative research design. One example of the emergent nature of qualitative research is discovering which participants in a study will produce richer data as the study progresses (Flick, 2009).

As argued by Tobin and Tippins (1993), data are “constructed from experience using personal theoretical frameworks that have greatest salience to the goals of the individual conducting the research" (p. 15). As has been described, a dominant theoretical framework influencing this study is ecological design in the form of permaculture. Permaculture involves designing from patterns to details (Holmgren, 2002; Mollison, 1988). In research, the patterns may be represented by ontology, epistemology and methodology while the details include methods, data handling and analysis. This section seeks to describe the research ecology design using the methodology and methods described in the previous sections.

The research design provided for data to be collected in a number of ways over an extended period of time. A chronological description would look like this:

- First teacher interview before the intervention
- Classroom observations and informal conversations with teacher and students
- Student pre-questionnaire
- Classroom observations and informal conversations with teacher and students
- Second teacher interview midway through the intervention
- Classroom observations and informal conversations with teacher and students
- Student post-questionnaire
- Student focus group interviews
- Third teacher interview after the intervention

While much of this inquiry involves interconnectedness, for ease of description the research design is presented in the following sub-sections: 4.6.1, Teacher Interviews; 4.6.2, Student Questionnaires; 4.6.3, Classroom Observations and Informal Conversations; and 4.6.4, Student Focus Group Interviews. Assurances of their rights as participants and ethical considerations were provided to the teacher and the students (including their guardians) prior to their participation in this study (see Section 4.9). Pseudonyms for participants, the school and field trip locations are used for the reporting of all data.

The sample in this study represents the only year 10 science class in the school selected for participation. Selection was based upon the school's proximity to the University of Waikato, a previous working relationship of the science department with my chief supervisor, and the school's participation in the New Zealand Enviroschool program. Some details about the school are included in Table 4.1 below.

Table 4.1: Size, decile rating, locality and student ethnicity of the school in this study

| School type | Composite * | Area school |
|---|---|---|
| Roll size | | 405 |
| Decile rating ** | | 4 |
| Locality | Suburban or rural | Suburban |
| Student ethnicity | Māori | 62% |
| | NZ European | 33% |
| | Asian | 1% |
| | Other | 4% |

* Composite School: A school whose roles include students at both primary and secondary levels.
** Decile Rating: 10 groupings of 10% of schools based on the extent to which they draw students from low socio-economic communities. Decile 1 schools are the 10% with the highest proportion and decile 10 schools are those with the lowest proportion.

The teacher in this study was a male, New Zealand European who had emigrated from another English-speaking OECD nation as an adult. He was a mid-career teacher with some professional background in physics and engineering prior to becoming a teacher and immigrating to New Zealand. Before this study he knew little about permaculture and described himself as not particularly green. I had met the teacher once before I approached him about participation in the study.

### 4.6.1 Teacher Interviews

As described in Section 4.4.2, a series of three semi-structured interviews were conducted with the teacher. Questions were prepared in advance and passed through a number of revisions. This interview strategy provided some structure but also flexibility, which may have allowed for a deeper discussion of the teacher's thoughts and feelings (Bryman, 2001; Kvale, 1996). The teacher interviews took place before the intervention began (19/02/10), mid-way through the intervention (26/03/10), and after the intervention (26/07/10). During the interviews, pre-written questions were used to guide the conversation from topic to topic, but I was also able to probe the teacher's responses and address additional issues that were not considered while drafting the questions. Described broadly, the questions investigated the teacher's ideas and feelings about using permaculture to teach science, how he thought the students responded to this approach, whether he considered it an effective approach for student science learning, and if he had noticed any changes in students' behavior that may have related to the intervention. Following each interview, notes were taken to describe environmental variables that may have affected the teacher and to document any non-verbal communication (Patton, 1990).

The first and second teacher interviews lasted 30 minutes, and the final lasted an hour. The first two took place at the school during the teacher's class-free time, and the third at his home following an evening meal we shared. The interviews were recorded and transcribed, checked for accuracy, and then sent to the teacher for verification, but not responded to. The questions included in these interviews are provided in Appendix B. Additional informal conversations with the teacher took place throughout the intervention, usually just after class. Notes were taken on these conversations immediately afterwards.

### *4.6.2 Student Questionnaires*

A pair of questionnaires administered near the beginning and after the conclusion of the intervention sought information about students' ecological literacy, scientific literacy, systems thinking skills, attitudes toward science and attitudes toward learning science. The process of developing the questionnaires included multiple draft reviews by experienced science education and EfS researchers, a student pilot and feedback from the science teacher involved in this study. The questionnaires are documented in Appendix C. The pre-questionnaire for the year 10 science students involved in this study was piloted with year 11 science students to assess its reliability and validity as well as the practicality of questions (Morrison, 1993; Oppenheim, 1992), the familiarity of terms provided for the concept mapping exercises (Stoddart, 2006), and the formatting of graphs in the SOLO Taxonomy section. The year 11 science students in the pilot had the same science teacher involved in this study the previous year. He was their year 11 teacher at the time of the pilot. These students were selected as the most appropriate population for the pilot because of their age and science learning experiences at this particular school. One potential problem with this population is that they all had elected to remain in science class in year 11, where the year 10 students in this study were obliged to enroll in science. It could be expected that some low achieving science students would have dropped out after year 10 and that those students remaining in the year 11 class may have had stronger science skills and/or literacy skills.

Along with the year 11 students providing valuable feedback on the questionnaire, the teacher aided with the re-formatting of the graphs used in the SOLO Taxonomy section to fit the exact format used in the school's science classes. Additionally, he suggested using size 14 letters rather than size 12, and providing more white space in between the semantic differential statements for ease of reading.

Both questionnaires consisted of the same closed, quantitative semantic differential statements (7-point scale), some open, qualitative questions, a concept mapping exercise and a SOLO Taxonomy exercise. In addition to these, the post-questionnaire included five Likert scale statements (5-point scale) as described in Section 4.4.1. The post questionnaire was not piloted because it was identical to the pre-questionnaire, save for the six Likert scale questions, which were peer reviewed.

Both questionnaires were self-administered in the presence of the researcher (Cohen et al., 2011) and the teacher in the science classroom. As explained in the following section, the students were given oral instructions on concept mapping and reminders of how to form a proposition with examples of linking words immediately before the administration of the pre-questionnaire on March 5, 2010. The next section of the questionnaire was the SOLO Taxonomy section described below. This was placed before the semantic differential section – which came last – because of potential fatigue in students after 20 or 30 minutes of working on the questionnaire. In other words, reading a pair of statements – mostly regarding attitudes and behaviors – and responding in a closed manner was deemed easier for students to do at the end of this three-part exercise than interpreting graphs and answering the progressively challenging questions in the SOLO Taxonomy section.

Although the class consisted of 26 students, only 18 students (eight boys and 10 girls) completed both questionnaires. Of those 18 students, some did not complete certain sections on both questionnaires. These discrepancies and how they were addressed are described in Section 4.7, Data Handling and Analysis. The results of the questionnaires are discussed in Chapters 6, 7 and 8.

#### *4.6.2.1 Concept Mapping Protocols*

Two important components must be considered when using concept mapping for evaluation: "a task that students perform to demonstrate and record their knowledge, and a scoring system which a researcher or teacher uses to evaluate the students' knowledge" (Stoddart et al., 2000). Protocols were developed to address both of these components along with a protocol for training students unfamiliar with concept mapping in how to construct maps. Each of these is discussed below in the following order: 1) training students to make concept maps; 2) the design and administration of the concept mapping exercise on both questionnaires; and, 3) the Concept Map Quality Scoring Rubric and Protocol (CMQSRP).

In order to increase the validity of concept mapping data it is critical to train students in how to construct concept maps prior to the pre-questionnaire (Stoddart, 2006). This training was planned into the first week of the intervention. On my first day in the classroom I introduced concept mapping as a way of recognizing interconnections and lead the students through an example of a concept map on a topic with which I thought they would be familiar due to the emphasis on sunburn prevention in New Zealand: ozone depletion. I projected the image of this concept map with the data projector and talked the students through the map from top to bottom, pointing out the difference between concept words and linking words and what makes up a proposition.

After that science-based map, I invited the students to join me in making a map on the whiteboard on what makes up the economy of their town. I provided short list of potential words and asked the students to brainstorm other words. I called on students individually to suggest linking words and propositions while I constructed the map on the board. The teacher had suggested doing another concept map on fast food, a topic he said was familiar to the students and of interest to them. Although we did not have time to do the second concept map on that day, I prepared a PowerPoint slideshow concept map on fast food, which I presented to the students one link at a time, and asked them why I might have chosen the linking words I did. On the third day I presented the students with the task of creating a concept map on the causes and effects of climate change. As the students worked in small groups I circulated around the room to encourage full participation and answer questions. Following this exercise, I presented my own concept map in the form of a PowerPoint slideshow and walked the students through it step by step. On the fourth day of class I administered the pre-questionnaire.

Concept mapping tasks used for assessment or evaluation can take a number of forms from constrained to open-ended and degrees between the two. Constrained tasks restrict participants to a limited number of words or a fill-in-the-blank format. Open-ended tasks may supply a few prompt words at most, but no other restrictions on map makers. Intermediate tasks may supply a list of concept words, sometimes called a ‘parking lot,’ but place no restrictions on how the map is drawn (Stoddart et al., 2000). For this study I chose an intermediate approach that provided students with 16 concept words in a parking lot, but encouraged them to add more words that they thought would be appropriate for the task of making a concept map “to show what you know about a sustainable system for producing food.” The 16 words were whittled down from an original 24 that were piloted with the year 11 science class. Unfamiliar concepts were dropped after the pilot as Stoddart (2006) advises: in pre- and post-test situations, the words provided should have meaning for students even before the teaching unit. The only restriction placed on the mapping process itself was a starting node at the top of the page that said, “A sustainable food system.” The format and instructions for the exercise were identical to the training map exercises described above. As explained in Section 4.6.2, the students were given oral instructions on concept mapping and reminders of how to form a proposition with examples of linking words immediately before the administration of the pre-questionnaire.

The final step of using concept maps for evaluation involves scoring (Miller et al., 2009; Stoddart, 2006; Stoddart et al., 2000). The intermediate approach involved in this study allowed for some flexibility in collecting both quantitative and qualitative data. Both approaches can be used to evaluate understanding of a topic and changes in understanding after a course of instruction (Edmondson, 2000; Kinchin, Hay, & Adams, 2000; Miller et al., 2009).

As described below, quantitative map scores were calculated by counting: the number of concept words used; the overall number of links; and, the number of cross-links. In addition, they were scored for sustainable propositions as explained below. Data was only analyzed for students who constructed a concept map on both questionnaires.

The first step in calculating scores involved counting the number of concept words used by each student in his or her concept maps out of the 16 words provided. The total number of concept words used by all students who completed the concept mapping section of both questionnaires were added together and divided by 16 times that number of students and expressed as a percentage. The rare cases in which students provided additional concept words for their maps were considered only during qualitative analysis.

Next I counted the number of links used by each student in his or her concept maps. In the case of the post concept map where the starting node - ‘A Sustainable Food System’ - was inadvertently excluded in the copy given to the students, each student was credited for one link in addition to those they formed. Additionally, I counted the number of crosslinks used by each student in his or her concept maps. Crosslinks establish interrelationships between different map segments.

Finally, concept maps were scored for the number of sustainable propositions they contained. Two concept words connected by a linking word or phrase forms a proposition. A proposition is a unit of meaning constructed in cognitive structure. As described in Section 4.4.1.2, a list of sustainable propositions was developed using expert maps from the Executive Board of Permaculture in New Zealand.

On the student maps, each proposition was analyzed for whether or not it trended toward sustainability. As explained in the theoretical framework, this would indicate evidence of sustainable thinking among students. Only those propositions that were considered to reflect sustainable thinking were counted in the tally. Propositions not included in the tally fell into a number of categories summarized in Table 4.2: unsustainable, common knowledge not necessarily sustainable or unsustainable, inaccurate/irrelevant.

Table 4.2: Scoring for Sustainable Propositions on Student Concept Maps

| Category | Score | Example |
|---|---|---|
| Accuracy | Sustainable | Food can be organic |
| | Unsustainable | Transportation needs petrol |
| | Common Knowledge | Plants benefit from sunlight |
| | Inaccurate/Irrelevant | Nitrogen kills weeds |

Propositions that maintained the status quo for conventional agriculture were considered unsustainable in most cases. Potential sustainability-related issues that students could have identified in this particular concept map included: use of fossil fuels (both on farm and in transportation – 'food miles'), soil fertility, insect and weed control, meat-centered diet (eating lower on the food chain), and water conservation.

As introduced in Section 4.4.1.2, a Concept Map Quality Scoring Rubric and Protocol (CMQSRP) was developed (see Appendix D). Developing a CMQSRP is important for scoring "the quality to content, knowledge, and skills seen in conceptual organization on pre- and post concept maps" (Miller et al., 2009, p. 369). The CMQSRP was used to establish quality scores for each comparison. In this study the expert maps used as comparison were constructed by a number of experienced permaculturists in New Zealand and supported by national and international literature on sustainable agriculture.

#### *4.6.2.2 SOLO Taxonomy*

As described in Section 4.4.1.1, the SOLO Taxonomy is scored at five levels: prestructural, unistructural, multistructural, relational, and extended abstract (Biggs & Collis, 1982). My challenge was to design an exercise for the pre- and post-questionnaires that reflected these levels while relating to the topics of study during the intervention and to the broader concept of sustainability. The decision was made to focus the exercise on agriculture, including the role of human labor and fossil energy. In this way, the opportunity would be presented for students to recognize increasing levels of relationships within the commonly acknowledged aspects of sustainability: economic, social, and environmental. The decision was made to include the information for the exercises in two graphs because reading graphs is a basic scientific literacy skill. As students progressed to higher SOLO levels they would use the cumulative information in the graphs to answer successive questions.

As noted in Section 4.4.1.1, some authors have identified the criteria for categorization as a weakness in the SOLO Taxonomy (Chan et al., 2002; Chick, 1998). To address this potential weakness, I took a literal, quantitative approach to the categorization of each SOLO level and the increments between them. For example, to achieve SOLO Level 2 a participant need only recognize one simple and obvious connection (Atherton, 2001). As seen in Appendix C, the first question of the SOLO exercise required students to look at a graph showing the percentage of people working in agriculture from 1961 to 2004 and to indicate what changed about the number over time. This task was designed to evaluate whether a student could achieve a unistructural level (SOLO Level 2) of understanding for one piece of information: the direction in which the graph trended over 45 years. If the student did not answer the question correctly, or left it blank, that student was considered not to have understood the task and was assigned a prestructural level (SOLO Level 1) of understanding (Biggs, 1999; Biggs & Collis, 1982; Chan et al., 2002).

The second question referred to the same graph but asked the students to compare two pieces of information: the percentage of people working in agriculture in high income countries versus low income countries. A correct answer was scored as multistructural (SOLO Level 3), as it indicated a student's ability to compare two pieces of information (Biggs, 1999; Biggs & Collis, 1982; Chan et al., 2002).

The third question referred to a graph showing a close relationship between the prices of corn, wheat, soybean and crude oil from 2000 to 2009, including a steep spike and decline between 2007 and 2009. The question asked why the prices of corn, wheat and soybean went up and down so much during 2007 and 2008, and to give reasons for the answer. The question was designed to identify a student's relational level (SOLO Level 4) of understanding: indicating that they could recognize the relationship of multiple pieces of information to a greater whole (Atherton, 2011; Biggs, 1999; Biggs & Collis, 1982; Chan et al., 2002).

The highest level, extended abstract (SOLO Level 5), was evaluated by asking students to use the trends in the two graphs to comment on their impacts on the three dimensions of sustainability: social, economic and environmental. In other words, as agriculture relies more on oil and less on working humans, what social, economic and environmental changes might occur? This question was designed to challenge students to apply the information from the previous incremental steps to issues not addressed heretofore in the exercise (Biggs, 1999; Biggs & Collis, 1982; Chan et al., 2002). While taking this type of quantitative approach to the SOLO Taxonomy may not be possible in all instances, it was deemed appropriate in this case because it could be applied to the example graphs that I used on the questionnaires and because it addressed the potential weakness of selecting appropriate criteria for categorization. While there will always be grey areas in qualitative research, thick description such as that provided in this section is a way to address potential weaknesses. Nowhere, potentially, is thick description more important than with observation data as discussed in the next section.

### *4.6.3 Classroom Observations and Informal Conversations*

As described in Section 4.4.3, semi-structured observation was used and I took on the role of observer-as-participant (Hammersley & Atkinson, 1983). During the first class I attended, the teacher introduced me to the students as a science education researcher. In this way, my overt role in the classroom was clear to the students (Bryman, 2001), but the teacher also emphasized my status as a permaculturist and "environmentalist" who would work with them to, in the teacher's words, "save the planet with science." As an observer and participant, I spent most of my time sitting at the back of the classroom taking notes, but also circulated through the students when they were working individually or in small groups on tasks assigned by the teacher. At times I answered students' questions, offered advice on tasks such as graphing data or following written laboratory instructions, or answered personal questions from the students about my taste in music and sport. In these ways I was able to build trust over time.

Observation data were collected during a total of 12 school weeks (not including holiday weeks). The science class was scheduled to meet three days per week, with class periods varying between 45 minutes and 85 minutes. Because of all-school assemblies, year 10 field trips, school swim day, a professional development day, and the funeral of a boy from the school who died in a car accident, many weeks saw only two class meetings. The total number of science classes covered during the intervention was 31.

Observations were recorded as notes during class sessions, and then reviewed and enhanced soon afterward. Different colors of ink were used for descriptive notes and reflective notes. The descriptive notes aimed to record only the dialogue and actions of the teacher and students. The reflective notes consisted of my thoughts, questions and comments on what I had observed and recorded in the descriptive notes (Bogdan & Biklen, 1992). Recording observations and notes during classes as well as immediately afterward enhanced the authenticity of participant classroom experiences and provided for more complete data and thick descriptions (Carspecken, 1996).

As mentioned briefly in Section 4.6.1, some informal conversations with the teacher took place, usually in the moments when the students were filing out of the classroom and other students were entering. In a similar manner, informal conversations took place with some students during class time, usually when they were working in small groups, or in the moments before or after class in the hallway or schoolyard. Notes were taken on these conversations as soon afterwards as was practical.

### *4.6.4 Student Focus Group Interviews*

As described in Section 4.4.2, three semi-structured focus group interviews were conducted with students immediately after the intervention (25/06/10). Focus group interviews were chosen to allow for interaction within the group based on the questions prepared in advance (Morgan, 1988). The semi-structured format allowed for both structure and flexibility in the conversation, which may have allowed for a deeper discussion of the students' thoughts and feelings (Bryman, 2001; Kvale, 1996). Described broadly, the questions investigated the students' ecological literacy, scientific literacy, systems thinking skills, attitudes toward science and attitudes toward learning science. The questions were developed over a number of drafts and piloted with a year 11 student for clarity and validity. The interview guide is included in Appendix E.

The interviews took place in a meeting room at the school and lasted an average of 20 minutes. Two groups of three and one group of four students rotated through the interviews while the science class was doing a laboratory exercise during an 85-minute class session. The interviews were recorded, transcribed and checked for accuracy. Although they were not participant validated, the transcripts were checked against the original recordings by a colleague and by me. Following each interview, notes were taken to describe environmental variables that may have affected the students and to document any non-verbal communication (Patton, 1990).

The groups were selected for compatibility by the teacher. Five boys and five girls participated. Only students whose guardians had provided written permission for interview participation *and* were present in class on that day took part in the interviews. Some guardians granted permission for their child to participate in the questionnaires but not interviews. This presents the possibility for bias as these students may have come from households that hold a higher regard for education and greater support for their children's learning.

## 4.7 Data Handling and Analysis

Education involves learning. "Learning is the relatively permanent change in human capability or disposition that is not ascribable simply to the processes of growth" (Gagne & Medsker, 1996, p. 6). In order to identify evidence of learning, protocols have been developed such as pre- and post-testing. "The objective measure of learning is the difference between post-test and pre-test scores" (Blumstein & Saylan, 2007, p. 976). Although a control group is often involved in large studies, that is not necessarily the case with small case studies such as this one that took place in a school with only one year 10 science class. As such, there was no control group available except, perhaps, in another school with another science teacher. That situation, however, would have posed significant challenges to validity and reliability. The absence of a control group does not mean the data collected are poor, but that the researcher must take care in how those data are presented and what conclusions are drawn from them. As discussed in the sections above, this inquiry consists of an interpretive case study approach in a naturalistic setting. That being the case, there must be consistency between methodology, methods and analysis.

As discussed in Section 4.3, methodology bridges the theoretical framework to the research questions, to the methods and on to the analysis. Researchers must consider their questions, frameworks, methodology and methods; and then choose an approach to analysis that abides to the principle of “fitness for purpose” (Cohen et al., 2007). Goetz and LeCompte (1984) suggest that researchers review their research questions as the first step in analysis. Given the importance of analysis, it is essential that it be aligned with and aimed at answering the questions that have driven the entire research program. As a reminder, the research questions for this study are contained in Section 4.2 above.

Qualitative research is recognized as data intensive, and some authors recommend reducing data to a manageable size for analysis (Miles & Huberman, 1984). However, while reducing data it is important not to have a reductionist perspective. The process of maintaining a holistic perspective while reducing data often involves content analysis as a way of “identifying, coding and categorizing the primary patterns in the data” (Patton, 1990, p. 381). Parlett and Hamilton (1976) describe ‘progressive focusing’ as a process of using a big picture approach to data gathering, and then carefully reviewing and reflecting on the data in order to discover patterns and core themes: those themes that are both frequent and significant across the data (Gonzales et al., 2008). The reduction process has been described to be like using a funnel (Cohen et al., 2007). In permaculture, this is known as designing from patterns to details (Holmgren, 2002). I suggest that site analysis in permaculture and data analysis in research both involve reflective processes that are intuitive yet rigorous and systematic (Goetz & LeCompte, 1984).

In this study, the patterns emerged from the initial analysis of the student focus group interviews. While Patton (1990) recommends using the interview guide as an analytical framework, that was not necessary in this case. Because the focus group interviews took place after I had been observing the class for 12 weeks, the process of reading the transcripts became a series of 'light bulb moments' as I identified patterns and themes emerging from the data. As stated above, the research questions framed the analysis, but it was the students' voices that began painting the picture inside the frame. The first brush strokes provided by the focus group interview data allowed me to turn to a rich palette of other data to confirm or refute the students' self-reporting on their learning and their enjoyment of their learning.

The process of data reduction involved identifying quotes from students about their perceptions of their science learning, their ability to recognize interconnections, their attitudes toward the environment, their attitudes toward learning science and the types of actions they take for the environment. The patterns of data revealed by the quotes emerged in two dimensions, which I identified as vertical (within-case analysis) and horizontal (cross-case analysis). The horizontal dimension represented how many students held similar perceptions and attitudes. The vertical dimension represented how well other data on a particular student supported what they said in the interview session. This data included classroom observations, observations by the teacher gathered through interviews and informal conversations, and the two questionnaires.

Although the low numbers in this study make the horizontal analysis indicative only, it was useful when combined with the vertical analysis because I was able to identify two categories of science learners in the class and then choose specific students from each category and present their case stories. While the theoretical framework aided in identifying some themes, patterns and categories in the data, others emerged from the data itself. The case stories provided examples of individual variation (Patton, 1990) as well as rich data with thick description (Merriam, 1988).

Observational data were analyzed vertically and horizontally as described above, with particular focus on the vertical dimension of individual students who would become the subjects of the case stories along with a few other students who were more willing to express their ideas and opinions. However, observations also provided the opportunity for limited horizontal analysis which provided insights into the culture of this particular classroom and how the students in general, or the teacher, responded to learning activities associated with the intervention or other elements of this science class.

To a limited extent, teacher interview data provided additional vertical and horizontal analysis on the students in his class. For example, the teacher's observations and perceptions on students' learning and students' enjoyment of learning. Additionally, these data were analyzed for the teacher's insights into the pedagogical approaches specific to the intervention as suggested by the research sub-question: How does a permaculture approach to junior secondary science impact on the teaching and learning of science? Because of the holistic nature of this inquiry, interview transcripts were analyzed for both big picture insights as well as comments on specific learning activities in which the students engaged.

Data interpretation required consideration of both the sociocultural views of the participants and my own experience as a science teacher and science education researcher in their classroom for 12 weeks. My experiences as an educator and an education researcher placed me in a strong position to interpret the contexts surrounding the students' perceptions and attitudes.

As noted in Section 4.6.2, due to varying degrees of student participation in the pre- and post-questionnaires, three different values for N (the number of students) are used in data analysis. At the beginning of the intervention the class consisted of 26 students, but only 18 of them (eight boys and 10 girls) completed both questionnaires. Because comparisons were made between the two questionnaires, only data were included for those students who *completed* (as opposed to participated in) each section of both questionnaires. Sixteen of the 18 students completed the semantic differential section on both questionnaires, and 15 students completed the two concept maps. N values are 16 and 15 respectively. A different decision was taken for data collected using SOLO Taxonomy because, as explained in Section 4.4.1.1, a failure to comprehend the task is scored whether the student writes down an incorrect answer or nothing at all. Therefore, data for all 18 students who participated in both questionnaires are included for SOLO Taxonomy data analysis, and the N value is 18.

Handling and analyzing the data as described above is believed to have been appropriate for the methodology, the research questions and the theoretical framework. It is also believed to have been appropriate to produce valid and reliable results as described in the following section.

## 4.8 Trustworthiness: Issues of Validity and Reliability of the Study

Validity and reliability are essential for all research, and care must be taken to ensure that the findings accurately describe the phenomenon being researched (Cohen, Manion & Morrison, 2011). However, validity and reliability have traditionally been applied within a positivist paradigm, using the following criteria: internal validity, external validity, reliability, and objectivity (Lincoln & Guba, 1985; Merriam, 1988). Because these four positivistic criteria are not easily applied to qualitative research, alternative conceptions of trustworthiness are applied that include: credibility, dependability, confirmability, and transferability (Guba & Lincoln, 1989).

In qualitative research, credibility can be enhanced by employing techniques such as prolonged engagement, persistent observation, member checks, peer debriefing, negative case analysis, progressive subjectivity, and triangulation (Lincoln & Guba, 1985; Onwuegbuzie & Leech, 2006; Teddlie & Tashakkori, 2009). Some of these steps have been described in the previous sections of this chapter and some are described below.

Prolonged engagement in a naturalistic research setting helps the researcher become more familiar with the setting, and to build trust and rapport with participants (Lincoln & Guba, 1985). Persistent observation provides the opportunity for the researcher to apply detailed focus and to identify key elements of the study (Lincoln & Guba, 1985). As described in Section 4.4.3, both of these techniques were used in this study, as were member checks, peer debriefing, and progressive subjectivity.

Negative case analysis involves a continuous revision of the emerging themes until all data are accounted for within the theory (Kidder, 1981) and all outliers have been explained (Lincoln & Guba, 1985; Miles & Huberman, 1994). In this inquiry, negative case analysis was performed during the analysis phase. This technique was particularly helpful in digging deeper and refining the theorizing regarding changes in students' attitudes toward learning science, which appeared at first, to be incongruous. An important part of the negative case analysis involved looking at multiple sources of data, or triangulation.

In education research, triangulation involves the use of two or more data collection methods, sources of data, data collectors or times of data collection (Denzin, 1970). While many tables have four legs, stability requires just three. A guild of three complementary plants - such as the Hopi ‘Three Sisters’: corn, beans and squash - provides a stable cultivated ecology for growing food. A ship lost at sea can find its way using three beacons by a process called triangulation. In research, triangulation allows for stable (robust) findings and locates conclusions out of an ocean of data. Stable research is said to be reliable. But triangulation in every case described above is not a linear progression of improvement. In other words, two plus one does not represent the same incremental increase in stability as one plus one. For example, a table with one leg benefits little from adding one more leg, but greatly from adding a third. Corn and squash planted together do not thrive like they do when beans are added to fix nitrogen in the soil to feed them. And a lost ship is still lost with only two points for reference. In all of these cases, there is a tipping point of integrity reached by triads when symbiosis turns to synergy. The whole becomes greater than the sum of the parts, and the system punches above its weight. Three, it appears, really is a magic number (Dorough, 1973; Johnson, 2006).

In this study, triangulation involved multiple methods, sources and times of data collection. The multiple methods were described in Section 4.4, and included: questionnaires, interviews and observations. The multiple sources were discussed in Section 4.7, and included: the students’ self-reporting, the teacher reporting on students and my observations of students. My observations took place over 12 weeks in the classroom, a time period long enough (prolonged engagement) to provide time triangulation of data for the teacher and for certain notable students who are profiled in Chapters 6, 7 and 8. By using multiple methods, sources and times of data collection, the credibility and dependability of the conclusions of this study should have been enhanced (Miles & Huberman, 1994).

Triangulation was used to address the credibility of data relating to some pedagogical practices utilized during the intervention, as well as students' ecological literacy, scientific literacy and attitudes toward science. More specifically, these included students': science learning; feelings of care for the environment; actions for the environment; systems thinking skills; recognition of ecological limits and possibilities; perspectives on science and technology; enjoyment of learning science in school. Themes emerged from the data regarding the areas of inquiry listed above and were then crosschecked against data gathered using a different method or from a different perspective. For example, students reported on their own enjoyment of learning in both the focus group interviews and on the questionnaires, but the teacher also commented on this from his perspective in the teacher interviews, as did I from my perspective during classroom observations. This process was repeated to greater or lesser extents for all major themes that emerged from the areas of inquiry.

While advances in trustworthiness occur between one and two, and two and three forms of data, subsequent improvements tail off thereafter. A more-the-merrier attitude turns to four's-a-crowd. That said, redundancy is not harmful in research or permaculture. If one plant in a guild succumbs to an insect pest or disease, or if one method is found to lack validity, then an extra component in the system proves critical. In fact, ecological validity in education research requires the consideration of as many characteristics and factors involved in the subject of study (Cohen et al., 2007). Brock-Utne (1996) promotes ecological validity when studying the adoption of new educational policies in actual classrooms. I submit that, when politics and scale are removed, that is essentially what I did in this case. In other words, I developed a new approach to teaching science, provided it to a teacher, and then attempted to chart what actually happened in his classroom. However, ecological validity can run up against boundaries determined by ethical considerations such as anonymity and non-traceability (Cohen, et al. 2007). These considerations were paramount for this study, which took place in a small school in a small town in a small country.

Dependability in qualitative research means providing clear descriptions of how data was collected and the context in which it was collected (Lincoln & Guba, 1985). Merriam (1988) encourages the use of three techniques to enhance dependability, which include:

the use of triangulation; establishing an audit trail; and, thorough descriptions of "the assumptions and theory behind the study, their own position with respect to the group being studied, the basis for selecting participants and the social context" (p. 172).

As described above, triangulation was used extensively in this study, and much of this chapter serves as an audit trail by way of describing "how data were collected, how categories were derived, and how decisions were made" (Merriam, 1988, p. 172). Additionally, this chapter, along with Chapters 2 and 3, address the assumptions and theory behind the study, and Section 1.3 also provides a description on my role. Chapter 5 embeds those ideas in the intervention.

Confirmability has been suggested as an appropriate way to describe the objectivity of naturalistic research, where the researcher cannot be objective (Lincoln & Guba, 1985). Like dependability, confirmability can be improved when a clear audit trail in provided. This allows the reader to assess any potential influence of the researcher, and to determine for themselves the extent to which that may have affected the investigation.

In qualitative, naturalistic research, such as case study, findings are not easily transferred from one group to another. In other words, the external validity characteristic of quantitative research does not apply. Instead of the researcher taking responsibility to ensure the validity of the study, the onus shifts to the reader to determine the transferability of the findings to their own situation (Lincoln & Guba, 1985; Merriam, 1988). As discussed in Section 4.5, this is especially true of case study research (Larsson, 2009; Nisbet & Watt, 1984). However, in order for the reader to fully appreciate the findings, it is the responsibility of the researcher to provide 'thick description' (Lincoln & Guba, 1985) of the context of the inquiry and of the data. This thesis seeks to provide such description, although transferability is a recognized limitation of this study.

## 4.9 Ethical Considerations

Much of the integrity of both permaculture and education research relies on their commitment to ethics. The permaculture ethics – care for earth, care for people, share the surplus – are easy to rattle off. Not so for the ethics of education research, and particularly qualitative or interpretive research (Bourma, 1996; Hitchcock & Hughes, 1989; Merriam, 1988). Hitchcock and Hughes (1989) warn that ethical problems are directly related to using participant observation and interviews to collect data. These and other ethical problems are well recognized by the Centre for Science and Technology Education Research at the University of Waikato, where thorough guidelines and procedures have been established for all education research. The Centre has developed guidelines for students conducting research as well as a Human Research Ethics Committee that reviews all ethics applications. I followed all protocols set out by the Centre.

Access to participants was gained through permission from the school's principal and Board of Trustees. Participants and their guardians were given the opportunity to decline participation or withdraw at any stage. Guardians were given full information about the role of the children in the study and were provided with an informed consent form that allowed them to tick boxes for their child's participation in the following: questionnaires; small group interviews; photos where the child cannot be identified; samples of school work reported anonymously. Different guardians gave different degrees of consent. For example, some guardians gave their consent for participation in the questionnaires but not focus group interviews, or photography, even when their child could not be recognized.

Confidentiality was ensured in the study by providing pseudonyms for all participants and locations in the reporting of all data. Data gathered from participants were kept in a locked cupboard, but participants were given the right of access to data gathered from them during the study. Additionally, they were given the right to decline participation or to withdraw from the study at any time without coercion.

## 4.10 Chapter Summary

This chapter has described the research methodology and methods for this inquiry. An interpretive methodology was selected for a naturalistic case study of a year 10 science class in New Zealand. Mixed methods included: student pre- and post-questionnaires, classroom observations, teacher interviews, and student focus group interviews. Of note, the pre- and post-questionnaires included concept mapping and SOLO Taxonomy exercises to assess systems thinking skills in students. As a qualitative inquiry, the quality of both data generation and analysis was subjected to high standards of credibility, dependability, confirmability, and transferability (Guba & Lincoln, 1989).

Triangulation through the use of multiple data collection methods helped provide the credibility and trustworthiness of the data. Additionally, questionnaires and interviews were peer reviewed, and questionnaires were piloted, before their administration to address face and construct validity. As a case study, special attention was paid to avoiding researcher bias. Some steps taken to enhance the trustworthiness of this inquiry include: extended engagement and observations in the field; leaving an audit trail; member checking; clarifying research bias; theoretical sampling; thick and rich description; assessing rival explanations; negative case analysis; and, triangulation (Lincoln & Guba, 1985; Onwuegbuzie & Leech, 2006; Teddlie & Tashakkori, 2009).

Ethical considerations of this study aligned with the policies and protocols of the University of Waikato. An ethics application was reviewed and accepted by the Human Research Ethics Committee at the University, which included copies of letters to the school principal, the science teacher, and parents and guardians. Permission was given by parents and guardians for students' participation, and confidentiality was ensured by providing pseudonyms and retaining all data in a locked cupboard.

Data analysis for this study was thematic within case. It involved identifying primary patterns and nested patterns in the data, and discovering core themes. Triangulation was used for data from the mixed methods to confirm these themes across method and participant (teacher's perspective, students' perspective, researcher's observations). Most patterns were revealed through interview transcripts, from which point I pursued two tracks of analysis that I called vertical (within-case analysis) and horizontal (cross-case analysis). The horizontal dimension (breadth) represented how many participants held similar perceptions and attitudes. The vertical dimension (depth) represented how well other data on a particular participant supported their interview data. Vertical analysis of rich data on some students led to case stories of two students who appeared representative of others in the class. Additionally, negative case analysis revealed no significant contradictions in the data.

As introduced in Section 1.6 and emphasized in the subsequent chapters, the use of permaculture was not limited to the intervention design and execution. A permaculture perspective influenced all aspects of the inquiry including the selection of an appropriate methodology, robust methods, and a holistic approach to data analysis. The latter of these is evident throughout Chapters 6, 7 and 8 where a permaculture perspective is applied to the data seeking to recognize patterns within it. A more literal application of permaculture was used in the design of the intervention described next in Chapter 5.

# CHAPTER FIVE - THE INTERVENTION

## 5.1 Chapter Outline

This chapter translates theory into practice. It describes how the theoretical framework constructed in Chapters 2 and 3 was interpreted into classroom learning experiences for students. The chapter does so in three steps. Section 5.2 highlights the key theoretical principles for the intervention, and describes how these were planned for in the intervention. Section 5.3 documents how I designed teaching and learning activities to suit the key principles, and inserted them into modified unit plans for the teacher. Section 5.4 describes which teaching and learning activities from the modified unit plans were used in the science class and to what extent. Table 5.1 summarizes all three sections by linking the key principles, the curriculum design, and what actually occurred in the classroom. Section 5.5 provides a chapter summary.

As noted in sections 3.3.2 and 3.4.1, specific permaculture principles (Holmgren, 2002; Mollison, 1988; 1991) were not explicitly used in the design of the intervention. Instead, ecological design thinking was used that embodies the permaculture principles. However, in order to demystify the process and provide documentation from the literature, Section 9.2.1 includes many of Mollison's (1988; 1991) permaculture principles in the discussion of research sub-question 1: What are the characteristics of a permaculture approach to junior secondary science?

## 5.2 The Theory of the Intervention

Advances in education practice must be grounded in theory. Chapters 2 and 3 provided the theory behind this inquiry, and key principles were summarized in Section 3.4. The present section describes how the theoretical framework assembled from ecological literacy, scientific literacy, transformative learning theory, and permaculture formed the overall structure for the intervention. While the specific activities that were proposed for the intervention are presented in Section 5.2, this section briefly discusses the *types* of activities that would serve as the means to the intended ends of this study – enhanced students' ecological and scientific literacy, and improved attitudes toward learning science in school. Additionally, it describes in more detail the order in which those activities could be facilitated to best foster transformative learning.

Before any classroom activities took place, or were even planned, the groundwork for cultivating a specific type of learning ecology was laid. Learning experiences would have to enhance students' knowledge of, and respect for, the environment and lead to subsequent action to support sustainability. Additionally, the activities would have to promote systems thinking skills, primarily with respect to recognizing interrelationships.

Pedagogical approaches would have to provide cognitive, affective, and psychomotor experiences. The teacher would need to take on the role of facilitator-of-learning in a student-centered learning ecology. Active student engagement would be nurtured by approaches including constructivism, social constructivism, experiential learning, and critical self-reflection. Permaculture would be highlighted as an example of the solution-oriented, local application of science and as a way to further emphasize interrelationships in both natural and human ecosystems. From a big picture perspective, the science units could be delivered in an order that aligns with transformative learning theory. That transformative chronology is described in the next section.

### *5.2.1 Transformative Chronology*

Education is four-dimensional. It takes place in space and in time. The space in which education takes place (inside or outside of classrooms) is discussed Sections 5.3 and 5.4. But timing is also important. Recent research indicates that the time when learning experiences take place can have a positive effect on student learning (Rohrer & Pashler, 2010). For example, the same amount of time spent studying can lead to greater learning when the timing of study is carefully planned. From a transformative perspective, timing can also be used to advantage with no extra work. In other words, an easy way to potentially cultivate new perspectives would be to thoughtfully align the units in accordance with transformative learning theory. As discussed in Chapter 3, the three fundamental stages of transformative learning are:

1) a 'disorienting dilemma' (Mezirow, 2000) or 'cognitive crisis' (O'Sullivan, 2002);

2) looking for and trying out alternative ways of knowing;

3) changing one's frame of reference by adopting an alternative worldview.

The teacher initially provided me with four potential science units to cover in the following order: Ecological Relationships; Plants and Photosynthesis; Plants for Food; Environmental Chemistry. The content of each unit is summarized here:

Ecological Relationships: Habitats, food webs, energy transfer.

Plants and Photosynthesis: Carbon cycle, primary production, sunlight energy.

Plants for Food: Human food web, sustainable development.

Environmental Chemistry: Climate change, acid rain, soil chemistry.

Because of time constraints the teacher and I decided to cut back to three units, and I suggested we re-align them in accordance with transformative learning theory. This meta-curricular approach was negotiated with the teacher during the initial negotiation period, and resulted in rearranging the units in the following order:

1) Environmental Chemistry

2) Ecological Relationships

3) Plants for Food

In this new order, climate change would provide a potential disorienting dilemma for students because of the predicted consequences stretching into the future. As well, any systemic investigation of climate change would, of necessity, address the human relationship to fossil energy. As noted in Chapter 3, rising or unstable energy prices have great potential to disrupt economic and social systems. From a systems perspective, it is the sum total of issues surrounding human dependence on fossil energy as well as the sum total of many environmental problems that is more disorienting than simply climate change in and of itself. As emphasized in Chapter 3, systems thinking is central to ecological literacy. It is also the cumulative effects of resource depletion and the subsequent environmental degradation that inspired, if that is the appropriate word to use, the permaculture movement (Holmgren, 2002). While climate change is the focus of the unit, the unsustainability of all outputs *and* inputs of a carbon-based economy is what serves as the potential disorienting dilemma.

The Ecological Relationships unit occupied the second step of transformational learning by using nature as a model for sustainability. Sustainability, it could be argued, is a perspective on the world that favors dynamic equilibrium over growth. As such, it is an alternative way of knowing compared to the dominant paradigm of continual growth. When seeking alternatives to unsustainable human practices, early permaculturists looked to two sources for guidance: natural ecosystems and indigenous human cultures (Mollison, 1988). Of these two, an investigation of natural ecosystems is the appropriate choice for a science class, although a look at sustainable indigenous practices provides high quality opportunities to include the nature of science. For example, the development of corn from a wild grass to a viable grain crop by native Mexicans, and then planting it in combination with beans and squash (the 'three sisters') suggests an understanding of plant physiology (Patel, 2007). Worldwide, early agriculturists, "particularly women farmers, are the first natural scientists; they are the custodians of biodiversity, they experiment, they save seed, they exchange and breed new varieties, with the aim of getting more out of the ground and making plants resistant to pests, easier to harvest and yielding more to eat, burn, weave and build than before" (Patel, 2007, p. 131). Appropriate Māori (indigenous New Zealanders) examples could be included in the unit, but the main focus would remain on examining how natural ecosystems achieve sustainability through a dynamic balance of interconnecting systems.

Finally, the Plants for Food unit fulfilled the third step of transformational learning by using ecological models of agriculture (as exhibited by permaculture) to provide direct examples of applied science and ecological design. The ecological worldview embodied by permaculture stands in contrast to the reductionist, growth-oriented worldview associated with modernity as explained in Chapters 2 and 3. Permaculture, therefore, can serve as both handrail and destination for an educational endeavor aimed at a transformation toward ecological literacy.

While much of this section focused on transformative chronology rather than transformative pedagogy, the following section provides examples of specific pedagogical approaches designed into the intervention to promote transformational learning and ecological literacy in students.

## 5.3 The Application of the Theory

To design the intervention, I took the original unit plans that the teacher provided, and added suggestions for pedagogical approaches, emphases and specific learning activities intended to reflect the theoretical framework in Chapter 3. The original unit plans appeared as spread sheets divided into four columns: learning objectives, possible teaching activities, learning outcomes, and points of note. I left the learning objectives and learning outcomes intact, and submitted suggestions only for teaching activities and notes. This is an important point regarding the intent of the intervention. I considered the learning objectives and learning outcomes to be non-negotiable. After all, the purpose of a science class is student science learning. My argument is that these objectives and outcomes can be better served by employing a holistic, local, relevant, experiential, environmental, solution-oriented approach to the teaching and learning of science. In theory, not only could this improve student science learning but also enhance ecological literacy and improve their attitudes toward learning science in school.

This section describes a number of the suggestions I made for the unit plans that can be found in Appendix F. This is not a comprehensive description. Rather, the intention is to provide the reader with a brief but illustrative overview of how the intervention was designed to bridge the gap between theory and practice. In other words, the pedagogical approaches, emphases and specific learning activities I proposed showed how the big ideas that fill the international literature may actually look in a classroom.

The units were emailed to the teacher in November 2009 for him to review over the summer school vacation period. Between the time I sent the modified units to the teacher and the start of the school year, I collected a file folder full of newspaper clippings on science and environmental issues in New Zealand and compiled several pages of ideas for additional learning activities. The articles were intended to provide students with national and local contexts for science and the environment, and to highlight the science topics of the units in the international news. For example, the Copenhagen summit on climate change made headlines in December, 2009. That summit, and New Zealand's participatory role and climate change policies could have added to the suggestions I made for the unit on Environmental Chemistry. That unit is described in the following section.

### *5.3.1 The Environmental Chemistry Unit*

As noted in the previous section, the primary focus of the Environmental Chemistry unit was climate change (called "global warming" in the unit plan). The first section of the unit plan was titled, "Is global warming happening?" In an attempt to allow students to answer this question, and to make the issue relevant, local and affective to students, I proposed to start the unit with one or more of the following possible teaching activities:

- Present pupils with recent newspaper articles on climate change. Ask them what they know about it. Why has it been in the news so much lately?

- 'Fire lane' activity: a series of questions to bring up discussion and debate, and to identify any misunderstandings.

- Ask students to identify the predicted effects of climate change for their community.

- Use concept maps to explore the interconnections between causes and effects.

I also noted the following as potential resources that the teacher may consider using in the "points of note" column on the unit plan:

- "The Age of Stupid" is a film produced by a Dunedin woman. It is about an archivist living in the future and looking back at the present era. This film can be used to develop a visioning activity.

- Permaculture co-founder David Holmgren just wrote a book called "Future Scenarios."

The above activities and suggested resources were meant to put the focus on local and New Zealand contexts, an uncertain future, students' previous learning, and interconnectedness. As described in Section 4.5.2.1, the concept mapping exercise would also serve as a training exercise for the students before the pre-questionnaire, which included a concept-mapping task to collect data.

But making connections was not just something to cultivate in students. I designed the intervention to include direct flow, or segue, between units and between sections within each unit, and to include learning loops from later sections back to earlier ones. An example of a segue between the Environmental Chemistry and Ecological Relationships units is described below. An example of a learning loop is described in Section 5.2.3.

As noted in Section 5.1, the Environmental Chemistry unit included a section on soil chemistry. I proposed in the modified unit plan that we cover much of that section on a field trip to a local permaculture farm. Knowing how enthusiastic most permaculturists are about soil, and as a former organic farmer myself, I thought this would be a good way to answer the key question of this unit – "How are soils different from each other?" – in a fun, experiential, outdoor setting with a local citizen scientist. At the same time the field trip could serve as a brief introduction to permaculture, which would be fully introduced in the following unit. I suggested that, along with the chemical testing of soils, we could introduce biological soil testing and the soil science and education work done by a company called Soil Foodweb that is popular among permaculturists and organic farmers, and has been operating in New Zealand since 1986. The idea of a food web in the soil would also provide a good segue to the Ecological Relationships unit and remind students of previous learning on food webs consisting of plants and animals. An interconnected web of life is what inspired the vision of permaculture (Mollison, 1988) as a positive, solution-oriented approach to the environmental and energy crises of the time. That positive vision was described by permaculture co-founder Bill Mollison in the Australian documentary series, *Global Gardener* (Russell & Gailey, 1991). I proposed a short clip of Mollison be used in the Ecological Relationships unit as described below.

### *5.3.2 The Ecological Relationships Unit*

As seen in Appendix F, the first possible teaching activities I proposed in the Ecological Relationships unit were to use the soil food web to remind students of other food webs and promote systems thinking. The original unit plan suggested to:

> Challenge pupils to predict the effects of making changes to the numbers of one type of organism. Encourage pupils to go beyond simple relationships by considering knock-on effects of a single change, *e.g. as the number of rabbits decreases, more grass will grow, providing more food for other grass-eating animals, whose numbers may increase as a result.*

To this I suggested, "Systems thinking activities and further concept mapping can be used here." I also suggested to, "Ask pupils to consider a range of examples of such changes in communities and their consequences. Introduce the concept of "the tragedy of the commons" (Hardin, 1968). Various activities and case studies can be employed here." Regarding case studies, I suggested a poignant and humorous account of the unintended consequences of DDT use in Borneo that ultimately lead to a proposal to parachute cats into remote areas to deal to the exploding rat populations that ensued after the DDT treatment.

In my opinion, this unit was the easiest to adjust with the fewest alterations to serve as the middle stage of a transformative learning experience. My rationale: during the process that Bill Mollison went through while developing the permaculture concept he spent long hours sitting quietly and observing natural ecosystems (Russell & Gailey, 1991). The existing unit plan called for field studies in one or two local ecosystems to answer the key question, "How do plants, animals and environmental conditions interact in a habitat?" As a note in the modified unit plan I suggested using the town itself as an example of a habitat to compare with the first natural habitat studied by students. Questions I wrote under that suggestion included:

> How does a human community function like a natural community? How does it differ? Given what we have learned about global warming, acid rain and peak oil, should we be concerned about the current structure of human communities?

Further down the original unit plan proposed: "If possible, ask different groups of pupils to make and collect data about the communities in two different habitats within the same locality, and share findings as a report in the classroom." To this I suggested:

Use the local human community as the second habitat. Ask students a series of questions such as:

Where does the energy come from for each?

What resources do each use? Where do they come from?

What does each produce? Where do those products go?

What are the nutrients of each system? Where do they come from?

What is the level of diversity of each system?

The original unit plan went on to advise: “Ask pupils to produce a report of their findings, describing what they did, comparing the communities and saying what led to their conclusions.” Such a report would promote scientific literacy and help students to start thinking outside of the square. It would also lay a little bit of groundwork for the central tenant of permaculture of designing human communities based on natural ecosystems. Concepts such a biomimicry – imitating nature for the development of human products and systems – would serve as a segue to the final unit – Plants for Food – where examples of local ecological food systems would serve as the final stage of transformative learning as laid out in Section 5.1.

### *5.3.3 The Plants for Food Unit*

The existing Plants for Food unit started with the key question, “Where does our food come from?” I seized on that question, the debates in New Zealand over indoor dairying and genetic modification, and a recent documentary film produced in the US, *Food, Inc.*, to suggest a dramatic opening for the final unit of the intervention. Although confined animal feeding operations (CAFO) and genetic engineering of seed do not dominate New Zealand agriculture the way they do in the US, there appears to be increasing pressure from certain sectors to push New Zealand in these directions (“Editorial: Global GE Use”, 2012). These debates would require citizens to have certain degrees of scientific literacy, ecological literacy and consumer literacy in order to participate meaningfully.

The other questions in the Plants for Food unit included, "How does competition with other plants affect plant growth?" and "How do pests affect plant growth?" I suggested that the learning objectives and learning outcomes addressing these key questions could be addressed during a carefully planned field trip to a well-known local organic farm. A few examples of learning objectives are below. Following them is a brief description of how they could be addressed during a carefully planned field trip.

> Pupils should learn that the organisms living in a habitat compete with each other for resources from the environment.
>
> Pupils should learn how treating fields with selective weed killers affects food webs.
>
> Pupils should learn that the numbers of a population of predators influence the numbers of prey organisms.
>
> Pupils should learn that at each step of the food chain persistent toxins are accumulated in the carnivores and that this process is bioaccumulation.

These learning objectives offered excellent opportunities to loop learning back to the previous unit, Ecological Relationships, and do so in the context of a learning experience outside the classroom. All of these learning objectives are ecological in nature and emphasize interrelationships and knock-on effects. An organic farm represents a cultivated ecology, and it stands to reason that most organic farmers' ecological literacy would be higher than that of conventional farmers and the general public. My role would be to work with a local organic farmer to design the field trip in a way that would emphasize the science of farming and the ecological relationships on their farm including food webs above and below the soil. At certain times I could step in and point out connections to what the students had learned in previous units. For instance, one learning loop may link back to the video clip of Bill Mollison talking about using nature as the model for growing food from *Global Gardener* (Russell & Gailey, 1991). Another learning loop could revisit the story of DDT and cats in Borneo. In this manner, student learning is not simply constructed on foundations of previous learning like a tower, but it revisits the previous learning and strengthens it as it builds upward like a spiral staircase.

Taking an example from nature, gum trees grow in a spiral that strengthens them against heavy winds. Designing student learning to be like a gum tree is a good example of permaculture design as applied to education.

The final key question of the Plants for Food unit was, "What is the perfect environment for growing plants?" In my modified unit I proposed that groups of students could partner with local permaculturists on a final project to answer this question. I described the final project in this way:

> Students are to choose how they can apply what they have learned in the previous units into a project that will directly address a local environmental issue. The projects they choose can either be 'direct actions' or 'indirect actions.' A 'direct action' is when students are personally involved in the action, such as planting a school garden or food forest. An 'indirect action' is when students take action to urge other people to get involved to solve the issue, such as a presentation to council or the local community. The two important components of an action are that it aims at solving an environmental problem and that students are involved in deciding what to do.

Final projects would not only require students to review and apply what they had previously learned *about* and *in* the environment, but also fulfill the third cornerstone of EfS by providing a learning opportunity *for* the environment.

### *5.3.4 Intervention Summary*

To summarize, the intervention was designed to provide holistic and transformative learning experiences for students while emphasizing the relevance of science and its local application in environmental problem solving. The design included education *about, in,* and *for* the environment. Concept mapping and learning loops were included to promote systems thinking skills and reinforce student learning. Field trips and guest speakers were suggested as ways for students to interact with citizen scientists and view first hand cultivated ecosystems for producing food. By giving an overview of the re-designed unit plans, this section has described the map that I drew up and gave to the teacher. The following section describes the route that the teacher actually took.

## 5.4 The Process of the Intervention

Section 5.1 briefly described the *types* of teaching and learning activities that would be essential to a transformative permaculture approach to the teaching and learning of science. Section 5.2 provided some examples of specific approaches, activities, and experiences that I suggested in the modified unit plans. This section uses data (mainly classroom observations) to report what actually happened while I was observing the class. In total, I spent 12 school weeks in the science class, on average 3 days per week totaling 31 days. Times spent with the class varied between 45 minutes and 85 minutes. Because of conflicting activities at the school, some weeks saw only two class meetings. As is often the case with research in schools, unforeseen complications and last minute changes occurred during this inquiry.

After designing the modified unit plans described in the previous section, I sent the electronic documents to the teacher on November 15, 2009. Despite a number of invitations, the teacher was unable to meet with me to discuss the plans until February of the following year. The school year had started, and he told me that he was teaching an introductory science unit. He suggested I join the class on 22 February, 2010 when he would start the Environmental Chemistry unit. Due to circumstances beyond our control, the start of the intervention was postponed until 26 February, 2010.

Because I had not heard from or met with the teacher over the summer, the start of the intervention felt a little rushed, and much of the Environmental Chemistry unit was spent training students in concept mapping before the pre-questionnaire. Mid-way through that unit, I provided an explanatory document (Appendix G) to the teacher that presented multiple perspectives on permaculture and how it could be applied to the next two units.

From the day I joined the class I started making classroom observations in the form of field notes. Developed from these notes, Table 5.1 provides a summary of the key theoretical principles for the intervention, what teaching and learning activities were designed to apply those principles, and brief descriptions of if, and how, they were applied in the science class. The one key principle not included in Table 5.1, transformative chronology, is described in detail in Section 5.1.1. As a meta-curricular approach, I consider it categorically different from the rest of the key principles. In other words, any one of the seven key principles in Table 5.1 could be observed during a *single* class period while a transformative chronology could only be observed over the course of many weeks. Regarding the application of this principle, I can report that the three units were covered as planned in the order best aligned with transformative learning theory.

Table 5.1: Suggested and Implemented Learning Activities from the Intervention

| | | |
|---|---|---|
| Affective Experiences | a) View clips of the film, The Age of Stupid.<br>b) Introduce the concept of the Tragedy of the Commons. | a) Not done.<br>b) Not done. |
| The Local Application of Science | a) Field trip to a local organic farm to study soils.<br>b) Compare a local natural ecosystem to the human community of the town. Do a field study of both places.<br>c) Field trip to a local organic farm to study the plant competition, insect pests and diseases. | a) Not done.<br>b) Not done.<br>c) Field trip was taken to a local community food forest. |
| Making Science Relevant | a) Recent newspaper stories on climate.<br>b) Learn about legumes and then later see how they are used by permaculturists to build soil fertility.<br>c) Video clip of Bill Mollison describing how he used ecology to help "invent" permaculture.<br>d) Watch a chapter from the film, Food, Inc., to see different uses of science – genetic engineering and organics – are used in agriculture. | a) Not done.<br>b) Adopted as planned.<br>c) Teacher showed a different video clip from the same programme.<br>d) One clip from Food, Inc. was used. |
| Student-Centered Learning | a) Fire lane activity assessing students' ideas about climate change. | a) Not done. |
| Taking Action for the Environment | a) Groups of students work with local permaculturists on projects for the environment at the end of the intervention. | a) Not done due to time constraints. |
| Experiential Learning Opportunities | a) Role play of the case study of DDT in Borneo.<br>b) Overnight field trip to Eco-Hostel to experience a developing permaculture property. | a) Not done.<br>b) Adopted as planned. |
| Emphasizing Interrelationships | a) Use concept mapping as learning exercises.<br>b) Use the Soil Food Web as a teaching tool.<br>c) Emphasize interrelationships using activities from the Linking Thinking curriculum (WWF, 2005).<br>d) Loop learning from the study of a human habitat back to the previous study of climate change by addressing energy sources. | a) Five concept mapping exercises were facilitated by the researcher.<br>b) Not done.<br>c) The Linking Thinking activities were not used, but the teacher often used the term "interconnections" during class.<br>d) Not done. |

Some teaching activities could be placed into multiple columns in Table 5.1. I selected their placement for where they were most relevant.

The data included in the right hand column of Table 5.1 is limited to what occurred in the science class only regarding the teaching and learning activities included in the modified unit plans. The table does not include examples of instances where certain key theoretical principles may have been realized but were not part of the original pedagogical design. As with any permaculture design, this intervention was intended to adapt to changing conditions. The modified unit plans served as a starting place from which the teacher and I could enter into an iterative process that allowed us to discover each other's teaching styles and embrace teachable moments as they arose. Where Table 5.1 indicates that a number of the key principles were not applied in the science class, some of the sections below describe how they may have come through in ways other than those in the original modified unit plans.

### *5.4.1 Emphasizing Interrelationships*

As Table 5.1 illustrates, a limited number of the suggested teaching activities to emphasize interrelationships were implemented during the intervention. Of those that were, the concept mapping exercises were of the utmost importance due to the need to train students in concept mapping before the pre-questionnaire was administered to them, as explained in Section 4.3.1.2. That section also documented how concept mapping can be used as a teaching tool as well as for assessment. In total, six concept mapping exercises were facilitated during the intervention. Since the teacher was not experienced in concept mapping, I ran all of the sessions, which included the following topics: the local town's economy; fast food; climate change; soil compaction and aeration; and, Eco-Hostel's relationship to climate change, peak oil and sustainable agriculture. The first two exercises focused on topics familiar to the students with the intent of building skills in concept mapping, not content knowledge. The third exercise – climate change – was aimed at building both skills and content knowledge before the pre-questionnaire was administered. Each concept mapping exercise had the additional purpose of emphasizing interconnectedness and nurturing systems thinking skills in students.

Although I did little of the teaching during the intervention, I used every opportunity to include concept mapping as part of my lessons. For instance, during a lesson on soil compaction and aeration, I used a concept map to illustrate the relationships between soil porosity, New Zealand farming practices, surface water runoff, watershed health, drought and flood cycles, native bush, and permacultural practices aimed at increasing soil porosity. This exercise was done as an introduction to a field study comparing infiltration rates of native bush, and the school's playing fields that experience compaction similar to paddocks populated by heavy, hoofed animals.

Another concept mapping exercise took place at Eco-Hostel as an introduction to a tour of the property. This concept map began with a significant recent event that we discussed a number of times during the term: the BP Deepwater Horizon accident in the Gulf of Mexico. Since the field trip to Eco-Hostel was a culminating learning experience, the concept mapping exercise connected the BP accident to peak oil and climate change (Environmental Chemistry unit), and then to the sustainable agricultural methods (Plants for Food unit) and energy measures – both renewable and efficiency – taken by the owners of the property. As a developing permaculture property, Eco-Hostel was designed using many of the concepts covered in the Ecological Relationships unit. In this way, the concept map not only expressed the connections graphically, but also established learning loops to the earlier units that were further enhanced during the rest of the property tour as described in Section 5.3.4. The sixth concept mapping exercise was used in conjunction with the Film, *Food, Inc.*, and is described briefly in the following section.

Although, as indicated in Table 5.1, the teacher chose not to use activities from the Linking Thinking curriculum (World Wildlife Fund, 2005), he often used the terms "interconnections" and "interconnectedness" during class (Classroom observation, 23/03/10). For instance, during the Ecological Relationships unit he guided the students through an activity that he called "Ecology Connections." He wrote the terms Ecology, Permaculture and Carbon Dioxide on the white board and drew chain links between them. He then asked the students, "What are the links between these?" Students offered insights such as:

> "All to do with the environment."
>
> "Plants breathe in carbon dioxide."
>
> "Permaculture is a scientific way of growing plants and reducing carbon dioxide" (Classroom observation, 23/03/10)

The teacher typed each response on his computer and projected the notes onto the data projector screen for all of the students to copy into their notebooks (Classroom observation, 23/03/10).

While the teacher and I embraced different approaches to emphasizing interrelationships, the data suggests that this key principle was successfully carried through from theory to practice during the intervention. The teacher's and students' responses to this approach are described in Chapter 6, and any observed changes in students' systems thinking skills are discussed in Chapter 7.

### *5.4.2 Making Science Relevant*

Looking across Table 5.1, it is clear that a number of the teaching activities in the columns labeled Experiential Learning and Local Application of Science also help make science relevant to students. In permaculture, elements of a system are designed to serve multiple functions such as these. While the implementation of the teaching activities in those columns are discussed in other sections below, this section seeks to describe a number of activities that address the question frequently asked by students worldwide: "Why are we learning this?" Regarding the video clip of Bill Mollison this question could be answered, "One reason we study ecology is so – like the co-founder of permaculture – we can take lessons from nature to design more sustainable human systems." Unfortunately, the desired five-minute clip of Mollison was not shown in class, but instead the teacher simply played the first five minutes of the DVD. While the entire programme was about ecological design, I had picked out this clip specifically because it showed Mollison sitting beside a forest stream talking about how the time he spent observing natural ecosystems helped him develop the ecological design principles of permaculture.

Although the above activity did not proceed as planned, another suggested video clip – from the film, *Food, Inc.* – was shown in conjunction with a lesson on seed germination and genetics. I selected the chapter "From seed to the supermarket" with the intention of linking previous learning to new learning and integrating the nature of science regarding the controversy over genetic engineering. The chapter was introduced with a concept map that I had prepared in advance as a PowerPoint slide show starting with "Seed

Germination" and ultimately leading to "Terminator Seeds" that do not germinate due to genetic alteration. Terminator seeds were developed by the Monsanto Corporation, which also markets a line of genetically altered seeds called "Round-Up Ready." After the concept map, I showed the film clip as the students followed along with a worksheet that I wrote, printed, and photocopied before class. Although the entire lesson took about one half of one class period (including a five minute debrief), the data that emerged relating to it is significant on multiple levels, especially regarding affective responses from many students that are discussed in Chapter 6. The following section further describes the classroom during this unexpected affective learning experience.

### *5.4.3 Affective Experiences*

As indicated in Table 5.1, the teacher chose not to use a film clip from *The Age of Stupid* or to introduce the concept of 'the tragedy of the commons' (Hardin, 1968). However, as described in the previous section, at least one affective experience appears to have taken place during the intervention. That experience involved viewing a clip from the film, *Food, Inc.*, that focused on Monsanto's genetically engineered (GE) 'Round-Up Ready' soybeans and how the company used various methods of intimidation on American farmers to coerce them into using the GE seed instead of saving their own non-GE seed. Inclusion of the chapter "From seed to the supermarket" was designed to support the study of seed germination during the Plants for Food unit, raise students' awareness of the role of genetic engineering in conventional agriculture, and examine if GE seed might be appropriate for local, sustainable food systems. It was not designed to garner emotional responses from students. The clip focused primarily on one man, Moe Parr, who took his mobile seed cleaner to farms throughout the state of Indiana to help farmers clean and save seed. In the film, Mr. Parr appeared a broken man as he told a tale of harassment and intimidation. Some scenes were dimly lit, and footage included Mr. Parr's interrogation tapes with investigators as well as similar stories from other farmers, some of who were interviewed in darkness with their voices disguised.

While the teacher was out of the classroom during the film clip, he appeared to be surprised to return and see the students actively engaged in a 10 minute debrief after the

11 minute film clip. As the students filed out of the room after class, he noted, “I’m surprised at how involved the students were during that” (Conversation, 21/05/10).

Weeks earlier, it had been my turn at surprise during another unanticipated affective experience. On that day, the teacher shared a newsbyte from the BBC on elephant poaching in Kenya. The images of dead elephants and the fact that poachers only got $42 per tusk prompted emotional responses from many of the students. “What a waste for just 42 dollars” one student said. “Someone needs to stop that,” added another (Classroom observation, 15/03/10).

While the students’ response to the newsbyte could have been anticipated, it was the newsbyte itself that was unanticipated. In an approach that could be categorized as an attempt at making science relevant to students, the teacher often started class with a science newsbyte from the British Broadcasting Company website (BBC, 2010). Although the newsbytes were always science-based, they rarely related directly to the science being studied in the classroom at the time. For instance, the students were not studying endangered species or savannah ecology at the time of the newsbyte on elephant poaching. Nonetheless, it appeared to trigger an acute emotional response in many students regardless of any direct relevance to classroom learning. While this type of random, unanticipated learning experience can contribute valuable data to an inquiry, interventions are meant to be intentional. The following section describes an educational experience that was carefully planned and scheduled in advance, but still was not without unanticipated complications.

### 5.4.4 Local Application of Science

Although examples of the application of science and scientific thinking in the community can be seen in Sections 5.3.1 and 5.3.6, this section uses one field trip to illustrate the translation of theory into practice. Table 5.1 indicates that a field trip to a local organic farm was suggested in the modified unit plan, but a field trip to a local community food forest was carried out instead. A major reason behind this change was proximity to the school: a trip to the farm would have required motor vehicle transportation, but the food forest was within walking distance of the school. Although a disadvantage to this field trip change was that an organic farmer could not share his or her passion for healthy soil and healthy food with the students on their own land, I tried to substitute one of the permaculturists involved in creating the food forest as our host. Unfortunately all four of the permaculturists I invited could not meet us on the day of the field trip. Additionally, about half of the science class (12 students) was late returning from a sport field trip that day and, although we waited for them for 20 minutes before departing, they missed the food forest field trip.

I was reluctant to be the host of the food forest field trip because I wanted to bring other voices to the students besides the teacher's and mine. Since this was not possible, I selected what I considered to be the next best option. In order to take the focus away from me as the host, I designed an Active Learner Worksheet (see Appendix H) that would guide students through an inquiry process and leave the teacher and me as passive resources that the students could draw on as they saw fit. This worksheet was designed along social constructivist lines to help students examine how principles of ecology, geology and hydrology were used to design and build the food forest. It was developed three days before the field trip and emailed to the teacher to preview. (This exercise, as an example of student-centered learning, is discussed in the next section.)

On the day of the field trip, the teacher photocopied and distributed the worksheet to the students in attendance at the beginning of class. Unfortunately, however, only two students arrived at the food forest with their notebooks and worksheets. The teacher was the last to arrive as he had waited in the classroom a few extra minutes for the missing students. When he appeared on site, he instructed the students to sit on the grass and proceeded to ask me a series of questions about the food forest. I was caught off guard, but did my best to answer the questions with an emphasis on the application of science in the design and maintenance of the food forest. Specifically, these included the use of biodiversity, symbiosis, microbial activity, nitrogen fixing legumes and soil structure. Because I had been with the students for several weeks, I was able to refer to previous learning experiences in the classroom and on the school grounds. I made statements like:

> "This is an example of people using what they know about ecology to grow food without added chemicals."
>
> "These plants on the ground take nitrogen from the air and put in the soil."

"Remember when we did the soil infiltration test in the bush near the school?"

Similar emphases on the application of scientific understanding were made during the field trip to Eco-Hostel, along with examples of how an understanding of physics was used to design and build energy-efficient, passive solar structures. The teacher's and students' responses to these learning experiences are discussed in Chapter 6, additional description of the Eco-Hostel field trip is in Section 5.4.6, and a further report on student centred learning follows immediately below.

### 5.4.5 Student-Centered Learning

It is a significant challenge for any teacher to take on new ways of teaching, and although suggestions were made in the modified unit plans as shown in Table 5.1 for student-centered learning approaches, the learning environment remained largely teacher-centred throughout the course of the intervention. The following example is intended to illustrate this point.

As briefly described in the section immediately above, my intention for a student-centred, social constructivist learning experience at the food forest was not realized. Without the active learner worksheets, students were unable to explore the food forest individually or in pairs as intended. Instead, the students sat on the grass as the teacher asked me a series of questions. The pedagogy was transmissive and the focus was on me. However, as only 12 students were in attendance, there could have been an opportunity for them to work in groups of three to do the soil percolation tests as I had prepared four sets of equipment. Unfortunately, this did not occur either. Instead, the teacher asked two students to do the tests while the other students remained seated on the grass and watched. He told the two students who brought their notebooks to record the data, which would later be shared with everyone back at the classroom.

In terms of a robust permaculture design, this lesson did not fulfill the intention of serving multiple functions as being student-centred, experiential, local and relevant. While the latter three may have been achieved to varying degrees, the former was not. The teacher may have sensed some disappointment in me after the field trip regarding so few students having the worksheets with them during the site visit. On the walk back to the school he said to me, "I guess I could have been more on it with their notebooks" (Conversation, 19-03-10), potentially indicating a recognition that the field trip could have been more valuable if he had ensured that everyone brought their notebooks and the active learner worksheets.

This is an example of the adaptive aspect of any permaculture design. Ecological design, by definition, is not fixed. It must be four-dimensional. It must evolve with changing conditions. For the teacher and me, this process appears to me to have been about finding middle ground. As I observed over the course of the intervention, he expressed a willingness to adopt different teaching strategies to varying degrees. The one he appeared least willing to embrace was student-centred learning. With this observation, I designed the next field trip to be experiential, local, relevant, and to emphasize interconnectedness, but not student-centred. That field trip is described in the following section.

### *5.4.6 Experiential Learning Opportunities*

The field trip to Eco-Hostel successfully served multiple functions and could have been placed in a number of columns in Table 5.1. A concept mapping exercise that introduced the field trip was briefly mentioned in Section 5.3.1, and the relevance and local application of science were also emphasized at Eco-Hostel. But in the interest of documenting another translation of theory into practice, the field trip is described here as an example of an opportunity for experiential learning. Experiential education has a long history and can be interpreted in many ways. I am an advocate of teaching to multiple intelligences and embrace a diversity of interpretations of experiential teaching and learning. During the overnight trip to Eco-Hostel, the students experienced: living on a developing permaculture property; walking through a large permaculture garden; seeing steam rise out of a compost heap; examining water retention swales up close; comparing infiltration rates of the garden soil to the compacted lawn next to the garden; walking around an energy efficient "eco-bach," and eating pizza cooked in a wood-fired earth oven. Each of these experiences represents varying degrees of applying science understanding and/or sustainable thinking.

Teacher's and students' responses to the field trip were very positive (see Chapter 6), some students reported learning science during the field trip (see Chapter 7), and many students reported to enjoy learning science with an emphasis on the environment (Chapter 8). But this type of experiential learning was the exception during the intervention. For the most part, students sat at desks and took notes from the white board and data projector screen, or copied information from their course books into their notebooks (Classroom observations). In the classroom, I observed that the students spent a significant amount of class time writing - on some days over 50 percent of a class period (Classroom observation, 15-03-10). On three days when the teacher was absent, the students spent the entire periods copying questions from their course books into their notebooks while a substitute teacher sat at the front of the classroom. Including these 3 days, I estimate that of the total cumulative hours students spent in their science class, close to half of them were spent copying information from the white board, the data projector screen, or their course books into their notebooks (Classroom observations). On one occasion, the teacher emphasized how fortunate the students were to have a structured exercise such as copying notes. He pointed out to them that at no other time in their lives besides school would they have a time set aside to practice this skill (Classroom observation, 18/06/10). As the teacher stated, “biology is seen as the science of learning names” (Teacher interview, 26/07/10), and he appeared to believe that the best way to achieve that was rote learning (Classroom observations). Data collected around students’ responses to this transmissive pedagogy - what they called “book work” - are discussed in Chapters 6 and 8. On the infrequent occasions when students were away from their desks and participating in experiential learning activities organized and run by the teacher alone, they worked in groups doing laboratory exercises such as the one described below.

During the first week of the Environmental Chemistry unit, the teacher split the class into boys and girls (12 of each) and asked them to form groups of four. He handed each group a sheet of paper with written instructions. It was not clear to me immediately that they were assigned different activities. The girls followed the instructions to make hokey pokey in an aluminium pie plate over a gas burner (Classroom observation, 05-03-10). This activity was called “Making $CO_2$,” but it was not made clear by the teacher to the girls how or why carbon dioxide was ‘made’ during the exercise.

While the girls got right into their activity, the boys remained seated for about five minutes not doing anything. Their activity was called "$CO_2$ Investigation." Once they did engage with the exercise, they followed written instructions to collect carbon dioxide in a plastic bottle and then set it in the sun and measure the temperature rise against a control bottle containing air. All three groups of boys appeared to be hung up on the step involving capturing carbon dioxide using a water trap. They seemed to be having great difficulty filling their plastic bottle with carbon dioxide, and spent much of their time splashing one another with water. So much time passed during their unsuccessful attempts at filling bottles with $CO_2$ that one group realized the end of class was approaching. One boy convinced his group that they should simply exhale into the bottle in order to fill it with carbon dioxide. After doing this, they sealed it with a rubber stopper housing a thermometer and placed it outside on the hot pavement next to a control bottle filled with air. But the class period ended before they were able to collect their temperature data. The other two groups of boys remained indoors at the sinks (Classroom observation, 05-03-10).

Regarding follow-up on these activities, during the next class period three days later the teacher presented a data set that he had constructed because the boys were unable to collect data from the exercise. He projected his data set onto a screen and asked the students to copy it down and then graph the temperature change vs. time for the bottle filled with $CO_2$ and the bottle filled with air. After the students had sketched their own graphs in their notebooks, the teacher projected a graph he made on his computer and asked me to come to the front of the classroom and "interpret" it for the students. I did this, and then the teacher asked the students to write their own graph interpretations in their notebooks. At the end of the class period, the teacher circulated through the students checking that each had made a graph and written an interpretation. He then dismissed them one at a time (Classroom observation, 08-03-10).

While the field trip to Eco-Hostel and the laboratory exercise described above can both be called experiential learning, their design, context and administration differ significantly. These important differences are examined in Chapter 9.

### *5.4.7 Taking Action for the Environment*

Many advocates of environmental education believe that, to be complete, EE must include elements of education about the environment, education in the environment, and education for the environment (Barker & Rogers, 2004). This intervention included many examples of education about the environment and a handful of learning experiences in the environment. But the absence of a clear component of education for the environment is undeniable. While student projects were designed into the modified unit plan for Plants for Food, time constraints arose due to many canceled class sessions as reported in Section 5.3. While this was unfortunate, it indicates the level of challenge facing the incorporation of high quality EE into secondary schools. But in the absence of students taking actions for the environment themselves, I submit that exposing them to permaculturists within their community who are taking actions for the environment may be the next best thing. As the next four chapters of data and discussion reveal, the field trips to local permaculture sites were well-received by the teacher and the students, may have been valuable learning experiences for students, and may have helped improve some students' attitudes toward learning science in school. Could it be possible that these field trips also served as a dilute substitute for students engaging in actions for the environment? In a time-constrained secondary school environment, such rich, multi-functional learning experiences as field trips to local permaculture properties could prove to be one key to the dual challenges confronted by this inquiry: incorporating high quality EE into secondary schools; and the attrition of students in science beyond the compulsory years.

## 5.5 Chapter Summary

This chapter has shown the translation of theory into practice through the development of an intervention. It described how the theoretical framework constructed in Chapter 3 was applied to design and then implement teaching and learning experiences using transformative and permaculture approaches. The key principles of these combined approaches consisted of: a transformative chronology; emphasizing interrelationships; making science relevant; affective experiences; examples of the local application of science; student-centred pedagogies; experiential learning; and taking action for the environment.

Different principles were applied in the classroom to different degrees. For example, rearranging the three science units into an order that aligned with transformative learning theory was regarded as straightforward and simple to do by the teacher. He agreed to do this during the initial negotiation. However, other key principles were never applied in the science class during the intervention. These included taking action for the environment and student-centred learning. The former did not occur due to time constraints and the latter appeared not to occur because of the teacher's preferred teaching methods and strict code of class discipline.

Most of the key principles were applied in the classroom to varying degrees in ways that were both planned and unplanned. For example, when it came to my suggestions in the modified unit plans for making science relevant, the local application of science and experiential learning, only one or two of the proposed learning activities were used by the teacher during the intervention. In other instances some key principles, such as affective experiences and emphasizing interrelationships, appeared to occur in the classroom but in ways that were not originally designed into the modified unit plans.

Data used in this chapter came primarily from classroom observations. The modified unit plans can be found in Appendix F. Viewing the classroom observation data in relation to the modified unit plans has provided the first stage of analysis that continues through the next three chapters. The first of those chapters, Pedagogical Practices, examines the observed and reported responses of the teacher and the students to certain pedagogical approaches aligned with the key principles explained in this chapter.

# CHAPTER SIX - PEDAGOGICAL PRACTICES

## 6.1 Chapter Outline and Introduction

This is the first of three findings chapters that present data on the impacts of the intervention in three broad categories: the teacher's and students' responses to the pedagogical practices aimed at accomplishing the key principles presented in Chapter 5; changes in students' ecological and scientific literacy; and, changes in students' attitudes toward science and toward learning science in school. Each of these chapters seeks to answer a different sub-question of the inquiry. This chapter seeks to answer sub-question 2: How does a permaculture approach to junior secondary science impact on the teaching and learning of science? Although the primary focus of this inquiry is on student learning, much of student learning is attributable to the teacher and his or her teaching. By presenting the findings on teaching before those on learning, my aim is to present a wider perspective on student learning, giving a clearer picture on the students' classroom (and out of classroom) experiences.

This chapter seeks to answer sub-question 2 by examining the teacher's and students' reactions to the pedagogical approaches representing the eight key principles in three primary ways: the teacher's responses; the teacher's perception of the students' responses: and, the students' responses. For the most part, this chapter focuses on what happened in the classroom, although, where appropriate, references are made to certain lessons that were not included by the teacher, or were included but not as designed. Additionally, some data are presented on ways in which some of the key principles may have been realized through learning experiences that were not part of the redesigned units.

This chapter is organized principally around the key principles described in Chapters 2 and 3. Section 6.2 addresses the reordering of the units into a transformative chronology and the role of disorienting dilemmas. Section 6.3 describes the emphasis on interconnectedness. Sections 6.4 and 6.5 discuss a number of strategies aimed at making science relevant for students, and the closely related principle of highlighting applications of science in the local community. Also closely related, Section 6.6 discusses the experiential learning opportunities on an overnight field trip to a local permaculture property. Finally, Section 6.7 takes a broader look at the extent to which students engaged in a holistic head, heart and hands approach to learning that includes the key principles – affective experiences and taking action for the environment. As a holistic analysis, some data are appropriate for more than one section of this chapter and the two chapters that follow. Writing, for me, is a linear process, and I struggle to express the interconnectedness of the data, the multi-functionality of certain pedagogical approaches, and the complexity of the learning process through it. My strategy to try to overcome this challenge in writing up the findings is to use extensive cross-referencing between sections and chapters.

Data collection for this study included questionnaires that were administered before and after the intervention, classroom observations, ongoing teacher interviews, and student focus group interviews immediately following the intervention. I spent a total of 12 school weeks in the science class, on average 3 days per week, totaling 31 days. Time spent with the class varied between 45 minutes and 85 minutes.

While the teacher involved in this inquiry did not have a background in transformative learning or permaculture, he welcomed me into his classroom with an open mind and a willingness to try some new pedagogical approaches. Working with a teacher to embrace a different approach to teaching and learning is a slow process. It takes a certain level of courage for an experienced teacher – like the one in this inquiry – to welcome a researcher into his or her classroom and to agree to try new things. As a guest in the classroom, I took on the role primarily of resource provider, and let the teacher pick and choose among the suggested lesson plans, videos, activities and field trips. As documented in Chapter 5, the teacher embraced different approaches to different degrees, and appeared to be more comfortable with a teacher-centred classroom and a transmissive teaching style. As a result, there is more data available on some approaches than others. One approach that he agreed to try without hesitation was re-ordering the three units, as discussed next.

## 6.2 A Transformative Approach to Science Education

As described in Section 3.2.2, the transformative learning process is reported to include 10 stages and is catalyzed by a disorienting dilemma (Mezirow, 2000). This section describes the teacher's and students' reactions to two approaches to transformative learning employed during the intervention. The first approach involved simply re-ordering the science units to fit more closely with the process of transformative learning, and the second involved using environmental and resource availability issues as potential disorienting dilemmas for students.

### *6.2.1 A Transformative Chronology*

As explained in Section 3.2.2, I streamlined Mezirow's (2000) 10-step transformative learning process into three essential elements: 1) a disorienting dilemma (Mezirow, 2000) or cognitive crisis (O'Sullivan, 2002); 2) looking for and trying out alternative ways of knowing; 3) and, changing one's frame of reference by adopting an alternative worldview. After my initial contact and negotiation with teacher, he offered four science units that he thought would suit the intervention: Ecological Relationships, Plants and Photosynthesis, Plants for Food, and, Environmental Chemistry. As described in Section 5.1.1, the unit on Plants and Photosynthesis was dropped for sake of time, and the three remaining units were rearranged to suit a transformative learning model as summarized in Table 6.1.

Table 6.1: Original Order and Re-designed Order of Science Units

| Order | Original | Re-designed |
|---|---|---|
| First | Ecological Relationships | Environmental Chemistry |
| Second | Plants and Photosynthesis | Ecological Relationships |
| Third | Plants for Food | Plants for Food |
| Fourth | Environmental Chemistry | |

Re-ordering the units not only suited a transformative chronology, but also made sense in terms of science learning. For instance, the carbon cycle was studied during the Environmental Chemistry unit and then revisited during the following two units to reinforce the learning and make connections between the units. Specifically, some of the biology topics of the later two units drew on chemistry concepts covered in the first unit.

During the early stages of negotiation, the teacher expressed no concern about re-ordering the units. He recognized that this simple maneuver would not cause extra work for him or disrupt the overall curriculum in any significant way. Months later, during the final interview, he reflected on the progression of the units by describing them as moving from the big picture to a more detailed perspective. “It’s logical. I do think that was better than going in and teaching about seed germination at the start. That’s just basically science-learning names. But this wasn’t. This was a whole crazy interwoven web of science: a good idea” (Teacher interview, 26/07/10). By referring to the transformative chronology as “logical,” “better,” and “a good idea,” the teacher appears to be expressing his appreciation for one component of what he also called, “a new way of teaching science” (Teacher interview, 26/07/10). This expression of appreciation for something new appears to indicate that the teacher has experienced learning about science teaching and learning, and that his perspective on it has changed as a result.

In the final interview, the teacher praised the transformative chronology as a logical process for student science learning, but did not mention the importance of science learning to address environmental problems, in this case the issue of climate change covered in the first unit. However, in the classroom he often told the students, “We are learning science to save the planet” (Classroom observation, 30/04/10). These frequent reminders to students about why learning science is important appear to relate to something the teacher wrote on the whiteboard near the beginning of the intervention: “The Big Picture → Save the Planet” (Classroom observation, 12/03/10). Within the context of teaching about ecological principles (the second unit) and food production (the third unit), it appears that the teacher may have recognized their connection to the first unit that focused on climate change.

Referring to the quote above from the final interview session, the teacher mentioned a “crazy interwoven web of science” (Teacher interview, 26/07/10). Although he made the comment in reference to a question about reordering the units, he touched on another key principle of the intervention: emphasizing interrelationships. The teacher’s emphases on interconnectedness (Classroom observation, 23/03/10) throughout the intervention were nearly as frequent as his proclamations about saving the world with science. His emphasis on interconnections is described in Section 6.3, after a closer look at the role of disorienting dilemmas within the context of transformative learning.

### *6.2.2 Disorienting Dilemmas: Planned and Unplanned*

This section discusses two environmental/social/economic crises that served as potential disorienting dilemmas during the intervention: one planned and one unplanned. The first – global climate change – was designed into the intervention by rearranging the three units as described above. By placing the Environmental Chemistry unit – which included climate change – first, it took the role of providing a potential disorienting dilemma for the students. According to transformative learning theory, a disorienting dilemma often sparks a transformative learning process (Mezirow, 2000). The second potential disorienting dilemma was the BP Deepwater Horizon accident in the Gulf of Mexico (BBC News, 29/04/10). The case of each potential disorienting dilemma is described below.

Climate change is a topic with which most year 10 students have some familiarity from experiences both inside and outside of school. It is commonly in the news in New Zealand (for example, Young, 2009), and the school in which this inquiry took place is involved in an educational program in the primary years called CarbonWise. (CarbonWise sets up tree nurseries in local schools to teach children about offsetting carbon emissions by planting trees.) While delivering the Environmental Chemistry unit, the teacher and I used a variety of teaching strategies on climate change that included: drawing on students' previous knowledge; climate change in the news; a concept mapping exercise; and, a laboratory activity. These pedagogical practices, however, are not the subject of this section. Rather it is the potential role of climate change as a disorienting dilemma explored below.

Classroom observation data did not provide substantial evidence that students responded affectively towards the issue of climate change. In other words, they did not appear to be significantly disoriented by it. For example, during one class period the teacher projected a newsbyte onto the screen from the BBC News website: Climate change human link evidence 'stronger' (BBC News, 05/03/10). He read the article aloud to the students and asked them to write one sentence about it. The student responses consisted of various re-statements of information contained in the article, such as "Humans are causing global warming," and "The Arctic ice is melting" (Student work, 08/03/10). There appeared to be no deep concern or sense of alarm. I observed the students to be more bored than disconcerted (Classroom observation, 08/03/10).

During the focus group interviews at the end of the intervention, however, students expressed some concern – and a bit of confusion – about global climate change. When asked why we should be concerned about the environment, a number of students identified climate change as one reason, although every one of them used the term "global warming." For example, Edward said: "Because if we don't do anything, the ecosystem could collapse from causes such as global warming" (Focus group interview, 25/06/10). On the post-questionnaire, Scott expressed his concern about climate change in the SOLO Taxonomy section when addressing the environmental effects of fossil fuel consumption: "More oil used = more $CO_2$ = more pollution and greenhouse gases = global warming = we all die!" (Post-questionnaire, 22/06/10). Sometimes with children of this age it is difficult to discern between what they say and what they mean. Was Scott serious here or was this written for dramatic effect? Was Edward serious in his statement above or was he simply repeating something he had heard previously? With such a contentious issue as global climate change where competing factions promote different agendas, it is difficult to ascertain just how concerned each individual may be. For this study, the data present a mixed picture of students' understanding of, and concern about, a changing global climate. Their reactions to the Deepwater Horizon accident, on the other hand, appeared more consistent and more acute.

The explosion on the drilling rig Deepwater Horizon in the Gulf of Mexico on the 20th of April, 2010 and subsequent gusher of oil from the sea floor made immediate headlines worldwide. The accident showed up as a newsbyte in our classroom 10 days later (BBC News, 29/04/10). This newsbyte was followed by other newsbytes covering the evolving story on 3, 7, and 14 May (Classroom observations, 03/05/10; 07/05/10; 14/05/10). Although the accident was not planned into the curriculum, the adaptive design strategy – common in permaculture – employed in the intervention allowed this unprecedented event to be incorporated in terms of the science and technology involved, and as a case study of the interconnectedness of ecological, economic and social effects of an environmental issue.

The teacher and I observed that students showed interest in and concern about the growing oil slick and its effects on the ecology and economy of the Gulf (Classroom observations, 30/04/10; 03/05/10). Many of them were following news of the oil spill at home and appeared eager to share information during classroom discussions on the topic. While many students appeared to be enthusiastic to exhibit their knowledge about the emerging story, there was initially no observable attitudinal change towards their personal or family's use of oil, or overt desire to take action. After class on May 3 when he presented the second newsbyte, the teacher told me, "The children seem really engaged with this oil spill. I think we should run with it" (Conversation, 03/05/10). What this translated into for the teacher were two additional newsbytes and a research exercise on the spill for the students to complete in the school's computer room. For me it meant linking the accidents to humanity's dependence on fossil fuels in conventional agriculture in a concept mapping exercise during the final unit of the intervention, Plants for Food. But how disorienting or disconcerting was this event on students? During a focus group interview after the intervention, three girls expressed their concerns about the Deepwater Horizon accident as follows:

Alison: "That was actually quite scary."

Ruby: "Yeah, that was not very good."

Mary: "That was not cool." (Focus group interview, 25/06/10)

Fear may be central to a disorienting dilemma. The fear expressed by Alison and other students over the oil spill could potentially spark a transformative learning process with regards to their perception of, and relationship to, fossil fuels – particularly oil – more acutely than the issue of global climate change. Although climate change has the potential to present a disorienting dilemma for students – and may have done so for some – the data suggest that the Deepwater Horizon accident in the Gulf of Mexico had more impact. Although there may be a number of explanations for this, one possibility is that the immediacy of the accident (as opposed to climate change which might be described as a 'slow emergency'), and the dramatic images of oil-soaked birds impacted the students more than the 'dire warnings' from scientists that seem to dominate the headlines on climate change. In the classroom and during focus group interviews, students appeared to exhibit greater concern towards the BP accident even though it occurred on the other side of the planet, than they did toward the predicted effects of climate change in their own country (Coumou & Rahmstorf, 2012; IPCC, 2007, 2012). The acute student response to the Deepwater Horizon accident may have been accentuated by their affective responses to images in the media of oil-soaked birds, and/or by a sense of relevance of their coincident study of ecology with news of the impacts on coastal ecosystems in the Gulf of Mexico. Making science more relevant to students, and the role of affective experiences are discussed later in this Chapter.

### 6.2.3 Section Summary

This section discussed findings relating to two aspects of a transformative approach to science education – a transformative chronology and the role of disorienting dilemmas. The teacher willingly accepted my suggestions to reorder the science units covered during the intervention to more closely fit a transformative chronology (summarized in Table 6.1). In interviews and informal conversations, he praised the approach, but his approval appeared to be more aligned with the context and relevance provided by the reordering of the units rather than the potential for transformation sparked by a potential disorienting dilemma.

Two potential disorienting dilemmas studied during the intervention were global climate change and the Deepwater Horizon accident in the Gulf of Mexico. Most students appeared to express more concern about the Deepwater Horizon accident than global climate change. While there are many possible explanations for this, it is possible that the students saw the Deepwater Horizon accident as something new, rapidly unfolding, and dominating headlines at the time. Additionally, images of oil-soaked birds released by the media may have affected them emotionally. In contrast, they may have viewed climate change as something old, slowly unfolding, and infrequently in the news. When news items about climate change do occur, they often simply announce the release of another scientific study.

Regarding both the transformative chronology and potential disorienting dilemmas, findings indicate that the relevance and contexts provided by them had an impact on both the teacher and students, and that the Deepwater Horizon accident may also have elliceted affective responses in some students. While findings relating to relevance, context and affective learning experiences are presented in latter sections of this chapter, it should be noted that those key principles are not separate from a transformative approach to science education. Those sections, along with this section, also appear related to the following section on systems thinking. In other words, they are all about students making connections between themselves and science, or engaging with science on a personal level.

## 6.3 Emphasizing Interconnections

Section 6.2.1 described the teacher's response to reordering the three science units to fit a transformative chronology. Contained in his statement is a reference to the "crazy interwoven web of science" (Teacher interview, 26/07/10) that he and I knit throughout the intervention. Part of that web can describe how some science topics in the latter two units addressed environmental problems contained in the first unit. The other part of the web represents how the teacher and I made frequent comments to the class about the interrelatedness not only of science topics, but also connections found in natural ecosystems, agricultural systems, energy systems and even interconnections involving the Deepwater Horizon accident in the Gulf of Mexico. Despite these frequent verbal emphases, many of the activities designed to stimulate systems thinking in students were not included during the intervention. As summarized in Table 5.1, three of the four systems thinking activities proposed in the redesigned units were not implemented. As such, the data available on the teacher's and students' responses to emphasizing interrelationships as pedagogy are limited.

While the teacher and I were united in the effort to emphasize interrelationships to a certain extent, as indicated in Section 5.3.1, our approaches differed. I used concept mapping exercises during most of the mini-lessons that I lead, and the teacher regularly used the terms “interconnections” and “interconnectedness” while speaking in class (Classroom observations, 12/03/10, 23/03/10, 01/06/10). Our combined emphases on interrelationships were one of the first things to come to mind during the final interview session. “A big part of it for me was this interconnectedness. It was almost our job really to link them” (Teacher interview, 26/07/10).

While my role as a researcher in the classroom was overwhelmingly one of observer, there were occasions when the teacher called on me to offer my perspective on an issue, as well as other pre-arranged occasions when I took on the role of science teacher. In both cases I emphasized and pointed out the interconnections between the topics and issues within and between the units. In the case of the latter, I used every opportunity to incorporate concept-mapping exercises into my mini-lessons as a way of helping students develop their systems thinking. The students had no previous experience with concept mapping, and so there was an understandable amount of confusion during the first few exercises. But while some students appeared to become more comfortable with concept maps over time, others appeared not to. For example, when asked about the concept maps in a focus group interview after the intervention, Mary said, “I was really confused by those” (Focus group interview, 16/06/10). She did not offer any further explanation, but the teacher suggested:

> I think they were a big challenge for children. I see it’s probably a great opportunity to try to think about interconnectedness because it is not something they’d normally think about, like connecting global warming to buying fast food. So I would describe it through the links through the interconnectedness web we were spinning through the course. And I think that would be one of the greatest challenges to the children with regards to being a difficult task to do and requiring the meta-cognition of all of that. (Teacher interview, 26/07/10)

From the teacher’s perspective it was the challenge and difficulty of learning a new skill that may have made concept mapping less enjoyable for some students. He also commented that he thought low literacy skills of some students would have made concept mapping difficult for them (Teacher interview, 26/07/10). However, after one class period during which I facilitated a concept mapping exercise, the teacher – who had been observing – told me that the students seemed to be engaged throughout the process (Conversation, 26/02/10). In my informal conversations with students during the intervention, some said that they enjoyed the concept mapping exercises and found them valuable in helping them see connections.

While the limited number of systems thinking activities implemented during the intervention makes analysis difficult, one possible effect of those that were used could have been making science more relevant to some students. When students trace interconnections they may see new relevance in science topics they did not recognize before. One key connection for a student to make is the connection to him or herself. In other words, "What does this science have to do with me?" Findings related to relevance are discussed next.

## 6.4 Making Science Relevant for Students

Making science relevant to students' lives has been identified as an important component of engaging them in school science (Fensham, 1985; Tytler et al., 2008). Putting science in a context of the environment is also central to EEfS (Tilbury, 1995). Making science relevant can be interpreted in many ways and the pedagogy of making science relevant can take many forms. Section 5.3.2 discussed which of the proposed teaching strategies from the redesigned unit plans were implemented by the teacher and to what extent. Table 5.1 summarized the two that were implemented: learn about legumes and then later see how they are used by permaculturists to build soil fertility; and, watch a chapter from the film, *Food, Inc.*, to see how different approaches in science – genetic engineering and organics – are used in agriculture. This section examines the teacher's and students' responses to those strategies as well as to another practice that the teacher already used on a regular basis: science newsbytes. While the field trips to local permaculture properties may also have helped to improve the relevance of certain science topics for students, those field trips are discussed in the following two sections.

Sections 5.3.2 and 5.3.3 described the screening of a chapter from *Food, Inc.* in the classroom and the affective responses from a number of students. Findings relating to the affective responses to the screening are presented in Section 6.7 below, but it is also worth noting here that the relevance of genetic engineering may have come as a result of the film clip's emotional impact on students. In other words, some students may have gained a new awareness and appreciation of the science of genetic alteration through the story of Moe Parr and his legal struggles with Monsanto told in the short film clip. Interestingly, the perceived relevance may have had more to do with an apparent injustice cast upon another human being rather than a connection between GE seed and the individual students.

Alongside the film clip, the suggestion of using legumes to highlight the relevance of science learning was used during the intervention. Legumes were introduced to the students during the second unit, Ecological Relationships, within a lesson on the classification of plants. During the third unit, Plants for Food, the use of legumes in agriculture was highlighted during the field trips to the food forest and Eco-Hostel. Putting the concept of nitrogen fixing plants in the context of local, applied science may have improved the relevance of legumes for some students, which may have improved their learning about them. Although no cause and effect can be guaranteed, data suggest that learning about legumes was retained by some students. For example, Keith added legumes to the concept map that he drew on the post-questionnaire with a link to nitrogen, forming the proposition: legumes absorb nitrogen. Seeing the use of legumes on two permaculture properties in his community may have helped him understand why it is worth learning about them in school. Along those lines, there was a slight shift between the pre- and post-intervention questionnaires in students reporting: "I understand why the science topics covered in school are taught" (see Table 8.5). While the sample size is not large enough to be statistically meaningful, these data are aligned with other findings regarding students' perceptions of the field trips (see Section 6.5) as well as classroom observations.

Although an argument could be made that highlighting local examples of science would usually increase its relevance for students simply because it is close to where they live, the reverse argument cannot necessarily be made. In other words, if something is local it is likely to be relevant, but if something is relevant it is not necessarily local. For example, a science newsbyte about a house in England made from recycled plastics (Classroom observation, 26/02/10) may help make science more relevant for some students because the contexts (housing and waste management) are familiar to them, but for New Zealanders, England is not local.

Because the teacher was already using science newsbytes as part of his teaching practice, I saw them as an opportunity to further reinforce the relevance of science for students. As explained in Section 3.3, permaculture involves observing what resources and systems exist in a place and then designing to enhance their productivity. In this instance, the design included enhancing the use of science newsbytes to have them either align with the topics being studied in class at the time, or to highlight the use of science in notable sustainability projects. Examples of these include the newsbyte on climate change discussed in Section 6.2.2, and another on a project by British Gas to produce bio methane from human fecal matter in Oxfordshire, England (Shah, 2010). But the use of newsbytes in another case – the Deepwater Horizon accident – seemed to have the most impact on students. As described in Section 6.2.2, the teacher used a total of four newsbytes about the accident: three from the British Broadcasting Company website (BBC, 2010) and one from the Aljazeera English website (Aljazeera, 2010). The responses of some students to the disaster as a potential disorienting dilemma – the first stage of a transformative learning process – were described in Section 6.2.2. One reason that transformative learning takes place may be that a disorienting dilemma suddenly makes new learning relevant (Mezirow, 2000). For example, a diabetes diagnosis may result in a learner suddenly seeing new relevance in learning about healthy eating and exercise. Although the Gulf of Mexico is half a world away from New Zealand, the Deepwater Horizon accident may have helped some students see the relevance of some of their science learning.

For his part, the teacher appeared to recognize the value in this approach: "It's a new way of teaching science basically, isn't it? It's about making it relevant, global and it's passionate, passionate" (Teacher interview, 26/07/10). This short passage confirms the challenge and promise of transformative pedagogies in a science classroom. The challenge is getting teachers to adopt a transformative style, which may challenge some teachers more used to a transmissive approach. But the promise – as recognized by the teacher in the quote above – is relevance and a broader perspective. The global perspective provided by some of the newsbytes and the study of climate change was combined in the intervention with examples of sustainability initiatives in the community. Together, these strategies embody the popular phrase 'Think globally, act locally.' In other words, the former exposes the relevance of science in international environmental news, and the latter emphasizes the application of science in sustainability initiatives at the local level.

As a matter of good fortune, the transition from a global to local perspective was facilitated by a newsbyte from the weekly community newspaper (Classroom observation, 26/06/10). During the second unit – Ecological Relationships – the local paper ran a story on the upcoming Annual General Meeting for Permaculture in New Zealand, which would be held locally during the April school holiday. The teacher and I used the article to raise awareness of local sustainability initiatives and to emphasize the commitment of permaculturists in the community by organizing the event drawing 200 people from around the country.

To summarize, the attempts to make science more relevant to students described in this section involved science newsbytes, a clip from the film, *Food, Inc.*, and placing the study of legumes in the context of local sustainable food projects. The use of newsbytes, which highlighted the role of science in world events, appears to have been most impactful on students when they caused an affective response. Some students' affective responses to newsbytes regarding the Deepwater Horizon accident appeared related to images of oiled wild fowl, which was similar to responses observed after another newsbyte on elephant poaching (see Section 6.7). Affective responses from many students were also observed after the film clip from *Food, Inc.*, which featured the prosecution of a seed cleaner by the Monsanto Corporation for alleged patent infringement. Findings also suggest a relationship between affective responses, relevance and disorienting dilemmas (see Section 6.2.2).

What these findings suggest is that relevance cannot be pigeon holed as one separate key principle, but may function more as an overarching theme, or umbrella concept. Further support for this idea appears to come from the study of legumes during the intervention, which included highlighting the role of legumes as an example of applied science on two local field trips. Field trips to local permaculture properties, as discussed in the following two sections, also appear to have helped make learning more relevant for students because of the opportunities they afforded to highlight science practiced in the community (Section 6.5) and to experience it (Section 6.6). The teacher appeared to summarize the connections of relevance to big picture thinking and the affective nature of the intervention with his use of the terms relevant, global and passionate as reported on the previous page. Those descriptors may apply both to the pedagogies involved in the intervention, and to the role that permaculture field trips played, as described in the following section.

## 6.5 The Local Application of Science

### *6.5.1 Field Trips*

Section 5.3.4 described one example of highlighting the local application of science that was implemented during the intervention: a field trip to a fledgling food forest. Although the field trip did not go to plan as a student-centered, experiential learning opportunity, it served to expose the students to a local, science-based, sustainability initiative. At the food forest, the teacher was able to take on the role of observer, providing me with a valuable perspective at a time when I was teaching rather than observing. He also acted as an observer on the field trip to Eco-Hostel, which is discussed in this section as well as Section 6.6. When asked after the intervention which activities he thought worked well, the teacher identified the field trips straight away.

> The field trips worked real well. That was because it could be seen as something real and not just something talked about in the laboratory. Especially at Eco-Hostel and at the food forest as well: the activities making it real to that person. (Teacher interview, 26/07/10)

During the interview, he went on to reflect on a number of other activities, but then returned to the field trips.

> So the field trips I guess was the greatest one. I suppose that's a big thing at the moment – trying to make it relevant. And that's what you were saying about this curriculum. Making it relevant to the students. (Teacher interview, 26/07/10)

In these passages, the teacher identifies the reality and relevance that the field trips provided. Although other approaches to making science relevant for students were described in the previous section, it appears that the teacher felt that the field trips were a particularly effective means at achieving that end. Some students reported similar responses to the field trips. For example, Tim reflected: "We actually got out doing stuff instead of just sitting in the class learning about what other people are doing" (Focus group interview, 25/06/10). Where the teacher highlighted the relevance provided by field trips, Tim emphasized their experiential component. Experiential learning activities are explored in Section 6.6, but again, from a holistic perspective the key principles of relevance, local application, and hands-on experiences appear to possess a synergistic quality.

Most students reported having enjoyed the field trips, and some expressed recognition of some classroom topics in the field (Focus group interviews, 25/06/10). On a 5-point Likert-scale, the students who attended the field trip to Eco-Hostel and completed both the pre- and post-questionnaires unanimously agreed or strongly agreed with the statement, "The field trip to Eco-Hostel helped me see permaculture in action." The mean was 4.4 with a standard deviation of 0.50. The sample size was 16 (Post-questionnaire, 22/06/10).

Students rated the field trip to the local food forest somewhat lower than the trip to Eco-Hostel when responding to the statement, "The field trip helped me learn about environmental projects in my community." The mean was 3.7 with a standard deviation of 0.67. The sample size was 16 (Post-questionnaire, 22/06/10) (see Table 7.2 in Section 7.2.1.2). Tim said the field trip to the food forest was "interesting" (Focus group interviews, 25/06/10). These findings appear to indicate that students recognized the contexts provided by field trips to local permaculture projects. But permaculture properties do not develop themselves, they are developed by citizen scientists called permaculturists. The following section discusses the teacher's response to my part-time role during the intervention as practicing permaculturist and field trip host.

### *6.5.2 Citizen Scientists*

As described in Section 3.3, permaculture is a system of science and ethics. As ecological designers, permaculturists use their knowledge of science to design regenerative landscapes, and use their knowledge of ecological principles to design sustainable human systems. As citizen scientists and sustainability practitioners, permaculturists can serve as more knowledgeable others (MKO) in these regards. Although a number of local permaculture practitioners were invited to participate in the intervention, none were available due to scheduling conflicts. As a result, I took on the role of practicing permaculturist during the two field trips. In these instances I viewed myself not as a researcher but as a site host. However, in the eyes of the teacher and students, it is unlikely that these were the only times they regarded me as a permaculturist. Nonetheless, this section explores some of the teacher's thoughts on the role of a local permaculturist as MKO and citizen scientist.

At the beginning of the intervention, the teacher reported having reservations that it may be "too hippy and not enough science" (Teacher interview, 26/03/10). Over the course of the intervention, however, he appeared to recognize and value the emphasis on science that I maintained at the forefront:

> I think your character went well with that. You were the scientist coming in. You weren't like some hippy permaculturist idealist. If that was what permaculture was, I wouldn't be interested in it. But what we've seen with you is that it is science, hardcore science. (Teacher interview, 26/07/10)

The teacher, who did not necessarily consider himself an environmentalist, was somewhat critical of, and cynical about, environmentalists who he perceived as failing to offer realistic solutions to global and local problems. By contrast, through our work together over 12 weeks he reported to appreciate a different type of environmentalist: a practicing permaculturist offering scientifically-based solutions.

> That's what I'm going to get from this: more the application of science rather than the basic facts, and that seems to be what you're about – that permaculture is applying the science. You don't necessarily need to go and have a degree in botany. You're learning methods to enhance what we've got. (Teacher interview, 26/07/10)

A permaculturist is often considered a 'Jack of all trades, master of none,' or, in some cases, master of one. As the teacher appears to have recognized, to practice permaculture on the land is to apply science. One need not be a specialist in a scientific field such as botany, which might be considered a reductionist approach to science. The permaculturist knows enough about physics, chemistry and biology to apply them in real life situations, and enough about systems thinking to enhance existing systems whether related to sustainable food production or energy-efficient dwellings. The teacher went on to express his developing understanding of permaculture beyond biology by referring to a new passive solar accommodation that he saw during the tour of Eco-Hostel.

> I did see permaculture as a biological subject, but the house is a classic example of why it's more than that, and with global warming with the chemistry as well. It seems like all of those – I like this idea of the Science Man here, and the physics, chemistry and biology would be in his belt, but his aim is to do more than those. (Teacher interview, 26/07/10)

Science Man is a character the teacher came up with mid-way through the intervention, as he seemed to grow to appreciate a permaculture approach to teaching and learning, and the broader applications of permaculture beyond biology. In other words, as the teacher got over his initial skepticism of an outsider coming into his classroom wielding an unfamiliar four syllable word – permaculture – he appears to have grown to appreciate some of the ways to teach applied science as environmental problem solving, as opposed to teaching just the basic facts and leaving the tree hugging to greenies. Although the teacher never specifically identified me as Science Man, it may be implied to represent my part-time role during the intervention as practicing permaculturist on the field trips. Had I been female, I'm confident he would have spoken of Science Woman. Additionally, had I been successful in arranging other permaculturists to host the food forest field trip, I believe the teacher would have included them as Science superheroes as well.

The teacher's statement above, that Science Man's aim is to do more with physics, chemistry and biology, can be seen from multiple perspectives. In one respect, Science Man's aim appears to be to "save the planet" as the teacher often emphasized during class (Classroom observation, 12/03/10, 30/04/10). In another respect, his aim is to engage students in learning science by demonstrating how biology, chemistry and physics can be used in sustainability projects. In the context of this intervention, Science Man was both a user of science and a teacher of science. The synergy of doing more with physics, chemistry and biology than simply teaching the facts is at the heart of regenerative educational design just as the synergy of experiential learning, local application and relevance have potential regenerative effects on student learning (Chapter 7) and attitudes toward learning science (Chapter 8).

### *6.5.3 Section Summary*

The field trips, which emphasized the local application of science, appeared to be well received by the students and the teacher. Students reported that the field trips helped them become aware of environmental projects in the community and to see permaculture in action. Some students expressed the importance of experiential learning activities on the field trips, discussed further in the next section. The teacher reported to appreciate the field trips as examples of applied science that highlighted permaculturists as active citizen scientists. The emphasis on the science of sustainability appears to have been significant for the teacher who appears to have experienced a shift in attitude toward the inclusion of sustainability issues in his Year 10 science class. Not only did the teacher report to recognize a broader approach to the teaching and learning of science, but also a broader understanding of the application of permaculture.

Another aspect of the local application of science is the applicator him or herself. Findings from interview data with the teacher suggest that the individual who appears before the students as the local citizen scientist is important. He expressed satisfaction that I did not come across as a hippy idealist (Teacher interview, 26/07/10). From his perspective, he described my persona like an imaginary superhero he called Science Man who has physics, chemistry and biology in his utility belt, to "Saving the planet" (Classroom observation, 12/03/10, 30/04/10), and teaches science student how to do the same. This appeared to be of critical importance for the teacher. Early in the intervention he required me to submit in writing for his preview everything that I intended to say to the students during class. This requirement, however, was dropped, as he seemed to become more trusting of me because of my constant emphasis on the *science* of sustainability. But the cultivation of a generation of Science Superheroes is likely to take more than just showing them what to do. They need to learn by doing themselves, as described in the following section.

## 6.6 Experiential Learning Opportunities

Section 5.3.6 described the field trip to Eco-Hostel as an example of experiential learning opportunity, but also identified it as local and relevant. Additionally, a concept mapping exercise that introduced the field trip emphasized the connections between the sustainability projects at Eco-Hostel to climate change and the Deepwater Horizon accident. In these ways, one field trip was able to address four of the key principles of the intervention. This short section focuses on data that highlights the experiential nature of the overnight excursion.

As discussed in Sections 6.4 and 6.5, the teacher reported that he felt that the field trips worked well. The teacher noted the role of activities that made learning ‘real’ for students. Some students reported similar responses. During a focus group interview, Tim noted that the trip to Eco-Hostel (where I lived at the time and maintained a number of large vegetable gardens) was a highlight of the intervention for him. He offered this explanation: “We went up and looked at your farm and we actually got out doing stuff instead of just sitting in the class learning about what other people are doing” (Focus group interview, 25/06/10). In the same focus group, I asked why the trip to Eco-Hostel was memorable. Scott replied simply: “I think it was just fun, so we remembered what we did.”

Students’ responses to the field trips were much stronger than their responses to a limited number of activities that occurred in the classroom that could also be described as experiential. One example was a laboratory exercise involving carbon dioxide described in Section 5.3.6. There was a certain level of chaos in the classroom during the laboratory exercise, and a number of boys were keener on talking to me about American football, and the video game *Halo 2*, than carbon dioxide and climate change (Classroom observation, 05/07/10). This contrasts significantly with the students’ observed engagement in and responses to the field trips as already indicated in Sections 6.4 and 6.5. While those responses appeared to be universally positive, it also appears impossible to separate out findings relating to the experiential learning activities from those relating to the local application of science from those relating to making science relevant to students, part of which appears to be related to students' affective learning experiences. In other words, it's not just about being hands-on, but being hands-on, global, local, relevant and passionate. From a systems perspective this is wonderful, but from a data analysis perspective it is daunting. Just as the teacher described a "crazy interwoven web of science" (Teacher interview, 26/07/10), this appears to be a crazy interwoven web of findings. With this in mind, the following section takes a slightly more holistic perspective on the key principles of affective experiences and taking action for the environment alongside the common emphasis in EE of combining cognitive, affective and psychomotor experiences (Barker & Rogers, 2004; Sipos, Battisti & Grimm, 2008).

## 6.7 Engaging Head, Heart and Hands

Holistic, transformative teaching and learning takes on approaches to engage students in cognitive, affective and psychomotor experiences that may not be commonly found in traditional secondary science classrooms. (In this section, psychomotor learning (hands) refers to students taking action for the environment rather than participating in experiential learning, which was discussed in Section 6.6.) As noted in Section 6.4, the teacher described the intervention as a different way of teaching science, and had expressed skepticism at its beginning. Later, he explained his initial reservations: "I was afraid it would be too hippy and not enough science" (Teacher interview, 26/03/10). By this, he may have meant too emotional and not cognitive enough. But by the final interview he appears to have found a role for both:

> Yeah, I think there was some passion in this that you wouldn't normally get with straight sciences. You don't normally get Science Man out when you're teaching about astronomy. And I really like the way it's not pure science but applied sciences. And then you can go back to teaching the science. (Teacher interview, 26/07/10)

In this passage the teacher notes a role for passion alongside science learning, as well as the value of applied science. Together these are the heart, head and hands of the holistic EE approach to teaching and learning unfamiliar to most science teachers (Steele, 2011).

Findings suggest the teacher experienced some changes in his thinking about the teaching and learning of science over the course of the intervention, but it is interesting that he concludes his statement above with, "then you can go back to teaching the science." Did he mean that Science Man came out simply to make a guest appearance and then you can get back to teaching science facts in more transmissive ways? Transmissive pedagogies certainly fulfill the *Head* component of student learning, but may not appeal to all students.

Section 5.3.5 described how the key principle of student-centered learning was not achieved during the intervention. What appeared to be the teacher's preferred method of engaging students' minds was having them copy notes from the white board, their work books or a projected set of notes from his computer. On one occasion, the teacher emphasized how fortunate the students were to have a structured exercise such as copying notes. He pointed out that at no other time in their lives besides school would they have a time set aside for them to practice this skill (Classroom observation, 18/06/10). Many students, however, did not report feeling lucky for these opportunities. Some complained about note taking – what they called "book work" – during focus group interviews. According to Scott, the dislike was universal: "Everyone objects against book work" (Focus group interview, 25/06/10). During the focus group interviews as well as my informal exchanges with students, taking notes and copying questions and answers from the course book were identified as the worst things they did in class. Tim described it as "boring" (Focus group interview, 25/06/10). Mary said, "You just kind of get sick of it" (Focus group interview, 25/06/10).

While book work made up a significant percentage of class time (Classroom observations), there were some instances when videos brought on what appeared to be emotional responses from students. The heart, or emotional intelligence, has not played a significant role in science education, which, as argued by Zembylas (2004), has rejected emotion in pursuit of neutrality. But findings suggest there may be a role for affective experiences in science classes to draw students into science learning. As described in Section 5.3.3, the teacher shared a newsbyte on 15 March from the BBC on elephant poaching in Kenya. The images of dead elephants and the fact that poachers received $42 per tusk prompted emotional responses from some students. "What a waste for just 42 dollars" one student said. "Someone needs to stop that," stated another (Classroom observation, 15/03/10).

I took note of the episode but thought little of it at the time. The newsbyte seemed to have little to do with the day's topic, and what I thought I was looking for at the time was how newsbytes could help make science relevant to students by direct connection to the topic of study. However, I was reminded of the students' emotional reactions two months later during an episode in the classroom that garnered a similar response. As described in Section 5.3.3, the chapter "From seed to the supermarket" from the film, *Food, Inc.* was shown along with a worksheet for them to fill out as they watched. As intimated by Section 5.3.3, student reaction was acute. They were alert and engaged through the 11-minute clip and the 10-minute discussion that followed (Classroom observation, 21/05/10). As the students filed out of the room after class, the teacher noted, "I'm surprised at how involved the students were during that" (Conversation, 21/05/10). Data from student focus group interviews indicate that information about Monsanto included in the film clip and class discussion remained with many of the students. These data on student learning are discussed in Section 7.2. But it was the engagement and reaction of the students to the topic that stuck in the teacher's mind. During the final interview, he commented:

> I thought that Monsanto – the kids really seemed to pick up on that. It seemed to be quite a – I think it was the way you sold it to them. I was almost quite surprised at their level of interest in that. I think it was something very new to them. I think the kids grab onto that new idea – something they had not thought of before (Teacher interview, 26/07/10).

While the teacher indicated that he thought it was the novelty of the issue that caught students' attention, classroom observation data, as well as comments made by students in the focus group interviews, suggest it was more the affective nature of the issue that engaged them. When asked what they learned from the intervention, Scott replied, "I learnt why Monsanto sucks." Oscar noted, "Seed companies are assholes." The film clip from *Food, Inc.* focused less on the science of genetic modification and more on the way that the Monsanto Corporation has used its patented science in relation to some US farmers. In this context as a socio-scientific issue, Monsanto was portrayed unfavorably in the film.

Along with noting the novelty of the topic of genetic engineering, the teacher also mentioned the way the topic was “sold” to the students. Selling, in an educational sense, is about pedagogy. Selling, in a marketing sense, is about appealing to ‘hearts and minds.’ From that perspective, I think this mini-lesson may have been successful because of its combined affective and cognitive components. While the affective component of the learning experience seems to have been prompted by the film clip, the cognitive component started with a ‘hook’ to stimulate the students’ minds before the video. That hook was a concept map that I created to link seed germination (the topic of the previous class session) to genetic engineering and sustainable agriculture as a way of providing background information before the film clip. In this way, I had planned for students to get more out of the clip itself. In other words, instead of viewing the clip with no background information and potentially responding only with confusion and boredom, they might have known enough key information and how it related to what they were studying in class to develop feelings – in some cases strong feelings – about the issue. Data from both student and teacher interviews appear to indicate that affective and cognitive learning experiences can work together quite effectively in some cases. Unfortunately, however, psychomotor experiences in the form of taking action for the environment were not included in the intervention as initially planned. A number of classes were canceled due to conflicts in the school, and there simply was not enough time at the end of the intervention for students to engage in direct or indirect sustainability actions. For the most part, this precluded data collection on the impact of such actions on students and the teacher. However, findings are presented in Chapter 7 on sustainable behaviors that may be linked to student learning.

To summarise, although a head, heart and hands approach to teaching and learning was not implemented to a great extent, some data suggest that combining cognitive learning with affective experiences engages students and makes learning memorable. Classroom observations and comments made during the focus group interviews suggest that justice and injustice are important issues to students. Their sense of justice seemed to apply to both human and non-human animals, and may have helped engage them in learning about the science related to certain socio-scientific issues. The emphasis here, as elsewhere in this document, is the complementary or synergistic nature of different key principles working together in what the teacher described as a "new way of teaching science" (Teacher interview, 26/07/10).

## 6.8 Chapter Summary

Findings in this chapter addressed research sub-question 2: How does a permaculture approach to junior secondary science impact on the teaching and learning of science? The findings discussed were those relating to the teacher's and students' responses to some pedagogical practices representing the key principles of the intervention summarized in Table 5.1.

The chapter began with an examination of two aspects of a transformative approach to science education: a transformative chronology; and, potential disorienting dilemmas. The teacher expressed no opposition to re-ordering the units during the negotiation period, and, on reflection after the intervention, identified the modified order as logical and appropriate. Part of re-ordering the units was aimed at presenting global climate change – a topic covered in the first unit – as a potential disorienting dilemma for students. While no findings revealed a high level of concern on this topic from students, an incident that occurred during the term – the BP Deepwater Horizon accident in the Gulf of Mexico – appeared to have an impact on some of them. Although both problems are related to humanity's use of oil, the BP incident was sudden, dramatic, and came with vivid images of oil-covered wildlife. Climate change, by contrast, is more accurately described as a 'slow emergency,' that often appears in the news only to announce the publishing of a new study on the topic. Students appeared to exhibit greater concern towards the Deepwater Horizon accident than anthropogenic climate change.

The next key principle, emphasizing interconnections, proved more difficult to implement fully as it was new territory for both the teacher and the students. The teacher's main expression of this principle was the use of the terms "interconnections" and "interconnectedness" while speaking to the class. My primary expression of this principle was the use of concept mapping activities with students. The teacher reported that our combined emphasis on interrelationships stood out for him as significant, but students' responses were mixed. Some students reported to enjoy the concept mapping exercises while others reported being confused by them. The teacher said that concept mapping was probably a great opportunity to cultivate systems thinking in students, but that it may have been difficult for some students because of the challenges of meta-cognition or lower literacy skills.

Section 6.4 discussed findings relating to some ways in which the teacher and I tried to make science more relevant. Three approaches to making science more relevant to students were discussed: learning about legumes in the context of local permaculture projects; watching a chapter from the film *Food, Inc.* about genetically altered soy bean seeds and the Monsanto Corporation; and, the use of newsbytes that highlighted the role of science in world events. The first two of these were my suggestions and the third was a practice already used by the teacher. Data from the pre- and post-questionnaires showed a small shift in students' recognition of the relevance of their science learning. Some of the relevance students may have recognized could have been related to their apparent emotional responses to certain science newsbytes and/or the story of an American soybean farmer in the film, *Food, Inc.* However, findings appear to indicate that this key principle of relevance is related to and dependent on a number of the other key principles such as the local application of science, experiential learning, and affective experiences. The teacher reported that for him this was a new way of teaching, which provided a big picture perspective while remaining relevant, and having an element of passion.

Field trips to two local permaculture projects were used as attempts to make science more relevant to students by highlighting the application of science in the community. Students reported that the field trips helped them gain awareness of local sustainability projects and to see permaculture in action. The teacher said the field trips were a good example of making science relevant to students. The teacher also emphasized the importance of the role of the host of field trips as a passionate citizen scientist.

Some students highlighted the experiential aspect of the field trips, but data relating to the key principle of experiential learning was limited as the teacher utilized more transmissive practices for the most part. However, findings appear to present a picture in which experiential learning along with the local application of science, and affective learning experiences combined to boost relevance for some students.

Although the synergistic impacts of these key principles would be difficult to analyze due to the multiple factors involved, the final section of the chapter took a somewhat more holistic perspective while examining a potential relationship between affective and cognitive learning experiences. Some data suggest that combining cognitive learning with affective experiences engaged students and made learning more memorable. The teacher noted a strong interest among many students in genetically altered seed and the Monsanto Corporation following a mini-lesson I taught that included a chapter from the film, *Food, Inc.* Classroom observations and comments made by students during the focus group interviews suggest that justice and injustice are important issues for students.

Overall, it was the emphasis on the *science* of sustainability that appears to have been significant for the teacher, who reported gaining a broader understanding of permaculture, and emphasized his appreciation of having a science-focused permaculturist as MKO to work alongside. A key aspect of my role, according to the teacher, was that of environmental scientist trying to "Save the world with science." While the students reported to enjoy the field trips and recognize the relevance they provided, did those learning experiences – along with others implemented during the intervention – result in greater student learning? That question is discussed in the following chapter.

# CHAPTER SEVEN - PERMACULTURE AND ECOLOGICAL LITERACY

## 7.1 Chapter Outline and Introduction

This is the second of three findings chapters that present data in three broad categories: the teacher's and students' responses to the pedagogical practices used during the intervention; changes in students' ecological and scientific literacy; and, students' attitudes toward science and toward learning science during the intervention. Each of these chapters seeks to answer different sub-questions of the inquiry. This chapter addresses sub-question 3: How does a permaculture approach to junior secondary science impact on students' ecological and scientific literacy?

Section 2.3.3 presented an argument that scientific literacy falls within ecological literacy, and the relationship between the two is presented graphically in Figure 2.3. The argument was that ecological literacy requires a certain level of scientific literacy as a prerequisite. Advances in ecological literacy must therefore either be accompanied by advances in scientific literacy or built upon a solid base of existing scientific literacy. Instead of addressing them separately, this inquiry enfolds them, and seeks to identify changes in the more holistic of the two.

Where Chapter 6 focused on the teaching side of the intervention, this chapter focuses on the learning side. It does so by examining the components of ecological literacy and documenting apparent advances made by participating students as suggested by data. Where Chapter 6 was organized around the eight key principles of the intervention, this chapter is structured to address the core elements of ecological literacy discussed in Section 2.2.3: ecological knowledge, including a special understanding of ecological limits and possibilities; caring about the environment; acting for the environment; and, recognizing interrelationships. Section 7.2 begins the findings on student learning by focusing on any changes in their recognition of ecological limits and possibilities, and then takes on the greater task of examining a broader set of data on student learning about science and sustainability. Sections 7.3 and 7.4 discuss the findings on students' caring about, and acting for, the environment. Finally, Section 7.5 employs an holistic perspective on the findings in the preceding sections integrated into a discussion of findings on students' system thinking skills.

Due to varying degrees of student participation in the pre- and post-questionnaires, three different values for N (the number of students) were used in data analysis. Sixteen of the 18 students completed the semantic differential section on both questionnaires, and 15 of the 18 students completed both a pre- and post-concept map. N values are 16 and 15 respectively. Because comparisons were made between the two questionnaires, only data were included for those students who completed (as opposed to participated in) both. The exception to this is data collected using SOLO Taxonomy because a failure to comprehend the task is scored whether the student writes down an incorrect answer or nothing at all. Therefore, data for all 18 students who participated in both questionnaires is included for SOLO Taxonomy data analysis, and the N value is 18. Data were collected during 31 class sessions lasting between 45 minutes and 85 minutes over 12 weeks.

## 7.2 Ecological Knowledge

As discussed in Section 2.2.3, ecological literacy requires a certain level of science knowledge. Orr (1992) highlights certain topics such as carrying capacity, population dynamics, trophic levels, thermodynamics, energetics, succession, and evolution. Other knowledge, or ways of seeing, critical to ecological literacy are the ability to recognize interrelationships (systems thinking), and ecological limits and possibilities (Orr, 1992). This section limits its focus to the foremost of these and the latter. A discussion of changes in students' system thinking skills is reserved for the end of this chapter in an attempt to take a more holistic perspective, and to transition to Chapter 8. As a way to wade slowly into a sea of data on student learning, this section begins with an examination of findings on students' recognition of ecological limits and possibilities before diving into the data on more general science learning.

### *7.2.1 Recognizing Ecological Limits and Possibilities*

Orr (1992) includes the ability to recognize ecological limits and ecological possibilities as essential aspects of ecological literacy. This ability is described as a special form of ecological knowledge in Section 2.2.3. The current, dominant economic philosophy of infinite growth without consequences makes it especially important to help students understand that, from an ecological perspective, there are real limits to growth of any system or population, and real consequences to ignoring those limits. For instance, an understanding of carrying capacity and population dynamics would allow an ecologically literate individual to participate in important discussions about the nature of growth and the prospects for unsustainable growth on the planet, examples of which may include human population or unfettered globalization.

Likewise, it is important to help students discover what is physically and biologically possible in terms of sustainable development and ecological design. It is especially important to help them differentiate between science fact and science fiction when examining competing 'solutions' to environmental problems. For instance, an understanding of thermodynamics would allow an ecologically literate individual to make informed decisions about their personal energy use, and to potentially question some of the claims being made about emerging alternative energy technologies such as hydrogen fuel cells, bio-fuels, renewables, tar sands, and shale gas. Of particular importance is the concept of energy returned on energy invested.

#### *7.2.1.1 Recognizing Ecological Limits*

For the purposes of this study, examples of unsustainable human behaviors were used to help students recognize some ecological limits of the planet. Three examples are: the addition of anthropogenic sources of carbon dioxide into the atmosphere beyond the Earth's buffering capacity; the extraction of finite mineral resources from the lithosphere; and, the expansion of oil drilling into more dangerous and expensive locations as a sign of peaking world oil supplies. While the former was part of the planned curriculum, the latter two came up as 'teachable moments' in the form of science newsbytes during the term. Together they address the common notion of unsustainable growth that lies at the heart of many environmental problems. In other words, it allowed a consideration of whether corporate and political obsession with economic growth has caused many of our planet's environmental problems, and that this focus may continue to ignore and deny many of the social and ecological consequences of growth.

Addressing the notion of growth on both questionnaires was a pair of statements in the semantic differential section: "There is no limit to the number of human beings who could live on Earth” and “There is a limit to the number of human beings who could live on Earth.” (Note that no lessons or newsbytes were included that specifically addressed human population growth.) Although the sample size is small, Table 7.1 below indicates a slight shift in students’ responses toward the recognition of ecological limits over the course of the intervention. While the number of students who agreed with statement B increased by only two of out of 16 from the pre- to the post-questionnaire, the class mean also shifted toward statement B, and there was a reduction in standard deviation. Because the questionnaires were coded to individual students, I was able to determine that six students shifted their opinions toward statement B. Notably, on the pre-questionnaire, all six of those students either agreed with statement A or had a balanced opinion. In other words, six of the ten students who believed there was no limit to the number of human beings who could live on Earth, or had a neutral opinion on the pre-questionnaire, shifted their responses toward the recognition of limits on human population. The other six students who agreed with statement B to begin with did not change their responses. Five of them circled number 7 and one of them circled number 6 on both questionnaires.

Table 7.1: Students' Opinions on the Limits to Human Population on Earth

| | Total Agree Statement A | Balanced Opinion | Total Agree Statement B | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Pre-questionnaire | 4 | 6 | 6 | 4.5 | 2.1 |
| Post-questionnaire | 3 | 5 | 8 | 4.9 | 1.7 |
| Change | -1 | -1 | +2 | Change towards agreement with B 0.4 | Less variance in data 0.4 |

*Note.* Semantic differential statements: A "There is no limit to the number of human beings who could live on Earth." B "There is a limit to the number of human beings who could live on Earth." (7-point scale, where A is 1 and B is 7). N = 16

As noted above, human population growth was not studied during the intervention. But the three topics listed above – anthropogenic climate change, the extraction of finite mineral resources, and deepwater oil drilling - are all potentially accelerated by human population growth. It is plausible that the shift in students' responses from the pre- to post-questionnaire represents an ability to translate their recognition of limits from one or all of those issues to the issue of human population growth. It would be this ability to translate learning from one area to another that interests me most, and appears to contrast with many students' struggle to translate learning to caring and caring to acting as discussed in Sections 7.3 and 7.4 below.

One significant mini-lesson that addressed the limits of Earth's mineral wealth garnered expressions of surprise from students. On 12 March, the teacher shared with the class a chart titled "How long will it last?" that he received through email from the manager of the local waste transfer station. The chart indicated the number of years remaining for 19 different minerals ranging from aluminum to zinc at current rates of global extraction. The teacher printed the chart for each student and facilitated a brief discussion that prompted student comments such as, “Wow, I’ll be 40 when silver runs out. That’s how old my dad is.” And, “I’ll be 50 when gold runs out!” (Classroom observation, 12/03/10). Although this exercise was brief and unplanned, it appeared to have an effect on the students regarding their perceptions of limits to the Earth’s capacity to provide.

Along the same lines, connections were made between the BP Deepwater Horizon accident and peak oil. Although no formal lessons were held on the topic of peak oil, it was included in a concept map, that I shared with the students when they visited Eco-Hostel, that showed links between everything they had studied within the timeframe of the intervention up to that point. Those topics included global climate change, the Deepwater Horizon disaster, certain ecology topics, and some approaches to sustainable agriculture. Although peak oil was included in the concept map (linked to why an oil company might go to such expense and take such risks at sea instead of simply drilling on land), the focus of the map was not on ecological limits but rather on ecological possibilities. Nonetheless, the connection of oil as a limited resource could have been made to the previous mini-lesson on the Earth’s finite mineral supplies. I observed no overt student response to the inclusion of peak oil in the concept map partly due to the fact I was teaching the lesson and partly because the field trip was not about “gloom and doom” but about hope, that is, the ecological possibilities demonstrated by the application of science at Eco-Hostel. Some of these are discussed in the next section.

#### *7.2.1.2 Recognizing Ecological Possibilities*

Section 3.3 described permaculture as a design system that recognizes and maximizes ecological possibilities. Permaculture was used in this study in part to demonstrate some possibilities regarding science-based, low-input, high productivity organic agriculture and, to a lesser extent, energy-efficient home design. These possibilities were demonstrated during the field trips discussed extensively in Chapter 6. While that chapter described how students responded to the field trips as an approach to teaching and learning, this chapter examines the data related to student learning and ecological literacy.

Data from the focus group interviews indicate that the field trips were considered enjoyable and provided opportunities for learning. When asked what they had learned over the course of the intervention, many students identified permaculture. For instance, Edward stated, “I didn’t know about permaculture until you came. Never heard of it” (Focus group interview, 25/06/10). This offers little surprise, as it is unlikely that many students of his age anywhere in New Zealand would have heard of permaculture, as it does not feature in the current or previous New Zealand school curricula, nor have much of a profile in the media.

But responses to the question above from other students revealed something more surprising. Both Ruby and Olivia identified organic gardening as something they had learned during the intervention. Ruby admitted, “I didn’t really know there was another way of gardening” (Focus group interview, 25/06/10). Olivia said, “I heard about it, but I didn’t really understand it” (Focus group interview, 25/06/10). Regarding the recognition of ecological possibilities, this appears to be a milestone for both learners. Knowing that it is possible to grow vegetables without purchased artificial chemical applications is the first step toward learning how to do it and then, perhaps one day doing it.

To the same question about what students had learned during the intervention, Mary noted that she was made aware of using chickens to prepare garden beds by taking advantage of their natural tendency to scratch the ground (Focus group interview, 25/06/10). Like the girls above, Mary reported her discovery of a new ecological possibility – that chickens can do the work of a rotary hoe. Tim also reported learning eco-agricultural techniques such as companion planting for insect pest control, and mulching for weed control (Focus group interview, 25/06/10). Edward reported that he was happy to have learned about the use of swales to retain water naturally on the landscape at Eco-Hostel (Focus group interview, 25/06/10). The teacher noted later that swales had “struck a chord” with Edward, who asked if they could build one at school (Teacher interview, 26/07/10). Edward had recently moved from Australia, and for that reason he may have been more aware of the importance of groundwater hydrology than his classmates. However, Edward’s swale intrigue may also have represented his ability to see cause and effect, and more importantly, a delay between the two. This possibility is explored further in Section 7.5 below.

By exposing students to permacultural practices at Eco-Hostel and the community food forest, I was able to demonstrate what is ecologically possible regarding low-input/high productivity food production. From the data presented above, these experiences appear to have influenced students' thinking about some ecological possibilities. The teacher also noted examples from the field trips that he felt had impressed the students. He expressed the value in the students' opportunity of, "seeing a big garden full of vegetables. And even releasing the warmth of the compost was quite surprising to them. And even that water system" (Teacher interview, 26/07/10). From the teacher's perspective, organic gardening, hot composting, and the use of swales were new learning experiences for the students. These aspects of permaculture landscape design and organic gardening – along with those identified by the students above – helped demonstrate ecological possibilities that appear to have impacted positively on students.

Of the students who completed both questionnaires and attended the field trip to Eco-Hostel, all agreed or strongly agreed with the statement "Permaculture is a good way to solve environmental problems," on the post-questionnaire. On a 5-point Likert-scale where 4 was 'Agree' and 5 was 'Strongly Agree,' the mean was 4.3 with a standard deviation of 0.43 (Post-questionnaire, 22/06/10). On the same 5-point Likert-scale, the same cohort of students unanimously agreed or strongly agreed with the statement, "The field trip to Eco-Hostel helped me see permaculture in action." The mean was 4.4 with a standard deviation of 0.50 (Post-questionnaire, 22/06/10). A different cohort of students – those who attended the field trip to the food forest and completed both questionnaires – expressed similar reactions but to a lesser extent as seen in Table 7.2.

Table 7.2: Students' Post-questionnaire Responses to the Following Statement Regarding the Field Trip to a Local Food Forest: "The field trip helped me learn about environmental projects in my community"

| | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree | Mean | Standard Deviation |
|---|---|---|---|---|---|---|---|
| Post-questionnaire | 0 | 0 | 4 | 4 | 1 | 3.7 | 0.67 |

*Note.* (5-point Likert scale). N = 16

Regarding the recognition of ecological possibilities exhibited by certain permaculture projects, the field trips appear to have been helpful to students. No students disagreed or strongly disagreed that the field trips: highlighted local environmental projects; demonstrated permaculture in action; or, that permaculture is "a good way to solve environmental problems" (Post-questionnaire, 22/06/10). But findings related to other aspects of ecological knowledge do not appear to be as clear as these data. Those findings are presented next.

### *7.2.2 Science and Sustainability Learning*

Knowing, caring and acting are essential components of ecological literacy (Orr, 1992). The latter two are discussed in Sections 7.3 and 7.4. Ecological knowledge is, in many ways, the pivot point of this inquiry, joining the arms of school science and EEfS. It is common ground between scientific literacy and ecological literacy in which the seeds of both can germinate and grow. It is also a keystone of my theoretical framework, and provides a potential 'foot in the door' for integrating more EEfS into secondary schools via the science curriculum. As discussed in Chapter 6, the teacher reported to be pleased with the scientific emphasis of the intervention: "But what we've seen with you is that it is science, hardcore science" (Teacher interview, 26/07/10). This section addresses ecological knowledge acquisition through data related to students' science and sustainability learning other than the recognition of ecological limits and possibilities and systems thinking.

#### *7.2.2.1 Scientific Literacy*

While scientific literacy is important to the theoretical framework of this thesis, the intervention focused more overtly on knowledge aspects of scientific literacy than on scientific thinking or skill development. However, scientific thinking and science skills were included to a certain extent in the units and data were collected regarding some aspects of scientific literacy. For instance, both questionnaires included the paired semantic differential statements: "Scientific ideas change over time" and "Scientific ideas do not change over time." As shown in Table 7.3 below, there was essentially no change in students' responses between the questionnaires.

Table 7.3: Students' Opinions on Whether Scientific Ideas Change Over Time

| | Total Agree Statement A | Balanced Opinion | Total Agree Statement B | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Pre-questionnaire | 14 | 2 | 0 | 2.1 | 0.97 |
| Post-questionnaire | 13 | 3 | 0 | 2.2 | 1.0 |
| Change | -1 | +1 | 0 | Change towards agreement with B 0.1 | More variance in data 0.03 |

*Note.* Semantic differential statements: A "Scientific ideas change over time." B "Scientific ideas do not change over time." (7-point scale, where A is 1 and B is 7). N = 16

These data appear to indicate a good level of students' understanding about the changing nature of scientific ideas, although there was a large standard deviation. It is possible that the school's science program has emphasized this through the years and that it has become an accepted aspect of these students' scientific literacy.

As described in Section 7.2.1.2, students reported learning about permaculture and many of the science-based strategies inherent in its practice. For example, Tim said he learned about companion planting of certain vegetable crops, and Darren said he learned about the use of certain plants to repel insects in an organic garden (Focus group interview, 25/06/10). Additionally, some students said that they learned about DNA and the genetic modification of seeds. Section 6.6 described some students' reactions to a mini-lesson about genetic engineering taught by me, which included a concept mapping exercise and a clip from the film, *Food, Inc.* While the film clip appears to have had an affective impact on some students (described in Section 7.3 below), they also included this topic as one of the memorable areas of learning during the course of the intervention. For Tim, it was the first thing that came to mind when asked what he had learned (Focus group interview, 25/06/10). Darren and Scott agreed that it was something they learned, and the following conversation from their focus group interview provides a glimpse at the types of socio-scientific issues students explored within the nature of science strand of the curriculum.

Tim: I learned that they're genetically modifying plants.

Darren: Yeah, that kind of sucks. Just keep it natural, because they've survived this far how they are. So why do they need to change them now?

Scott: And also changing them is really stupid.

Tim: They're making them.

Scott: Because you're screwing around with DNA and stuff.

Tim: And because they're making them so that you can't like get other seed off the plant. You have to buy a new one, which is kind of stupid. (Focus group interview, 25/06/10)

While it can be argued that genetic engineering is brilliant science, it is not the type of science that is embraced within ecological literacy. Indeed, some may describe it as the ultimate in reductionist science. In the exchange above regarding the film made in the US, Darren presents an insight into the long genetic heritage of plants, and Tim comments on the strict control that corporations have on their patented seed. What has been common practice for farmers for thousands of years – saving seed – is now against the law in the US, not only for those who buy Monsanto's GE seed, but also for those neighboring farmers whose own crops may become cross-pollinated by GE crops upwind. It is the economic and social impacts of genetic engineering that highlight the nature of science inquiry here, as revealed in the boys' words.

#### *7.2.2.2 Science Vocabulary*

The first thing that came to Scott when asked what he had learned during the intervention was the amount of new vocabulary (Focus group interview, 25/06/10). His response was related to the amount of "book work" that he complained about, as described in Section 6.7.

Scott: One, the definitions of lots of words.

Tim: Yeah, that was kind of a bit boring.

Scott: Lots and lots of new words. (Focus group interview, 25/06/10)

Science classes at the secondary level will inevitably involve the learning of new vocabulary. I have heard colleagues joke that perhaps science should be in the foreign language department. But the use of proper scientific terminology is an important component of both scientific and ecological literacy. While some students reported to have resented the amount of new vocabulary, data in Table 7.4 below indicates a slight increase in the use of the words on the concept mapping exercises of the pre- and post-questionnaires, as well as the use of some additional terms that three students independently included in the latter. However, the high standard deviation indicates high variability in word use amongst the students.

As described in Section 4.5.2.1, the concept mapping exercise was identical on the pre- and post-questionnaires. It provided students with 16 terms in a 'parking lot' and asked them to build a concept map showing what they knew about a sustainable system for producing food. Students were also asked to provide additional terms that they thought might fit. While no students came up with words outside of the 'parking lot' on the pre-questionnaire, the new words that three students included in their post-maps were: soil, legumes, shops, pollution, and people.

Table 7.4: The Number and Percentage of Words Used by Students in Concept Maps on the Pre- and Post-questionnaires

| | Number of concept words used | Percentage of concept words used |
|---|---|---|
| Pre-questionnaire mean | 11.5 | 71.7 |
| Pre-questionnaire standard deviation | 4.0 | 24.7 |
| Post-questionnaire mean | 12.1 | 75.5 |
| Post-questionnaire standard deviation | 4.0 | 25.2 |

*Note.* N = 15

With a sample size of only 15, these data are by no means definitive. Additionally, a number of factors could have impacted on the increase in word use from the pre- to the post-concept maps. For instance, students may have become more comfortable with the process of concept mapping itself. If that were the case, however, it would show that some learning had taken place. That type of learning – which may be called systems thinking – is discussed below in Section 7.5.

Differences between students' pre- and post-concept maps were not limited strictly to the number of words used. Some student maps appeared to reveal science learning in the form of corrected misconceptions. For instance, on the pre-map Edward included the propositions: "nitrogen kills weeds" and "nitrogen kills insects" (Pre-questionnaire, 05/03/10). On the post-map, his propositions regarding nitrogen included: "farms benefit from nitrogen" and "nitrogen can be used in gardens" (Post-questionnaire, 22/06/10). In the case of the former, Edward appears to have had a misunderstanding of the use of nitrogen in agriculture. While his statements regarding nitrogen in the latter map are more general in nature, they can also be considered more accurate. Most farms do benefit from nitrogen, and nitrogen can be used in gardens.

In some cases, an increase in the number of words used by students between the pre- and post-maps may suggest science learning. For example, as shown in Table 7.5, Scott used 11 words on his pre-map and 16 on his post-map. Taking the word nitrogen as an example again, Scott did not include it on his pre-map but did include it on his post-map within the proposition: "fertilizers put nitrogen in the ground" (Post-questionnaire, 22/06/10). Again, this does not prove that Scott did not know enough about nitrogen to include it on the pre-map, but classroom observations showed Scott as a good science student who was eager to demonstrate his accurate knowledge in class (Classroom observations). Considering this, it seems unlikely that Scott would have held back expressing his science knowledge on the pre-questionnaire.

Table 7.5: Scott's Use of Words in the Concept Maps on the Pre- and Post-questionnaires

| | Number of concept words used | Percentage of concept words used |
|---|---|---|
| Pre-questionnaire | 11 | 69 |
| Post-questionnaire | 16 | 100 |

There is also the case of Olivia, who used fewer words from the 'parking lot' on the post-map than the pre-map as shown in Table 7.6. She did not use the word nitrogen on either map. Classroom observations along with focus group interview data do not show Olivia as a keen or capable science student. For example, she expressed her misunderstanding of climate change after the intervention: "I still don't really get global warming. That's confusing… like, is it, like, the sun coming closer and heating and making the ice melt? Is that what it is?" (Focus group interview, 25/06/10). As described in Sections 8.2 and 8.3, Olivia indicated a negative attitude toward science and toward learning science in school. On her post-questionnaire she strongly agreed with the statement "I do not like learning science in school," and at the bottom of one page she wrote, "I'm bad at science.

I don't understand it!" (Post-questionnaire, 22/06/10). But as described in Section 8.3, Olivia's dislike of learning science appears to have been affected by her difficulty relating to the teacher and certain of his teaching styles (Focus group interview, 25/06/10). As shown in Table 7.8 below, she used 13 words on her pre-map but only 10 on her post-map.

Table 7.6: Olivia's Use of Words in the Concept Maps on the Pre- and Post-questionnaires

| | Number of concept words used | Percentage of concept words used |
|---|---|---|
| Pre-questionnaire | 13 | 81 |
| Post-questionnaire | 10 | 63 |

In Olivia's case, it is possible that rather than expressing her science learning on the post-map she simply rushed through the exercise because of a negative attitude toward the class. Given this possibility, it is unfortunate that her data in Table 7.6 drew down the class mean for word use on the post-map (Table 7.4).

#### *7.2.2.3 Sustainable Propositions and Quality Map Scores*

Orr (1992) often defines ecological literacy by describing how an ecologically literate individual would think and act. One key to sustainable action is differentiating between what is sustainable and what is not. Probing this ability in students involved collecting data around their perceptions of a sustainable food system on the pre- and post-questionnaires. The students were instructed to use the 16 concepts provided – along with any others they thought should belong – to make a concept map to show what they knew about "a sustainable system for producing food." The rich data from their concept maps were analyzed quantitatively as presented in the previous section, and qualitatively as described below. For the purposes of evaluating students' recognition of sustainable and unsustainable practices, I developed a process for evaluating sustainable propositions (see Section 4.5.2.1).

Put succinctly, two concept words connected by a linking word or phrase form a proposition. For example, the terms food and organic can be connect by the phrase "can be" forming the proposition: food can be organic. A proposition is a unit of meaning constructed in cognitive structure. Each proposition was analyzed for whether or not it trended toward sustainability according to the protocol summarized in Table 4.2. Only those propositions that were considered sustainable were counted in the tally included in Table 7.7.

Table 7.7: The Number and Percentage of Sustainable Propositions Made per Student in Concept Maps on the Pre- and Post-Questionnaires

| | Number of sustainable propositions | Percentage of sustainable propositions |
|---|---|---|
| Pre-questionnaire mean | 1.8 | 13.5 |
| Pre-questionnaire standard deviation | 1.4 | 9.4 |
| Post-questionnaire mean | 2.2 | 16.7 |
| Post-questionnaire standard deviation | 2.2 | 15.2 |
| *Note.* N = 15 | | |

While the sample size was small, these data show a slight increase in the number of sustainable propositions for the class as a whole. Some students exhibited greater advances than others as implied by the large standard deviation in the post-mean. Scott, for example, included two sustainable propositions in his pre-map and five in his post-map. Additionally, Scott was one of just four students to increase their quality map scores (discussed below), and one of only two to achieve a quality score of two on the post-questionnaire.

As described in Section 4.4.1.2, I developed a Concept Map Quality Scoring Rubric and Protocol (CMQSRP) that was used to assign quality map scores. Like the sustainable proposition data shown in Table 7.7, the data relating to quality scores in Table 7.8

suggest a slight increase in the class as a whole, while individual students made greater and lesser gains.

Table 7.8: Quality Scores of the Concept Maps on the Pre- and Post-questionnaires

| | Quality score |
|---|---|
| Pre-questionnaire mean | 0.73 |
| Pre-questionnaire standard deviation | 0.46 |
| Post-questionnaire mean | 0.93 |
| Post-questionnaire standard deviation | 0.59 |
| *Note.* N = 15 | |

As a case study, these data are useful only to a certain degree. The richness of case study lies in the stories of individuals such as Scott, Olivia, Edward and Natalie. While a discussion of the latter pair is postponed until Section 8.4, a discussion of the former pair rounds out this section. Scott, as mentioned above, was one of two students to achieve a quality score of two on the post-questionnaire. A quality score of two requires a certain quantity and diversity of sustainable propositions. Scott included five sustainable propositions on his post-map that addressed three of the main sustainability aspects listed in the CMQSRP: reducing the use of fossil fuels in production and transportation; an emphasis on local markets; and, building and maintaining soil fertility. Three of Scott's sustainable propositions that met these aspects were: "local transportation uses less petrol"; "farms are local"; and, "weeds sometimes get composted gets turned into fertilizers." While the phrasing may be awkward, Scott appears to have developed a better grasp of certain aspects of sustainable agriculture between the questionnaires. He expressed his knowledge broadly and clearly on the post-map.

Olivia, on the other hand, did not. Related to her reduced use of concept words on the post-map (see Table 7.6), is her reduced number of sustainable propositions and lower quality score. She included two sustainable propositions on the pre-map, and earned a quality score of 1. Her sustainable propositions were "gardens can be organic," and "animals can be used for transportation." But her post-map included no sustainable propositions and earned a quality score of zero. Although Olivia's data may not appear to be important in the present discussion, it is included here to provide a backdrop for later discussions on her attitudes toward science (Section 8.2) and toward learning science (Section 8.3).

### 7.2.3 Section Summary

This section presented findings related to changes in a number of aspects to students' ecological knowledge. Section 7.2.1 focused on a special type of ecological knowledge: the recognition of ecological limits and possibilities. Data from the pre- and post-questionnaires, classroom observations, teacher interviews, and focus group interviews appear to indicate that students gained awareness of both ecological limits and ecological possibilities during the intervention. Awareness of ecological limits appears to have been gained primarily through the discussions of finite mineral resources and non-renewable energy supplies, although the study of unsustainable rates of anthropogenic carbon dioxide emissions could also have influenced students' awareness. Student learning about ecological possibilities appears to have been influenced by the field trips to the local food forest and to Eco-Hostel, each of which provided examples of science-based ecological approaches to growing food that were previously unfamiliar to many students.

Section 7.2.2 discussed findings related to other aspects of ecological knowledge: scientific literacy, science vocabulary, and sustainable thinking. Regarding scientific literacy, some students appeared to have gained awareness of socio-scientific issues such as genetic engineering. Another aspect of scientific literacy – communicating in science – was assessed through students' use of science vocabulary words. Findings indicate increases in students' word use and accuracy of usage. Evidence for changes in students' sustainable thinking appears to vary among students, but to have increased for most. While the number of sustainable propositions and quality scores on the post-concept maps increased for the class as a whole, the standard deviations on their responses also increased. While these data are indicative only, they can serve to support the case stories of individual learners in Chapter 8. Another aspect of ecological literacy – caring about the environment – is discussed next.

## 7.3 Caring about the Environment

As discussed in Section 6.7, many students displayed notable affective responses to a newsbyte on elephant poaching in Africa and a movie clip about the Monsanto Corporation's treatment of some American soybean farmers (Classroom observations, 15/03/10; 21/05/10). Additionally, some students expressed concern about the Deepwater Horizon accident in the Gulf of Mexico (Classroom observations, 03/05/10; 07/05/10; 14/05/10). When asked if they felt any differently about the environment after the intervention, Ruby, Mary and Alison all responded affirmatively. Mary added, "Especially with the whole oil spill thing" (Focus group interview, 25/06/10). Ruby and Alison agreed that the Deepwater Horizon accident had affected their feelings about the environment. All three girls went on to talk about what they had learned during the intervention, so I tried to steer the conversation back to their attitudes toward the environment.

Researcher: But even beyond the learning that you've done, I'm more getting at your feelings for the environment…do you think that learning about the environment relates to your attitudes toward the environment?

Ruby: Yeah (hesitation)

Mary: For some people

Alison: Yeah

Mary: There's the odd few that don't really care about either one

Ruby: But yeah, we like the environment…I guess a lot more.

Mary: Yeah, because we have to live with it and if it, like if it starts dying, then we will too, I guess.

Alison: And I hug the trees more often now. (All laugh.) Because there's this tree down at the bush track that I hug some times when we go for walks.

Ruby: Alison just loves trees.

Mary: Alison loves trees.

Alison: Trees are awesome. I wear a t-shirt that says, “Hug a Tree” (Focus group interview, 25/06/10).

Although the Deepwater Horizon incident was discussed as a potential disorienting dilemma in Chapter 6, it may be possible that some students’ disorientation with the massive oil leak arose from a sense of care for the environment. And that learning about the ecology of the spill may have produced deeper levels of care for the environment. For example, Darren expressed concern about oiled birds and other sea life while Scott noted worry about the effects on the coastal ecology of Louisiana (Focus group interview, 25/06/10). This would seem a natural response from children of this age presented with images of oil washing up on beaches and covering pelicans.

However, there exists some seemingly contradictory data regarding students’ attitudes toward the environment in the questionnaires. An unexpected response arose from the paired statements: “I feel I should take actions to help the environment,” and “I do not feel I should take actions to help the environment.” Interestingly, the data shown in Table 7.9 present a slight shift toward the latter statement combined with an increase in the standard deviation.

Table 7.9: Students' Opinions on Taking Actions to Help the Environment

| | Total Agree Statement A | Balanced Opinion | Total Agree Statement B | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Pre-questionnaire | 8 | 8 | 0 | 3.1 | 0.93 |
| Post-questionnaire | 9 | 5 | 2 | 3.3 | 1.1 |
| Change | +1 | -3 | +2 | Change towards agreement with B 0.2 | Greater variance in data 0.17 |

*Note.* Semantic differential statements: A) "I feel I should take actions to help the environment," and B) "I do not feel I should take actions to help the environment." (7-point scale, where A is 1 and B is 7). N = 16

While one student appears to have shifted toward agreement with statement A, two students shifted to agree with statement B. This is curious given other data, especially the data representing students' responses to another paired set of semantic differential statements: "Making money should be given priority over protecting the environment," and "Protecting the environment should be given priority over making money." The data in Table 7.10 indicate a notable shift in students' attitudes toward protecting the environment over making money.

Table 7.10: Students' Opinions about Prioritizing Making Money or Protecting the Environment

| | Total Agree Statement A | Balanced Opinion | Total Agree Statement B | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Pre-questionnaire | 2 | 7 | 7 | 4.4 | 1.5 |
| Post-questionnaire | 1 | 5 | 10 | 5.3 | 1.4 |
| Change | -1 | -2 | +3 | Change towards agreement with B 0.9 | Less variance in data 0.1 |

*Note.* Semantic differential statements: A) "Making money should be given priority over protecting the environment." B) "Protecting the environment should be given priority over making money." (7-point scale, where A is 1 and B is 7). N = 16

Given the emphasis on money in our society, and the consumer marketing focus on teenagers in particular, I consider this important data. On the surface, it may appear to be at odds with data from Table 7.9. But it is possible that, although many students feel there should be a shift in priority from making money to protecting the environment *in general*, some of them may not feel that they, themselves, should take actions to help the environment. It may be meaningful that the first pair of statements includes the word I and the second pair does not. In other words, the former is more of a personal statement and the latter is more of a general statement.

There appears to be a disconnect between an attitude that "*they* should do something about that," and "*I* should do something about that." Who are *they* anyway? If *they* are the government or corporations, it appears unlikely that either will shift priorities from making money to protecting the environment anytime soon. The debate on carbon taxes illustrates this well. If *they* are other people, wouldn't those people be thinking that some other *they* should be doing something? And so it goes. The gap between reported feelings and observable actions has confounded environmental educators for decades. Data from the present study related to taking action for the environment are presented in the next section.

In summary, classroom observations and focus group interview data suggest that many students have feelings of care for the environment, especially when it comes to wildlife. Some students also appear to have a strong sense of social justice regarding certain relationships between corporations and people. Three notable learning experiences that took place in the classroom demonstrated that in the pursuit of profit sometimes wildlife and people suffer. While each was brief – 10 minutes or less – it is possible that they influenced some students into shifting priorities towards protection of the environment over making money. However, when it came to making a personal statement - “I feel I should take actions for the environment” – there was no indication of a shift toward a sense of stewardship, and even a slight move away from it. So what is the apparent disconnect between caring and acting? That question is addressed in Chapter 9 along with the data of the following sections.

## 7.4 Acting for the Environment

In an EEfS research context, taking actions for the environment has a number of interpretations. In the original context of this inquiry, it had two. The first was as part of a holistic approach to EEfS including education *about* the environment, education *in* the environment, and education *for* the environment. Education *for* the environment entails engaging students in meaningful action-based learning projects that have a net direct or indirect benefit for local or global ecology. EEfS research can evaluate the potential outcomes of student involvement in such learning experiences. However, due to time constraints, students were not involved in formal actions for the environment during the intervention.

The other interpretation of acting for the environment – and the only one for which data were collected – relates to students engaging in environmentally-friendly behaviors of their own accord. As EEfS is largely about cultivating behavior change, the success of EEfS initiatives may be judged on their ability to motivate such change. As shown in Table 7.11 below, at the conclusion of the intervention, seven of the 16 students who completed both questionnaires agreed with the statement, "This science unit has motivated me to take actions for the environment" (Post-questionnaire, 22/06/10).

Table 7.11: Students' Responses on the Post-questionnaire to the Statement: "This science unit has motivated me to take actions for the environment"

| | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree | Mean | Standard Deviation |
|---|---|---|---|---|---|---|---|
| Post-questionnaire | 0 | 2 | 7 | 6 | 1 | 3.8 | 0.78 |

*Note.* (5-point Likert scale). N = 16

However, reporting motivation to act does not necessarily translate into acting. Interestingly, between the pre- and post-questionnaires, students reported a slight shift away from taking actions for the environment as seen in the two tables below.

Table 7.12: Students' Reporting on Taking Actions to Help the Environment

| | Total Agree Statement A | Balanced Opinion | Total Agree Statement B | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Pre-questionnaire | 4 | 8 | 4 | 3.8 | 1.1 |
| Post-questionnaire | 3 | 9 | 4 | 4.2 | 1.3 |
| Change | -1 | +1 | 0 | Change towards agreement with B 0.4 | Greater variance in data 0.2 |

*Note.* Semantic differential statements: A "I take actions to help the environment." B "I do not take actions to help the environment." (7-point scale, where A is 1 and B is 7). N = 16

Table 7.13: Students' Reporting on Their Food Purchasing Decisions

| | Total Agree Statement A | Balanced Opinion | Total Agree Statement B | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Pre-questionnaire | 4 | 7 | 5 | 4.0 | 1.1 |
| Post-questionnaire | 2 | 4 | 10 | 4.9 | 1.2 |
| Change | -2 | -3 | +5 | Change towards agreement with B 0.9 | Greater variance in data 0.1 |

*Note.* Semantic differential statements: A "I take the environmental impacts of food production into account when buying food or asking my parents or guardians to buy food for me." B "I do not take the environmental impacts of food production into account when buying food or asking my parents or guardians to buy food for me." (7-point scale, where A is 1 and B is 7). N = 16

While these data represent neither the expected nor the intended outcomes of the intervention, they do offer food for thought. On the surface these findings might appear to indicate that students have changed their behavior toward less sustainable actions, but another possibility exists. It is possible that with a broadened view of ecological problems and possibilities, the students viewed their actions with a more discriminating eye. They may have valued their contributions less, although their actual behaviors may have remained the same, or possibly even improved.

In the focus group interviews, students reported engaging in generic eco-friendly behaviors that were not necessarily part of the lessons covered. For instance, Mary reported taking shorter showers, and Alison reported turning off the lights when leaving a room (Focus group interview, 25/06/10). Because of these stereotypical answers, I suspected their responses might not have been completely genuine. The students appeared to be providing what they thought were the 'right answers.' When I probed deeper, the girls brought up a project they had done in science class the previous year.

Mary: We did this thing, um, last year. Remember the performance thing we did with the rubbish?

Alison: Oh yeah, that was so scary.

Mary: After that I started yelling at people when they littered.

Ruby: Well I never really littered or anything before that.

Mary: Its just I never would tell anyone else to.

Alison: Yeah.

Ruby: I've just always been kind of… friendly towards the environment. So it doesn't really make much of a difference. (Focus group interview, 25/06/10).

Still probing deeper, I proceeded, "Well, I guess I'll rephrase the question. Can any of you identify one action that you might do more or differently now than you did three months ago?"

Ruby: Look at the back of things to see how they're made. I guess.

Mary: Yeah

Researcher: Anyone else?

Alison: I'm thinking. I don't know.

From these responses there appears to be few, if any, strongly identified actions for the environment that resulted from the intervention. However, as many education researchers (and parents) have come to observe, teenagers often take action in the form of talking or complaining. Considering this, I probed even deeper.

Researcher: Well, here's a related question. Do you talk more about the environment with friends or family?

Ruby: Um, Do we? Do we? I don't know. I yell at them not to litter.

Mary: Same here. I yell at them when they start littering. I'm like "Pick it up".

Researcher: But you would have done that last year, after your performance piece.

Mary: Yeah.

Alison: Yeah.

Ruby: I don't know. Not really I guess.

Researcher: So you haven't noticed that you're engaging in more conversations than you used to.

Mary: No, but I guess if we did I guess we would have a stronger argument than what we had before (Focus group interview, 25/06/10).

This last statement from Mary exhibits much of what has frustrated the EE movement over the last four decades. Her words demonstrate a common disconnection between what one knows and what one does regarding the environment. Specifically, there appears to be an attitude in many students (and many adults for that matter) summed up in this type of a statement, "I could do that if I needed (wanted) to, but I don't need (want) to right now." It is similar to the attitude that many smokers have about quitting: "I could quit anytime…if I wanted to." The disconnection between knowing, caring and acting is discussed in more detail in Chapter 9.

As my exposure to the students was limited almost exclusively to class time, I asked the teacher in the final interview session if he had noticed any changes with regards to attitude change or behavior change. He replied, "Yeah, I suppose so. The forging of a relation, particularly after that camp. A positiveness in that class. I can't really tie it down to anything specific" (Teacher interview, 26/07/10). Looking at his response now leads me to believe that he misinterpreted the question, as I was not specific that the changes I was looking for involved *environmental* attitudes and *sustainable* behaviors. He seems to have commented on classroom attitudes and behaviors, especially after that overnight trip to Eco-Hostel, which he referred to as "that camp." Unfortunately, I did not notice this at the time of the interview. But information I learned about the dynamics of that class later in the interview may help explain why his answer focused on relationship and positiveness in the class. The classroom dynamic is discussed in Chapter 8.

Regarding students' actions, I asked the teacher a related question about whether any parents, guardians, or other teachers had mentioned noticing any differences in the students with regards to attitude change or behavior change? He replied, "The parents' evening was quite recent. And the parents told me – the ones that filled out the permission slip – that the kids have been talking about the science at home" (Teacher interview, 26/07/10).

It is interesting that the teacher cites the parents who both filled out the research consent form and attended the parents' evening at the school. Eighteen of the 28 parents and/or guardians returned a signed consent form allowing their child's participation ranging from filling in the questionnaires through involvement in focus group interviews. These actions may indicate that these parents are more interested and involved in their childrens' school experiences. If data from the focus group interviews is any indication, it would appear that students were talking to their parents about the oil spill, genetic engineering, and various aspects of water management and food production practiced through permaculture. Although it may be a stretch to say that students talking to their parents about these issues qualifies as indirect actions for the environment, it is not inconceivable. It may have been that some parents started recycling, composting, or changed their light bulbs at home in response to what their child learned in school. Indeed, it is not uncommon to hear environmental educators say that we need to educate the children so that they can go home and educate their parents.

But when it comes to identifying students' direct actions for the environment, challenges arise in a school setting where their lives are highly structured and programmed. For example, within the context of a science classroom, it is difficult to observe students engaging in overt sustainable behaviors. They may use a piece of scrap paper to take notes or recycle an old assignment, but even these behaviors would be difficult to observe in this particular classroom as the students were required to take notes in a lesson book that was collected and marked by the teacher, and there was no obvious recycling bin. On one occasion, I observed papers co-mingled with non-recyclable waste in a rubbish bin in the classroom.

However, one moment stands out in the classroom regarding potential sustainable behavior change. Just over a month into the intervention – after the unit on climate change but before the Deepwater Horizon accident – the local weekly newspaper contained an article raising awareness about the upcoming Permaculture in New Zealand (PINZ) annual *Hui* (meeting) that would be held at the local *marae* (a communal, sacred place that provides a venue for social and religious functions). Also included in the paper was an article about Earth Hour, which was to be recognized the following evening. Earth Hour is an international event that encourages people to switch off their lights for one hour in order to "take a stand against climate change" (Earth Hour, 2012). While I brought a copy of the paper for each student for the purpose of sharing the articles on permaculture, Edward noticed the article on Earth Hour. The teacher seized the moment and asked the class, "How many of you plan to take part in Earth Hour tomorrow?" A show of hands indicated slightly over half of the students planned on participating (Classroom observation, 26/03/10). Unfortunately, the following week the students were involved in school testing and then went on holiday for two weeks. As a result, I did not see the students for three weeks and was not able to assess how many of them actually did participate in Earth Hour.

To summarize, in the absence of student learning experience *for* the environment, data collection on students' actions was limited to assessing voluntary sustainable behaviors. However, assessing such behavior in a school setting is difficult as schools are highly structured, and there is little room for students to demonstrate overt, voluntary sustainable behaviors. As such, data on students' actions for the environment relied largely on self-reporting, which has significant reliability problems. Interestingly, more students reported being motivated to act for the environment than actually taking action. The actions students reported included recycling, turning off lights, and taking shorter showers. There appears to be evidence that these were actions that students took before this intervention, and that they were learned in previous years at school or, potentially, at home. Overall, there appears to remain a gap between knowing, caring, and acting. It is the relationship between the three that intrigues me, and it is the development of a strategy that helps learners recognize the relationship between them – or any set of interconnected elements of a system – that brings the discussion to the final section of this chapter.

### 7.5 Recognizing Interrelationships

The challenging task of collecting data relating to the systems thinking skills of students was addressed in the questionnaires through concept mapping and SOLO Taxonomy exercises, as well as one Likert-scale statement on the post-questionnaire. Additional data were collected through classroom observations and focus group interviews.

As described in Chapter 6, the teacher often used the terms "interconnections" and "interconnectedness" when addressing the class. At the same time, I emphasized interrelationships through a number of concept mapping exercises with the students. At the conclusion of the intervention, the students would have been familiar with these concepts, and reported overwhelmingly on the post-questionnaire that they "learned about interconnections in nature and human communities" as shown in the table below (Post-questionnaire, 22/06/10).

Table 7.14: Students' Responses on the Post-Questionnaire to the Statement: "I learned about interconnections in nature and human communities"

| | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree | Mean | Standard Deviation |
|---|---|---|---|---|---|---|---|
| Post-questionnaire | 0 | 0 | 3 | 10 | 3 | 4.0 | 0.61 |

*Note.* (5-point Likert scale). N = 16

But what participants self-report they can do and what they can do are not always the same. However, data from the focus group interviews provide some examples of students making connections.

Researcher: Do you think you are better at seeing interconnections than you were before the unit?

Ruby: Yes.

Mary: Mmm…interconnections as in one thing causes the other?

Alison: Oh, Yeah.

Mary: Yeah.

Researcher: Can you give me an example of recognizing interconnections?

Ruby: That just killed it. Ummm. (Laughing)

Mary: Seed grows into a tree.

Alison: Tree grows fruit. Fruit falls off.

Mary: Then you eat the fruit.

Alison: Then poo it out. Makes another tree. Makes another fruit.

Mary: Then poo it out makes another tree, and it grows.

Mary: It's also the same with bad stuff, like littering, or if it goes into the ocean and kill some fish.

Alison: Or a dolphin.

Mary: Yeah, or a dolphin. They might think it's a jellyfish. And they'll eat it and they'll die. And decrease the population. (Focus group interview, 25/06/10).

While the example of the tree that the girls discussed represents their recognition of cycles, the example of littering better demonstrates systems thinking skills by way of identifying knock-on effects and unintended consequences. In other words, the former example demonstrates their recognition of connections. The life cycle of plants can be connected in a stepwise fashion as the girls have described above. Connections can be cyclical or linear, but do not necessarily branch out. The girl's latter example of littering and dolphins represents their recognition of interconnections. Interconnections are less predictable and are of a branching and cross-branching nature rather than cyclical or linear. They also may pose the question, what next? For example, what happens after the dolphin population decreases? Will there be negative feedback or positive feedback? Then what? The distinction between connections and interconnections is discussed further below with an analysis of the number of links and crosslinks students were able to create on their pre- and post-concept maps.

In a separate interview, three boys provided other good examples of systems thinking. Tim offered an insightful response to the question, "Do you think that you are any better at seeing interconnections than you might have been a couple months ago?" Tim said, "Things like fitting together, like plants helping other plants, is that what you're talking about? Yeah, I would say so" (Focus group interview, 25/06/10).

Not only does Tim answer in the affirmative, but he also provides an example from the field trips: beneficial relationships between certain plants when grown together. After Tim's insight, Scott noted that he had gained a broader, more integrated perspective of the oil spill in the Gulf of Mexico. This prompted the other boys to join in, as seen in this interchange during a focus group interview.

Scott: I did think of that oil spill differently after we learned about it. 'Cause it's reached the shore in some places now and it's really bad.

Darren: When I first read about it I was like oh, it's just an oil spill.

Scott: That's what I thought too.

Darren: And they'll get over it, contain it all. But now they've showed all these images of birds and sea life.

Scott: Yeah, I thought it was all, 'cause, you know I thought they had a back up plan or something, like they knew what to do.

Tim: You'd think so.

Darren: Yeah, they should have something that automatically just shuts it off.

Scott: But they didn't.

Tim: Well they do have like this valve thing, but that's way down under the water at the way bottom.

Scott: It doesn't even work. They tried to turn it off. (Focus group interview, 25/06/10).

Days earlier in class, Scott had expressed his recognition of the interconnections between the ecological, social, and economic impacts of the accident. He described how coastal estuaries were beginning to become contaminated with oil, which would have an effect on the nursery grounds of valuable seafood species in the region and lead to problems for local fisherman. This was in stark contrast to a reductionist statement Scott made in class over a month earlier. On that occasion, after a class discussion about the US Coastguard setting floating oil alight to stop it spreading, Scott exclaimed: "Imagine all that petrol going to waste!" (Classroom observation, 30/04/10).

Scott appears to be one of the students who made gains in systems thinking skills based on the concept mapping and SOLO Taxonomy data from the pre- and post-questionnaires (see Table 7.15 below). On the post-concept map he used more of the provided words, created more links and cross links, and developed more sustainable propositions (Scott's concept maps are included in Appendix I).

Table 7.15: Scott's Pre- and Post-concept Map Scores

| | Number of concept words used | Percent of concept words used | Number of links | Number of crosslinks | Number of sustainable propositions | Percent of sustainable propositions |
|---|---|---|---|---|---|---|
| Pre-Q | 11 | 69 | 14 | 0 | 2 | 14 |
| Post-Q | 16 | 100 | 22* | 1 | 5 | 24** |

*Note.* * One added for lack of starting node (see Section 4.6.2.1). N

** Percentage does not include the extra point for starting node. N – 1

The progress represented by the numbers above could be attributed to many different factors, some completely unrelated to the development of systems thinking skills. While the gains in the number of words used and number of sustainable propositions created were discussed in Section 7.3 above, the increased number of links and crosslinks are the data relevant to this section. For Scott, both of these increased from the pre- to the post-concept maps. This would appear to be consistent with data from classroom observations and the focus group interview.

Similarly, data from all of the students who completed concept maps on the pre- and post-questionnaires indicate increases in both the number of links and the number of crosslinks. However, in both cases the standard deviation also increased.

Table 7.16: Number of Links and Crosslinks in the Concept Maps on the Pre- and Post-questionnaires

| | Number of links | Number of crosslinks |
|---|---|---|
| Pre-questionnaire mean | 13.3 | 0.4 |
| Pre-questionnaire standard deviation | 5.1 | 0.8 |
| Post-questionnaire mean | 14.7* | 1.5 |
| Post-questionnaire standard deviation | 6.1 | 1.6 |

*Note.* * One added for lack of starting node (see Section 4.6.2.1). N = 15

What stands out is not so much the increase in the number of links (13.3 to 14.7) but the increase in the number of crosslinks (0.4 to 1.5). Although the numerical increase in each case is roughly the same, the increase when expressed as a percentage increase differs greatly. While the number of links increased by 10.5%, the number of crosslinks increased by 275%. As discussed above regarding focus group interview data from Mary and Alison, there appears to be a distinction emerging between students' ability to recognize connections and their ability to recognize interconnections.

This could be a subtle, yet significant distinction. Connections – especially in a school science learning context – could simply be memorized and parroted back on demand. This may not represent significant learning or advances in systems thinking skills. Additionally, it may represent only first order change: doing more of the same but doing it better (Sterling, 2001). Interconnections, however, may not be so easily memorized and repeated. They may represent recognition over regurgitation. If this is the case, these data may support some of the central aims of this thesis. Along those lines, further analysis of data from the SOLO Taxonomy exercises on the pre- and post-questionnaires is presented below.

As described in Section 4.6.2.2, the SOLO Taxonomy section was identical on both questionnaires. The exercise presented graphic data on the relationship of agriculture to human labor and fossil energy over several decades, and asked students a series of questions. The questions were designed to assess their recognition of higher and more complex relationships both in the data, and between the commonly acknowledged aspects of sustainability: economic, social, and environmental.

The SOLO Taxonomy data appear to indicate that some students made progress regarding systems thinking skills while others did not. This is consistent with data from the concept mapping exercises, classroom observations, and focus group interviews. Scott has been used as an example of the former above and below. On the SOLO Taxonomy exercises, Scott's score changed from 4.33 to 5. What accounted for the improved score were his insightful comments on the economic, social, and environmental impacts of relying more on oil and less on human beings to produce food. His responses to each aspect of sustainability included at least two knock-on effects. For example, regarding environmental impacts, he wrote, "More oil used = more $CO_2$ = more pollution and greenhouse gases = global warming = we all die!" (Post-questionnaire, 22/06/10). Because a score over 4 is high, it appears as if Scott already had a more holistic perspective than many of his peers to begin with. This is indicated by the data from all students who participated in both the pre- and post-questionnaires as seen below in Table 7.19. He was one of only two students to score over 4 on the pre-questionnaire (05/03/10).

Table 7.17: The SOLO Taxonomy Levels for Students who Participated in the Pre- and Post-questionnaires

| | # of students at SOLO level 0 - 1 | # of students at SOLO level 2 | # of students at SOLO level 3 | # of students at SOLO level 4 | # of students at SOLO level 4.33 - 5 | Mean | Standard Deviation |
|---|---|---|---|---|---|---|---|
| Pre-Q | 6 | 0 | 10 | 0 | 2 | 2.5 | 1.2 |
| Post-Q | 2 | 1 | 8 | 1 | 6 | 3.3 | 1.2 |

*Note.* N = 18

As explained in the introduction to this chapter, the SOLO Taxonomy data are being included for all 18 students who participated in both questionnaires since a failure to comprehend the task is scored at Level 0/1 whether the student writes down an incorrect answer or nothing at all. For example, Olivia left six questions blank and wrote one incorrect answer on the pre-questionnaire (05/03/10). On the post-questionnaire, she wrote "Don't know" twice, scribbled three question marks, included one incorrect answer, and finally wrote, "I'm bad at this kinda stuff" (Post-questionnaire, 22/06/10). As described in Section 7.2, Olivia's concept mapping data showed a decrease in the number of words used and links made from the pre- to the post-questionnaire. A potential explanation for this involving a conflict with the teacher is discussed in Section 8.3. Because that conflict may have influenced Olivia's effort on the SOLO Taxonomy and concept mapping sections of the post-questionnaire, her data will not be closely considered in this section. Instead, Natalie's data may provide better insight into a student who appears not to have made significant advances in systems thinking skills, and whose data may not be influenced as much by negative feelings toward the teacher.

Regarding potential gains represented by the SOLO Taxonomy data in Table 7.17, a number of students show greater differences between the pre- and post-scores than Scott. Of particular interest are those students who went from a score of 1 to a score of 3, and those students who went from a score of 3 to a score over 4. Unfortunately, no interview data and little classroom data are available for the former group. However, there is a good deal of data for Edward, whose SOLO score increased from 3 to 4.33.

Edward, as described above in Section 7.2.1.2, was the student who expressed interest in the swales at Eco-Hostel and asked the teacher if they could build swales on the school grounds. Edward's improved score resulted from a greater recognition of the environmental impacts of a heavy reliance on fossil fuels in conventional agriculture – climate change – as well as suggesting some ways communities can reduce carbon dioxide emissions and protect against food price shocks caused by a volatile oil market: "use less petrol on farms and use a wider range of local farms" (Post-questionnaire, 22/06/10).

Concept mapping data also suggest that Edward made strides regarding systems thinking skills as indicated by the greater number of links and especially crosslinks shown in Table 7.18 below. (Edward used "farms" as his central node in the post-map.)

Table 7.18: Edward's Number of Links and Crosslinks in the Concept Maps on the Pre- and Post-Questionnaires

| | Number of links | Number of crosslinks |
|---|---|---|
| Pre-questionnaire | 17 | 0 |
| Post-questionnaire | 21* | 3 |

*Note.* * One added for lack of starting node (see Section 4.6.2.1).

While an increase from zero to three crosslinks could represent nothing more than Edward's improved concept mapping skills, it could also represent advances in systems thinking as suggested by his improved SOLO score above. Unfortunately, Edward did not get the chance to express a perspective on his own systems thinking skills in the focus group interview because a comment by Olivia derailed the question and I felt at the time it was best to wrap up the interview as the students were showing fatigue. However, I do feel it is significant that Edward picked up on the use of swales at Eco-Hostel (Teacher interview, 26/07/10).

Swales may not appear on the surface to be particularly intriguing or significant. But that is part of the function of swales. Most of what goes on with swales is below the surface:

specifically, the infiltration and percolation of storm water into the ground. Swales represent both a hidden function and a time-delay. Their benefits appear in their immediate surroundings as well as further down the watershed. Swales are literal and figurative banks. The ground is banked up into low berms, and water is banked in the ground instead of running off. Systems thinking is four-dimensional. It includes the recognition of oscillations, delays, and rates of change. It may be possible that swales "struck a chord" (Teacher interview, 26/07/10) with Edward because he could see the interconnections between time and space, near and far. Swales are the embodiment of the precautionary principle. They represent patience, and what permaculturists call "small and slow solutions" (Holmgren, 2002, p. 181). Swales and their potential lessons – both literal and figurative – are discussed further in Chapters 8 and 9.

Natalie's concept mapping data in Table 7.19 below shows little or no improvement in systems thinking. The number of links she used on the post-map increased by two simply because she used two more words than on the pre-map. She included no crosslinks on either map.

Table 7.19: Natalie's Concept Map Scores on the Pre- and Post-Questionnaires

| | Number of concept words used | Percent of concept words used | Number of links | Number of crosslinks | Number of sustainable propositions | Percent of sustainable propositions | Quality Score |
|---|---|---|---|---|---|---|---|
| Pre-Q | 6 | 38 | 6 | 0 | 0 | 0 | 0 |
| Post-Q | 8 | 50 | 8* | 0 | 1 | 14** | 1 |

*Note.* * One added for lack of starting node(see Section 4.6.2.1). N
** Percentage does not include the extra point for starting node. N – 1

Additionally, Natalie's SOLO score did not change from the lowest possible mark between the pre- and post-questionnaires. On the pre-questionnaire Natalie appeared to confirm her low score by writing after the last question: “I don’t understand this test. It’s too hard” (05/03/10). On the post-SOLO Taxonomy section she wrote, “What, this is crazy!” (22/06/10).

These data appear consistent with her self-reporting on what she learned during the intervention. Natalie reported neither to agree nor disagree with the statement, “I learned about interconnections in nature and human communities” (Post-questionnaire, 22/06/10). While her neutrality could mean a number of different things, what is most relevant is a lack of agreement with the statement, which appears to be supported by data from her SOLO Taxonomy scores and concept mapping.

To summarize, the data presented in this section around systems thinking skills appear to echo much of the other data presented in this chapter. That is, it seems to indicate that while the class as a whole experienced moderate gains in systems thinking skills, certain individuals may have experienced greater and lesser advances. There appeared to be consistency in data triangulated between pre- and post-SOLO Taxonomy scores, the number of crosslinks students used on their concept maps, classroom observations, focus group interviews, and self-reporting on learning. The discussion of two students – Edward and Natalie – profiled in this section is continued in the next chapter, and particularly in Section 8.4.

## 7.6 Chapter Summary

This chapter presented findings relating to research sub-question 3: How does a permaculture approach to junior secondary science impact on students’ ecological and scientific literacy? The findings were discussed in sections aligned with the components of ecological literacy: ecological knowledge; an attitude of care for the environment; a tendency to take action for the environment; and, systems thinking.

The discussion of data on students’ ecological knowledge included: the recognition of ecological limits and possibilities; some basic aspects of scientific literacy; science vocabulary; and, sustainable thinking. A broad set of data suggests that students gained awareness of both ecological limits and ecological possibilities during the intervention. Awareness of ecological limits appears to have been gained primarily through the discussions of finite mineral resources and non-renewable energy supplies, and awareness of ecological possibilities appears to have been influenced by the field trips to local permaculture properties. Regarding scientific literacy, some students appeared to have gained awareness of socio-scientific issues such as genetic engineering. Another aspect of scientific literacy – communicating in science – was assessed through students' use of science vocabulary words. Findings indicate increases in both students' word use and accuracy of usage. Evidence for changes in students' sustainable thinking appears to vary among students, but to have increased for most of them.

Findings on students' attitudes toward the environment suggest that many of them care about human-caused impacts on wildlife, issues of environmental justice, and that protecting the environment should be given priority over making money. However, when it came to making a personal statement such as, "I feel I should take actions for the environment," there was no indication of a shift toward a sense of stewardship. The eco-actions that students reported included recycling, turning off lights, and taking shorter showers, but some evidence suggests that these were actions in which students engaged before the intervention, or that they were learned in previous years at school. Overall, there appears to be a gap between knowing, caring, and acting. Part of that disconnect may be related to students' ability or inability to connect, or, more accurately, interconnect components of systems. Findings related to systems thinking appear to indicate that while the class as a whole experienced a moderate increase in ability, individuals may have experienced greater and lesser advances. In case study research such as this, the richness of the data lies more at the individual level than with the group as a whole. Chapter 8 takes a closer look at individual learners than Chapters 6 and 7, and includes case stories of two students who appear to be indicative of many of their classmates.

# CHAPTER EIGHT - ENGAGING STUDENTS IN SCIENCE

## 8.1 Chapter Outline and Introduction

This is the last of three findings chapters, which present data in three broad categories: the impacts of pedagogical practices involved in the intervention; students' ecological and scientific literacy; and, students' attitudes toward science and toward learning science. This chapter focuses primarily on research sub-question 4: How does a permaculture approach to junior secondary science affect students' attitudes toward studying science? Concern has been expressed about students' attitudes about learning science in school, a trend of disengagement with science, and high attrition rates beyond the compulsory years (Gough, 2004; Osborne, 2003). Student disengagement with science poses obvious threats to scientific literacy, but also – as argued in Section 7.1 – to ecological literacy. Succinctly stated, the argument is that advances in ecological literacy must either be accompanied by advances in scientific literacy or built upon a solid base of existing scientific literacy. If some students drop out of school science because of poor attitudes and low engagement in learning (Caygill, 2008; Crooks, Smith, & Flockton, 2008; White, 2003), the aim of science education advocates would appear to be to engage students in science with pedagogies that stimulate them and boost relevance. Some such pedagogies were described in Chapter 5, and the teacher's and students' responses to them were discussed in Chapter 6. Evidence for student learning in response to those pedagogies was discussed in Chapter 7.

The present chapter links to findings in the previous two chapters to reiterate key points and to enhance the overall picture of student engagement with science during the intervention. Section 8.2 examines students' attitudes toward science in general and Section 8.3 examines their attitudes toward learning science in particular. Section 8.4 profiles two individual learners through case stories. This chapter seeks to provide perspectives that are both broad and deep. A broad perspective is gained by looking at the class as a whole, and includes findings from the previous two chapters. A deep perspective is gained by profiling two individual learners who appear to be representative of other students in the class. Through these two perspectives a clearer picture emerges of how a permaculture approach to junior secondary science affects students' attitudes to science and toward learning science. The first of those is discussed next.

## 8.2 Students' Attitudes Toward Science

This section presents data on students' attitudes toward science, particularly their views on the relationship of science to environmental problems and potential solutions. Data are presented from the pre- and post-intervention questionnaires and classroom observations, along with focus group and teacher interviews.

While the small sample size in this study means all quantitative data needs to be considered with caution, two paired sets of statements in the semantic differential section of the pre- and post-questionnaires provides a good place to start exploring students' attitudes toward science. The first pair of statements probed whether students thought that science and technology could or could not be blamed for many environmental problems. The second pair of statements probed whether students thought that science and technology could or could not be used to help solve environmental problems. While the data from all those students who completed both the pre- and post-questionnaires are presented below in Tables 8.1 and 8.2 below, one student, Edward, seemed to have captured much of the student sentiment when he reported on some things he had learned during the intervention: "How science can create genetically modified seeds that can help in a way and wreck everything else in another way" (Focus group interview, 25/06/10). The ability to weigh both the costs and benefits of certain kinds of science and different technologies can be difficult and confusing for students, who may prefer to see things as black and white. Edward's statement speaks to this challenge.

When considering the costs and benefits of science – a key skill in scientific literacy - the overall class data presents what appears to be a better recognition of the certain costs than of potential benefits. Table 8.1 shows a shift toward the recognition of problems – often unintended consequences – of science and technology, while Table 8.2 indicates that students moved towards a balanced opinion on the role of science and technology in environmental problem solving.

Table 8.1: Students' Opinions about the Impacts of Science and Technology on the Environment

| | Total Agree Statement A | Balanced Opinion | Total Agree Statement B | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Pre-questionnaire | 5 | 11 | 0 | 3.5 | 0.87 |
| Post-questionnaire | 8 | 7 | 1 | 3.0 | 1.0 |
| Change | +3 | -4 | +1 | Change towards agreement with A 0.5 | More variance in data 0.13 |

*Note.* Semantic differential statements: A "Science and technology can be blamed for environmental problems." B "Science and technology cannot be blamed for environmental problems." (7-point scale, where A is 1 and B is 7). N = 16

Table 8.2: Students' Opinions about the Role of Science and Technology in Solving Environmental Problems

| | Total Agree Statement A | Balanced Opinion | Total Agree Statement B | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Pre-questionnaire | 11 | 3 | 2 | 2.8 | 1.3 |
| Post-questionnaire | 9 | 7 | 0 | 3.0 | 1.0 |
| Change | -2 | +4 | -2 | Change towards balanced opinion | Less variance in data 0.3 |

*Note.* Semantic differential statements: A "Science and technology can be used to help solve environmental problems." B "Science and technology cannot be used to help solve environmental problems." (7-point scale, where A is 1 and B is 7). N = 16

While the use of science and technology were presented as both villain and hero during the intervention, the overwhelming emphasis by the teacher and me was on science as hero. As described in Section 6.6, the teacher presented an image of Science Man using science to save the planet. Alongside that, I emphasized the science of sustainability on field trips to local permaculture sites. Considering these overt approaches, it is interesting that there was movement in the students' attitudes toward neutrality from statement A (Science and technology can be used to help solve environmental problems) in Table 8.2, *and* movement towards neutrality from statement B (Science and technology cannot be used to help solve environmental problems). A balanced opinion in a semantic differential exercise can mean a number of different things. For instance, some students may have more easily recognized deepwater oil drilling and genetic engineering as examples of science and technology that could impact negatively on the environment (Table 8.1), than some more subtle science-based permaculture practices such as companion planting, swales and chicken tractors as examples that could impact positively. Along the same lines, some students may have accepted both sides of the science and technology story and become more undecided in their opinions. The apparent neutrality may, in fact, represent greater confusion about the whole issue, or a more sophisticated understanding of science, or that the students think that some, but not all, science and technology can be used for better or worse.

As alluded to above, less time and attention were spent looking at environmental problems caused by science and technology during the intervention. The sources and causes of global climate change were presented to students, but they may have already been familiar with much of that. As described in Section 6.3, the topic is frequently in the New Zealand news, and the school runs a CarbonWise program. As described in Section 6.5, during the first days of the unit, the teacher asked the class to write down five things they knew about 'global warming,' and then to take notes as he called on students to share what they had written down. The information on climate change offered by the students covered the basics (Classroom observation, 08/03/10). The manner in which the rest of the unit was taught, from my observations, was a fairly reductionist analysis of carbon dioxide as a molecule rather than a holistic, critical look at the role of carbon-based fuels in our society. While I had proposed a more critical perspective – such as using clips from the film, *The Age of Stupid* - in my curriculum design as shown in Chapter 5, the teacher did not embrace that approach.

The small amount of class time that was spent questioning the role of science and technology in society was limited to newsbytes (and the ensuing classroom discussions) on the Deepwater Horizon accident, and the issue of genetic engineering that was presented to the students by me in a mini-lesson that lasted about one half of a class period. As described in Section 6.6, the mini-lesson started with a concept map prepared by me in advance to link the students' previous learning about seed germination in the Plants for Food unit to Monsanto's 'terminator seeds' (that do not germinate) and to another genetically engineered product in Monsanto's catalog, 'Round-Up Ready' soybeans. The concept map was presented to the students as a PowerPoint slideshow with each slide adding another concept and link to the growing map. The concept map started with 'Seed Germination' and ended with 'Round-Up Ready Soybeans.' This provided an introduction for a chapter from the film, *Food, Inc.*, which provided a critical look at how science and technology (and patent law) can be used by large corporations to manipulate and intimidate farmers in the pursuit of profits. Students' strong affective responses to the film clip are described in Sections 6.6 and 7.4.

In total, the instances focusing on the 'darker side' of science and technology accounted for significantly less class time and were discussed less frequently than the instances where science was promoted as a valuable tool for a sustainable future (Classroom observations). Although this may have influenced some students to appear more positive about science than they actually were, I would argue against this possibility because I suspect the teacher and I offered more examples of problems with science and technology than most junior secondary science teachers do, and more than this teacher normally would have. Four newsbytes on the Deepwater Horizon accident and a one-off mini-lesson on genetic engineering did not rival the near daily reminders from the teacher that "We are saving the planet with science!" and the overtly solution-oriented permaculture field trips. Yet the data above appears to indicate a stronger impact on students from the lessons that included the unintended consequences of science and technology than those on the potential positive uses of science and technology to solve environmental problems. Potential reasons for this are discussed in Chapter 9.

Despite the small sample size, the quantitative data corroborates data from focus group interviews. As noted above, Edward was clearly able to see at the end of the intervention how science could have both positive and negative effects for humanity and for the planet. But Edward's may be a more holistic perspective that reflects a higher degree of scientific literacy than some other students such as Olivia.

During the focus group interview, Olivia described her dislike of science (discussed below) and her dislike of learning science (discussed in Section 8.3). During an impromptu attempt by Edward to explain 'global warming' to her, Olivia admitted, "I don't really get science. It's too hard. I don't understand it. And I don't like it" (Focus group interview, 25/06/10). What follows is a brief interchange between Olivia, Edward and me.

Researcher: Do you feel that science is relevant to your life?

Olivia: I don't want it to be. (All laugh)

Edward: Has to be, unless we reject all technology.

Researcher: But in reality, is your life affected by science?

Olivia: What do you mean?

Researcher: You flip a switch and a light goes on. Does that have anything to do with science?

Olivia: Yeah.

Researcher: OK, then you get in a motorcar and you come to school. Does that have anything to do with science?

Olivia: (Giggles) Yes.

Researcher: OK, let's say there's a flood and maybe your house gets flooded. Does that have anything to do with science?

Olivia: Um. I don't know. Probably.

Researcher: OK. Do you think that maybe if science wasn't so hard you would like it more?

Olivia: Yep. (Focus group interview, 25/06/10).

The rest of the conversation flowed into Olivia's attitude toward learning science, and is therefore included in Section 8.3. However, it should be noted that it appears as though her attitude toward science is closely related to her attitude toward learning science in school. The same appears true of Edward, although he reports to like them both. This comes as little surprise as it would seem likely that any learner would have a more positive attitude toward something that they perceive they are good at learning rather than poor at learning. While this correlation would not ensure causation in every case, it could be implied that for many students who spend much of their lives in school being evaluated on their learning, that their attitude toward those topics in which they find success will be more favorable than for those subjects they do not. Considering this, a more extensive discussion in the next section explores students' attitudes toward learning science using a permaculture approach.

To summarise, students' attitudes toward science were primarily gauged through their views of the relationship between science and environmental problems. During the intervention, science was presented as both cause of some environmental problems and as a potential solution to some. Data from the pre- and post-questionnaires, classroom observations and focus group interviews appear to suggest that most students recognized that the use of science could be blamed for causing many environmental problems currently facing the world. Likewise, many students also recognized that science and technology could be used to help solve environmental problems. However, it appears that the intervention may have resulted in more certainty in the case of the former and less certainty in the case of the latter. Uncertainty leading to reflection and questioning is a key outcome for scientific literacy, and in terms of transformative learning theory, it is a key step in transformation. Uncertainty, rather than representing confusion, could be representing critical reflection on the benefits and costs of science and technology. Classroom observation and interview data suggest a correlation between students' attitudes toward science and their attitudes toward learning science. This relationship is explored in the next section.

## 8.3 Students' Attitudes Toward Learning Science

As suggested above, young people – who spend a large portion of their lives in school – are likely to experience more enjoyment learning those subjects in which they experience academic achievement than those in which they do not (Pekrun, Goetz, Titz & Perry, 2002). While the reasons for each student's success or failure are numerous and not addressed extensively in this thesis, many authors argue that when pedagogies are experiential, relevant and student-centered, the learning process can become more enjoyable and more effective (Blumstein & Saylan, 2007; Mabie & Baker, 1996; Matthew, 2004; Ramsden, 1998;). More enjoyment in learning a topic may lead to greater effort and to a higher level of academic success. The result of this may be that students develop more positive feelings toward that topic in general. This potential correlation is explored below.

Similar to the data presented in Tables 8.1 and 8.2 above, data relating to students' attitudes toward learning science from the pre- and post-questionnaires appear to move in two directions. Data from the post-questionnaire indicate that most students "enjoyed learning science with a focus on the environment" (Post-questionnaire, 22/06/10) or were ambivalent about it as indicated in Table 8.3 below.

Table 8.3: Students' Responses to the Statement: "I enjoyed learning science with a focus on the environment."

| | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree | Mean | Standard Deviation |
|---|---|---|---|---|---|---|---|
| Post-Q | 0 | 1 | 7 | 7 | 1 | 3.5 | 0.70 |

*Note.* (5-point Likert-scale). N = 16

The student who disagreed, Olivia, did not attend the field trip to Eco-Hostel, which appears to have been the keystone learning experience for other students during the intervention. But even with her disagreement with the statement, the class mean – 3.5 on a 5-point scale – is well on the side of agreement with the statement.

However, other data from the pre- and post-questionnaires appear to tell a different story. When responding to the paired statements "I like learning science in school" and "I do not like learning science in school," there was a shift in the class mean from the former to the latter as shown in Table 8.4 below.

Table 8.4: Students' Enjoyment of Learning Science in School

| | Total Agree Statement A | Balanced Opinion | Total Agree Statement B | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Pre-questionnaire | 6 | 6 | 4 | 3.5 | 1.6 |
| Post-questionnaire | 5 | 5 | 6 | 4.1 | 1.7 |
| Change | -1 | -1 | +2 | Change towards agreement with B 0.6 | More variance in data 0.1 |

*Note.* Semantic differential statements: A "I like learning science in school" B "I do not like learning science in school." (7-point scale, where A is 1 and B is 7). N = 16

While the data in Tables 8.3 and 8.4 appears conflicted, it is important to note that the latter represents a general attitude toward learning science in school and the former represents students' response to a specific series of experiences of learning science with a focus on the environment. As described in Chapter 4, semantic differential is often employed to gauge participants' attitudes toward something in general. In this case it was students' attitudes toward learning science in school. Alternatively, a Likert-scale is often used when referring to specific learning experiences. In this case it was learning science with a focus on the environment. Taking a holistic view of the data surrounding the students' overall learning experience, it appears possible that some students could have identified "learning science with a focus on the environment" (Post-questionnaire, 22/06/10) with the field trips, which were always overtly environment-focused, whereas their general classroom experience was only periodically environment-focused. Or, potentially, students recognized experiential learning in the environment as environment-focused, but not bookwork as environment-focused, even though some of the bookwork was about ecology.

As presented in Sections 6.4, 6.5 and 7.2, there appear to be ample data from classroom observations and focus group interviews to support the students' upbeat responses in Table 8.3 regarding their enjoyment of learning science with a focus on the environment. Up to this point, however, there have been little data presented that would support the findings in Table 8.4: a slight shift in students' negative attitudes toward learning science in school, although such shifts are hard to interpret, particularly in small samples. In other data, Sections 6.6 and 7.3 addressed some students' critical responses to the teacher's note-taking requirements, but a number of those very students, including Scott, Darren and Tim, reported on both questionnaires to like learning science in school. Other students, such as Mary, complained about bookwork and reported not enjoying learning science in school. Given that the data presented in Table 8.3 (learning science with a focus on the environment) show a mean above neutral and data presented in Table 8.4 (learning science in school) show a mean below neutral, the question arises as to what was happening in this science class during the intervention that students may not have enjoyed. One possibility is bookwork.

### 8.3.1 *"Everyone objects against bookwork"*

Scott uttered the statement above in a focus group interview after the intervention (25/06/10). As described in Section 6.5, the teacher was new to a transformative approach to teaching and learning science and often resorted to transmissive pedagogies. Based on classroom observation, he served as chief instructor for the vast majority of class time. It is possible that in many cases students were responding to his traditional teaching style and way of relating to the students when presented with generic statements such as those in Table 8.4: "I like/do not like learning science in school." This possibility appears to be supported by data from classroom observations and focus group interviews. For instance, on 18 June 2010, I asked Scott what the class had done on the previous day when I was absent. He replied, "I can't remember. That means it was probably bookwork" (Conversation, 18/06/10). This came as little surprise to me as I had observed that the students spent considerable time copying information from the white board and data projector into their notebooks. Additionally, they spent a significant amount of class time copying questions and answers from the course book into their notebooks. The students appeared never to take the course books home with them. They were only used within the classroom (Classroom observations). During the focus group interviews, taking notes and copying questions and answers from the course book were identified by some students as the worst things they did in class during the intervention. Tim described it as "boring" (Focus group interview, 25/06/10), and Mary said, "You just kind of get sick of it" (Focus group interview, 25/06/10). Such transmissive pedagogies that do not necessarily engage students in science are likely to impact on their attitudes toward learning science.

In the classroom, I observed that the students spent a significant amount of class time writing - on some days over 50 percent of a class period (Classroom observations). On three days when the teacher was absent, the students spent the entire periods copying questions from their course books into their notebooks while a substitute teacher sat at the front of the classroom. Including these three days, I estimate that of the total hours students spent in the classroom, close to half were spent copying information from the white board, the data projector screen, or their course books into their notebooks (Classroom observations).

With a background in physics and not biology, it is possible that the teacher's comfort zone for teaching biology might have been to use a reductionist approach: "If you are learning about flowers in biology, you take them apart and you label all the bits" (Teacher interview, 26/07/10). But he did recognize the differences inherent in a permaculture approach to teaching biology. "With permaculture, you'd be thinking about how to grow the flowers. There's a big difference in that" (Teacher interview, 26/07/10). As described in Section 6.5, the teacher did not have a background in transformative learning or permaculture. As a result, it appeared as though on many occasions instead of taking on suggestions from the modified unit plans to facilitate experiential or student-centred lessons, he chose to stick with more transmissive pedagogies.

But learning science *does* require learning new words. During the focus group interviews, I probed the students' complaints.

Researcher: Now, what you said, Scott, about learning lots of vocabulary. Do you think you've been learning more science vocabulary than in previous science classes?

Scott: Umm… Probably, because normally we don't do definitions and stuff like that. We don't really do that much book work in science.

Researcher: So, last year, for instance, you didn't do as much bookwork. But were you learning new science vocabulary words?

Darren: I reckon we were a little bit.

Tim: Not as much as we were this year.

Darren: Not as much as this year.

Scott: We were doing hands-on stuff.

Darren: I still remember tons of stuff, which we did last year. I can't really remember that much this year because we all did book work and that's just boring.

Tim: Last year we did tons of experiments and stuff.

Darren: Hands-on work is a lot better.

Tim: Yeah, tons more awesome. (Focus group interview, 25/06/10)

Curiously, another focus group reported differently on their year 9 science learning experiences.

Ruby: We worked a lot out of textbooks in year 9.

Mary: Yeah. (Focus group interview, 25/06/10)

But then the girls' reported to also have had outdoor learning experiences.

Alison: We went to the outdoor classroom a lot of times.

Mary: Yeah we did a lot of outdoors stuff.

Alison: That's the year we did ecology.

Mary: We had Miss Smith (pseudonym) for ecology and stuff.

Ruby: Heaps of ecology that year, more than here.

Alison: And we went to the um… the peninsula.

Mary: The observatory.

Ruby: The observatory.

Alison: Yeah, that was fun.

Mary: That was cool. (Focus group interview, 25/06/10)

While Tim, Darren and Scott reported more bookwork in year 10 than in year 9, Ruby and Alison reported the opposite. But what they all appeared to agree on was more experiential coursework in year 9. These data may be important because the intervention described in this thesis took place during the first two terms of year 10. The pre-questionnaire was administered within the first month of the school year when students would have had little experience with their new science teacher. But the post-questionnaire was administered almost midway through term 2, when they would have had plenty of experience with the year 10 science teacher. Therefore, when answering questions about their science learning experiences, it is possible that the students' responses in the pre-questionnaire may have been influenced more by their year 9 science class, which many of them described as more experiential. As shown in Table 8.4, four students reported not to like learning science in school on the pre-questionnaire, but six reported not to like it on the post-questionnaire. This change occurred despite only one student reporting disagreement with the statement "I enjoyed learning science with a focus on the environment" on the post questionnaire (see Table 8.3). A possible explanation may be that they enjoyed those times in class when they perceived that they were learning science through environmental problem-solving and permaculture, but not enjoyed the overall experience of learning science during the intervention because of what many of them considered boring bookwork. Nonetheless, most students reported to recognize the relevance of their science learning, which may also have impacted on their attitudes toward learning science.

### 8.3.2 The Relevance of Science Learning

As shown in Tables 8.5 and 8.6 below, nearly all students agreed or had a neutral opinion that they understood "why the science topics covered in school are taught," and that their science classes have given them "a better understanding of the way the world works." There was essentially no change between the pre- and post-questionnaires.

Table 8.5: Students' Understanding of Why Science Topics Covered in School Are Taught

| | Total agree statement A | Balanced opinion | Total agree statement B | Mean | Standard deviation |
|---|---|---|---|---|---|
| Pre-questionnaire | 11 | 3 | 2 | 2.9 | 1.2 |
| Post-questionnaire | 12 | 3 | 1 | 2.7 | 1.0 |
| Change | +1 | 0 | -1 | Change towards agreement with A 0.2 | Less variance in data 0.2 |

*Note.* Semantic differential statements: A "I understand why the science topics covered in school are taught." B "I do not understand why the science topics covered in school are taught." (7-point scale, where A is 1 and B is 7). N = 16

Table 8.6: Students' Opinions about the Relationship between Science Classes They Have Attended and Their Understanding of the World Outside of a Science Classroom

| | Total Agree Statement A | Balanced Opinion | Total Agree Statement B | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Pre-questionnaire | 11 | 4 | 1 | 2.5 | 1.3 |
| Post-questionnaire | 11 | 4 | 1 | 2.5 | 1.2 |
| Change | 0 | 0 | 0 | No change | Less variance in data 0.1 |

*Note.* Semantic differential statements: A "Science classes I've been in have given me a better understanding of the way the world works." B "Science classes I've been in have not given me a better understanding of the way the world works." (7-point scale, where A is 1 and B is 7). N = 16

As described in Section 6.4, the teacher used newsbytes to emphasize the relevance of science to students and I used permaculture to do the same. Given that data in Tables 8.5 and 8.6 indicate no change in what students reported as their recognition of the relevance of science from the pre- to the post-questionnaire, two possibilities exist. One is that our overt efforts at making science relevant made no impact on students. The other is that their year 9 teacher had also emphasized the relevance of science – possibly through field studies and frequent trips to "the observatory" on "the peninsula" (Focus group interview, 25/06/10) – which had an impact on students that their year 10 teacher and I simply maintained. Given many students' reports of "awesome" hands-on work (Focus group interview, 25/06/10) in year 9, it is possible that the bar had been set fairly high and that the year 10 teacher and I simply maintained it. But had we not made such efforts to emphasize the relevance of science it is possible that students' responses shown in Tables 8.5 and 8.6 could have shifted toward statement B in both cases: not understanding why the science topics in school are taught, and not gaining greater understanding of how the world works through science class. Other than field trips, newsbytes and bookwork, what other factors could have affected students' attitudes toward learning science? Another possible factor is explored next.

### 8.3.3 Classroom Dynamics

While data appear to indicate that students' recognition of the relevance of science remained consistent through the intervention, there were a number of students – six of the 16 – who reported not enjoying learning science in school on the post-questionnaire (Table 8.4). As discussed in Section 8.2, Olivia was one of those students. On the pre-questionnaire (05/03/10) she reported a balanced opinion about her enjoyment of learning science in school, but on the post-questionnaire (22/06/10) she reported to strongly agree with the statement, "I do not like learning science in school." This represented a move from a ranking of four to a ranking of seven on a seven-point scale. When asked why she did not like science class during the focus group interview, she responded, "I liked science last year, but I don't anymore because of the teacher" (Focus group interview, 25/06/10). When asked if she thought that her feelings about the teacher affected how she felt about learning science, Olivia responded in the affirmative (Focus group interview, 25/06/10).

From classroom observations, the teacher interview, and student focus group interviews, it was apparent that all parties recognized that conflicts existed in the classroom. Some classroom observation data appear to confirm that certain students did not relate to the teacher or his teaching style. Emily, for instance, was asked to leave the science class mid-way through the intervention after a confrontation with the teacher on a day I was absent. While she remained at school, she did not return to science class.

Conflicts in the classroom appeared to affect different students to different degrees. While many students, such as Edward, reported no change in their positive attitudes toward learning science in school, others such as Olivia, Elaine and Heather reported a greater dislike of learning science in school on the post-questionnaire. There were times when Olivia, along with a number of other girls including Elaine, Heather and Emily, appeared to be annoyed or upset with the teacher (Classroom observations). Both Elaine's and Heather's responses on their like/dislike of learning science in school moved further toward dislike on the post-questionnaire. Elaine's attitude toward learning science moved from a six to a seven with the number seven circled many times on the post-questionnaire. Heather's ranking moved from a five to a six, but the number seven was circled and crossed off.

### 8.3.4 Section Summary

Findings from this study appear to indicate that some students developed a greater sense of the risks that can occur from the use of science and technology over the course of the intervention, but some may have become more cautious, uncertain, or discerning about their potential benefits. At the same time, students' self-reporting on their recognition of the relevance of their science learning in school did not change from a relatively high level of recognition of relevance between the questionnaires. For some students, it appears their attitudes toward science may have been influenced by their attitudes toward learning science, and those attitudes, for some, were affected by their attitude toward the teacher and some of his traditional pedagogies. Some students complained about bookwork, but still maintained an overall favorable opinion on learning science in school. Other students complained about the teacher and recorded a decreased enjoyment of learning science from the pre- to post-questionnaire. However, when it came to learning science in the context of the environment – which may have been interpreted by students to refer to the permaculture field trips – the feedback was more positive. These findings appear to divide the class into two groups regarding their attitudes toward learning science. One group was positive or neutral about learning science with a focus on the environment and positive or neutral about learning science in school. The other was positive or neutral about learning science with a focus on the environment and negative about learning science in school. The following section examines more in-depth the learning experiences of a pair of students, one of whom fits each of these descriptions.

## 8.4 Case Stories

As summarized above, it appears that students involved in this intervention can be grouped into broad two categories in terms of their attitudes toward various aspects of learning science. Although every learner is unique, the experiences of the learners in this science class appear to fall into a pair of basic story lines as exhibited below. The case stories in this section seek to illustrate two different science-learning experiences by profiling two individual learners and drawing on a wide range of data in an attempt to give an holistic perspective of each. The students were selected on the basis of the quality and quantity of available data.

The first case story, which follows Edward, tells the tale of a student who appears to like learning science in school, and demonstrates a good understanding of science. Edward reported to enjoy the environmental and permaculture approach to learning science, but no more so than his overall enjoyment of learning science in school (Post-questionnaire, 22/06/10). The second case story, which follows Natalie, tells the tale of a student who appears not to like learning science in school, and does not demonstrate a good understanding of science. However, Natalie – and most other students who fit her description – reported to enjoy the environmental and permaculture approach to learning science, but reported *not* to enjoy the general process of learning science in school (Post-questionnaire, 22/06/10). As stated above, every learner is unique, and while other students in the class may fall between these two on a Likert scale or in the teacher's marking book, certain aspects of their learning experiences and attitudes toward learning science may be represented by those of Edward and Natalie.

### *8.4.1 Edward*

Edward's story is included to represent a student who appears to engage with science on many levels. He reports to like learning science in school, appears to demonstrate an age-appropriate understanding of science (Classroom observations), and is likely to continue studying science beyond the compulsory years. On both questionnaires (05/03/10, 22/06/10) Edward strongly agreed with the statement, "I enjoy learning science in school." He was a regular contributor in science classes (Classroom observations) and demonstrated an understanding of a number of different science concepts during the focus group interview. In the following exchange with Olivia, he seized on a brief misstatement to make a science-based joke.

Edward: But we are self-sufficient now. We make…we've got our own water.

Olivia: You make your own water? How?

Edward: Two hydrogen particles and two oxygen particles and you smoosh them together. And you've got water.

Olivia: Weird.

Researcher: You do that in the kitchen or in the shed?

Edward: In the kitchen.

Olivia: Is that actually true?

Edward: That's how you make water. (Focus group interview, 25/06/10)

While he began to describe his family's roof-water catchment system, he was quickly able to switch gears and use his understanding of the atomic composition of water for a laugh. Although he was not quite accurate in the number of oxygen atoms, he was thinking in terms of the basic ingredients from which one would "make" their own water. Whether Olivia actually believed him is not considered here.

Edward appeared to be a confident science student at the start of the intervention, and appeared to make strides in science learning during the intervention. As seen in Table 8.7 below, his use of concept words, links and sustainable propositions outpaced the class mean on both questionnaires.

Table 8.7: Edward's pre- and post-concept map scores compared with class means

| Student | # CW | % CW | # links | # crosslinks | # SPs | % SPs | Central Node | Quality Score |
|---|---|---|---|---|---|---|---|---|
| Edward Pre-Q | 16 | 100 | 17 | 0 | 4 | 24 | | 1 |
| Class Mean Pre-Q | 11.5 | 71.7 | 13.3 | 0.4 | 1.8 | 13.5 | | 0.73 |
| Edward Post-Q | 15 | 94 | 21* | 3 | 7 | 35** | Food/farms | 1 |
| Class Mean Post-Q | 12.1 | 75.5 | 14.7* | 1.5 | 2.2 | 16.7** | | 0.93 |

*Note.* * One added for lack of starting node. N

** Percentage does not include the extra point for starting node. N – 1

While it appears that Edward may have forgotten to use one concept word on the post-questionnaire, he still managed to make more overall links (17 to 21). Additionally, he created three crosslinks on the post-map where he had none on the pre-map. These increases may represent nothing more than Edward's improved concept mapping skills, but they could – especially the number of crosslinks – also represent advances in systems thinking as discussed in Section 7.5. This suggestion appears to be supported by Edward's improved SOLO Taxonomy score from 3 to 4.33 between the two questionnaires.

Given the increased number of sustainable propositions (4 to 7) Edward was able to form between the two concept maps, it is surprising that there was no change to his quality map score of 1. This is because the Concept Map Quality Scoring Rubric and Protocol requires the recognition of multiple aspects of sustainable agriculture to raise a quality score from 1 to 2. Edward simply included more sustainable propositions within the same aspects of sustainability. This may indicate depth of learning about sustainability but not breadth.

Elsewhere, however, Edward appears to have made advances in both depth and breadth. As described in Chapter 7, data suggests that he made advances in science learning

(Section 7.2) and recognizing interrelationships (Section 7.5). For instance, as described in Section 7.2.2.2, there appears to have been a change in Edward's understanding of the use of nitrogen on farms. He often volunteered correct answers when the teacher posed science questions to the class (Classroom observations), and demonstrated a good understanding of climate change in the focus group interview (25/06/10).

Interestingly, Edward did not use the term water on his post-map given that he reported his family collects their own water off the roof (Focus group interview, 25/06/10), and that the teacher recalled his interest in the use of swales to manage runoff and increase infiltration at Eco-Hostel (Teacher interview, 26/07/10). Edward's uses of the term water in his concept map on the pre-questionnaire (05/03/10) were straightforward: "water helps grow gardens"; "water helps grow plants"; "water drunk by animals." But he did not use these simple propositions on the post-map (Post-questionnaire, 22/06/10). Perhaps he was in the process of reconsidering the role of water in sustainable agriculture at the time of the post-questionnaire and had not yet come to a new understanding. Like a swale, Edward may have absorbed new information and was storing it temporarily. It simply had not resurfaced yet as a spring. The use of an insightful sustainable proposition including water would have boosted his quality score to 2.

Regarding Edward's attitude about the different approach to teaching and learning science in the intervention, he agreed (not strongly) with the statement "I enjoyed learning science with a focus on the environment" (Post-questionnaire, 22/06/10). He invited his father to Eco-Hostel for part of the field trip (Observation, 04/05/10), and named it as the most memorable aspect of the intervention (Focus group interview, 25/06/10). For a previously engaged science student like Edward, the different approach to the teaching and learning science may not have been significant enough to change his already positive attitude toward learning science, or to add new relevance to the science curriculum. Edward showed no change in his strong agreement with the statement: "I understand why the science topics covered in school are taught." Both his pre- (05/03/10) and post-questionnaires (22/06/10) indicated that he felt confident with the existing context of his science learning. While the emphasis on using science for local environmental problem-solving may have appeared relevant to him, the data suggest no more relevant than science involving test tubes and Bunsen burners in a laboratory. For him – and other similar students – it may have been a case of enjoying school science enough to see no need for change. As discussed below, this does not appear to be the case for Natalie and others like her.

As proposed above, Edward's story is meant to represent that of an academically capable science student who liked learning science before the intervention and liked learning science after the intervention. In addition, much of the data discussed above indicate that Edward learned about science and sustainability, made strides in recognizing interconnections, and that some new sustainable ideas resonated with him, particularly swales. However, Edward did not report to be inspired to act on his new learning. To the statement, "This science unit has motivated me to take actions for the environment," Edward reported neither to agree nor disagree (Post-questionnaire, 22/06/10). It is possible that his family already takes significant actions for the environment as indicated by their use of runoff water from their roof (Focus group interview, 25/06/10), his father's attendance at the Eco-Hostel field trip, and his stated intention to participate in Earth Hour (Classroom observation, 26/03/10). Or, perhaps, these new ideas have soaked in and are being stored until they will re-emerge. Could it be that Edward is learning like a swale?

To many people, a swale may not appear to be particularly intriguing or significant. After all, it is just a ridge of earth. But that is part of the beauty of swales. They are humble. They are patient. Most of what goes on with swales is below the surface, specifically the infiltration and percolation of storm water into the ground. Swales represent both hidden function and time-delay. Their benefits appear in their immediate surroundings as well as further down the watershed after weeks, months or even years. Swales are literal and figurative banks. The ground is banked up into low berms, and water is banked in the ground instead of running off. The subtlety and patience of swales could easily be overlooked in a world of bigger, better, faster, stronger. I submit that it takes a keen observer – especially at the age of 14 – to recognize their significance. Why had the swales at Eco-Hostel "struck a chord" (Teacher interview, 26/07/10) with Edward?

I also suggest that recognizing the significance of swales may indicate an affinity for systems thinking. Systems thinking is four-dimensional. It includes the recognition of oscillations, delays and rates of change. Swales require us to see the interconnections between time and space, near and far. I would also argue that systems thinking inspires caution, and that swales are the embodiment of the precautionary principle. They embody what permaculturists call "small and slow solutions" (Holmgren, 2002, p. 181).

But what of small and slow learning: learning that percolates, where information is absorbed and stored in learners, and released (used) at later times? In some cases, the water table may be so low that it takes a long time to replenish it. In other cases, a higher water table needs simply to be topped off for a spring to gush forth. While Edward seems to have had a high water table before the intervention, Natalie appears to have had a low one. What is below the surface cannot be seen, but when a tipping point comes for a learner, like a spring breaching the Earth's surface, it is easy to recognize. Some teachers call this the 'light bulb moment,' and the data suggest that Edward had some of them. If enough light bulb moments are strung together, it can be described as transformative learning. As swales can help to improve watershed health and transform desertified landscapes back to greenery, information – put to the right use by the human mind – can do the same. Permaculture seeks to do just that. It translates learning and knowledge into earthworks that regenerate landscapes and contribute to a more sustainable future. Swales and their potential lessons – both literal and figurative – are discussed further in Chapter 9.

### *8.4.2 Natalie*

As introduced above, Natalie's story is included to represent another type of science student: one who indicated to not normally enjoy learning science in school but reported positively about learning science with an emphasis on the environment. Natalie was selected for this section because among the four students (all girls) who reported not to like learning science in school on both questionnaires, she was the only one not to report a *greater* dislike on the latter. On both questionnaires she circled number 5 on a 7-point scale on the side of agreement with the statement "I do not like learning science in school." While less extensive than Olivia's data, Natalie's data appear to have the potential to be less influenced by a conflict with the teacher.

Of the six students (including Natalie) who reported not liking learning science in school on the post-questionnaire (22/06/10), five (including Natalie) agreed or were neutral about the statement “I enjoyed learning science with a focus on the environment” (22/06/10). (The sixth student, Olivia, disagreed with this statement. But, as noted, she did not attend the field trip to Eco-Hostel and she had conflicting views with the teacher as described in Section 8.3.) Put simply, this cohort – represented by Natalie – reported greater enjoyment of learning science with a focus on the environment than their overall enjoyment of learning science in school. For instance, Natalie agreed with the statement, “I do not like learning science in school,” on both questionnaires, but reported on the post-questionnaire to strongly agree with the statement “I enjoyed learning science with a focus on the environment” (22/06/10).

While Natalie may have enjoyed a different way of learning science, she appears to have missed out on learning one of the main emphases of the intervention: interconnectedness. On the post-questionnaire she reported neither to agree nor disagree with the statement, “I learned about interconnections in nature and human communities” (22/06/10). While her neutrality could mean a number of different things, what is relevant at the moment is that her lack of agreement with the statement appears to be consistent with data from her SOLO Taxonomy scores and concept maps. In the case of the former, Natalie’s SOLO score did not change from the lowest possible mark between the pre- and post-questionnaires. On the pre-questionnaire Natalie appeared to confirm her SOLO score of zero by writing after the last question: “I don’t understand this test. It’s too hard” (05/03/10). On the post-SOLO Taxonomy section she wrote, “What, this is crazy!” (22/06/10). In the case of concept mapping, Natalie increased the number of links by two between her pre- and post-concept maps as shown in Table 8.8 below, but only in direct relationships to her increased number of concept words. She did not add any crosslinks, which may be a better indicator of systems thinking.

Table 8.8: Natalie's pre- and post-concept map scores compared with class means

| Student | # CW | % CW | # links | # crosslinks | # SPs | % SPs | Central Node | Quality Score |
|---|---|---|---|---|---|---|---|---|
| Natalie Pre-Q | 6 | 38 | 6 | 0 | 0 | 0 | | 0 |
| Class Mean Pre-Q | 11.5 | 71.7 | 13.3 | 0.4 | 1.8 | 13.5 | | 0.73 |
| Natalie Post-Q | 8 | 50 | 8* | 0 | 1 | 14** | Plants | 1 |
| Class Mean Post-Q | 12.1 | 75.5 | 14.7* | 1.5 | 2.2 | 16.7** | | 0.93 |

*Note.* * One added for lack of starting node. N

** Percentage does not include the extra point for starting node. N – 1

While no evidence suggests she made gains in recognizing interrelationships, some data in the table above indicate that Natalie did learn about science and sustainability during the intervention. Her use of concept words increased from six to eight and her quality score increased from zero to one. The improved quality score resulted from her inclusion of one sustainable proposition on her post-concept map (22/06/10): "food can be organic." Although Natalie's relationship to learning science in school appears to be vastly different from Edward's, there are some indications that Natalie is also learning like a swale: taking in new information and storing it for later use. For her, as stipulated at the end Section 8.4.1, it may be a case of a lower water table that will take longer to recharge.

It may be argued that Natalie's dislike of learning science in school is related to her academic struggle with it and potential questions she may have about why she is being asked to learn certain things in science class. On the pre-questionnaire (05/03/10), she reported a neutral position between the statements "I understand why the science topics covered in school are taught" and "I do not understand why the science topics covered in school are taught." But on the post-questionnaire (22/06/10), she shifted her opinion toward slight agreement with the former. When coupled with her strongly favorable response to "learning science with a focus on the environment" (Post-questionnaire, 22/06/10), it is possible that learning science in the context of environmental problem-solving through permaculture helped Natalie understand a little more about why she was being asked to learn the science topics that fell within the scope of the intervention. Her reported enjoyment of learning science with a focus on the environment and greater understanding of the context of science learning may account for her strong agreement with the statement: “This science unit has motivated me to take actions for the environment” (Post-questionnaire, 22/06/10).

What, exactly, those actions may be are unknown. While Natalie reported on the pre-questionnaire, “I don’t litter, try not to use plastic bags” (05/03/10) when asked to give examples of actions she takes for the environment, she left that section blank on the post-questionnaire. Could it be that in this case too, Natalie is processing her experience like a swale? The data suggests she has absorbed some science learning, and increased her enjoyment of learning, and motivation to take actions for the environment. It may be, then, just a matter of time before these percolate to the surface in the form of new actions for the environment? While these questions are addressed in Chapter 9, one final link back to Chapter 7 is in order.

In Section 7.4 I offered a possible explanation for the slight shift away from students reporting that they take actions for the environment between the pre- and post-questionnaires. Natalie falls into this category, as despite her strong agreement with feeling motivated to take actions for the environment (Post-questionnaire, 22/06/10), her self-assessment on her personal actions dropped from the pre- to post-questionnaires. One possible explanation for this change discussed in Section 7.5 was that with a new, broadened view of ecological problems and possibilities, some students might have viewed their own actions with a more discriminating eye. When set against the actions being taken at Eco-Hostel, for instance, they may value their contributions less, although their behaviors may have remained the same, or possibly even improved. This discussion is continued in Section 9.2.2, after a summary of this chapter and an introduction to Chapter 9.

## 8.5 Chapter Summary

This chapter explored students’ attitudes toward science and toward learning science in school. It did this for the entire class in Sections 8.2 and 8.3 using data from the questionnaires, classroom observations and student focus group interviews. Section 8.4 profiled two students who appeared to represent many other students' attitudes and science learning experiences.

Students' attitudes toward science were primarily framed within the contexts of environmental problems and potential solutions. Data from the pre- and post-questionnaires, classroom observations and focus group interviews appear to suggest that most students recognized that the use of science has caused many environmental problems. But many students also appeared to recognize the roles science and technology can play to help solve environmental problems. However, two examples of science and technology causing environmental problems that were studied during the term – the Deepwater Horizon accident and genetic engineering of commercial seed – appeared to be more impactful on most students than some of the permaculture examples of applied science that were demonstrated to help solve environmental problems.

A broad set of data appear to indicate that some students' attitudes toward science were influenced by their attitudes toward learning science. Students' attitudes toward learning science appear to be influenced by confidence with the subject, the relevance of the subject, the context of the subject, and the teacher's classroom practices. The data appears to have presented students' perceptions of two parallel science-learning experiences during the intervention. One of those experiences involved field trips and more of a transformative approach to teaching and learning, and the other involved bookwork and a more transmissive approach. Data from the questionnaires, focus group interviews and classroom observations appear to indicate greater student satisfaction with the former and less with the latter.

The parallel science-learning experiences described above appeared to influence a divide in the class into two groups regarding their attitudes toward learning science. One group was positive or neutral about learning science with a focus on the environment and positive or neutral about learning science in school. The other group was positive or neutral about learning science with a focus on the environment and negative about learning science in school. Section 8.4 examined the learning experiences of one student, Edward, who fitted the former description and one student, Natalie, who fitted the latter.

The key difference regarding students' attitudes toward learning science – the main focus of this chapter - between the two is that Natalie reported a higher level of enjoyment learning science with a focus on the environment than her general enjoyment of learning science in school. She also reported that the science learning during the intervention had motivated her to take actions for the environment. Given each case story and the overall aims of this inquiry, it appears possible that previously under-engaged science students such as Natalie may have enjoyed and been inspired by this different approach to the teaching and learning of science, while previously engaged students such as Edward appeared to enjoy it and learn from it, but may have been less affected by it.

When I was a young teacher a colleague once told me, "The cream will always rise to the top. Where we need to work is with the skim milk." Regardless of my literal disdain for skim (trim) milk, I hold great regard for science students like Natalie. The education system does not appear to have served her or the planet. Ecological illiteracy costs individuals, society and all life on Earth. For students with low ecological and scientific literacy who do not enjoy learning science in school, it appears that a permaculture approach to science can help affect their attitude toward learning science when it includes a focus on the environment that is local, relevant and solution-oriented.

Cultivating ecological literacy is a complex and variable process. But within the confines of a science classroom it appears that the most basic prerequisite is that students enjoy learning science. Enjoyment of learning may lead to engagement with the subject and further in-depth study. Relevance and motivation may lead to the active use of science in day-to-day life. Improved scientific literacy may lead to increased ecological literacy. And then, as the teacher was fond of saying, "We are using science to save the planet!"

So why is that not happening already? What is the disconnect? How can we fix it? What does this inquiry have to contribute to the field? These questions are discussed in Chapter 9.

# CHAPTER NINE - DISCUSSION, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

## 9.1 Chapter Outline and Introduction

Although environmental education (EE) has been around for half a century, in many countries, including New Zealand, it remains difficult to incorporate EE into the mainstream of education. This is particularly true at the secondary level where compartmentalization and a strong subject subculture works against holistic approaches to sustainability education, and national assessments put pressure on teachers to deliver only that information on which they think students will be tested.

This thesis investigated a novel approach to including environmental education for sustainability (EEfS) at the secondary level by also addressing another challenge: increasing attrition rates from science beyond the compulsory years. This type of approach to problem-solving – feeding two birds with one seed – is central to the ecological design system known as permaculture. Although permaculture is one of many ecological design systems, it is one of the oldest and most widely practiced (Holmgren, 2002), and some authors argue it is the most comprehensive (Morrow, 2006). As described in Section 3.4, permaculture was used on multiple levels throughout this inquiry. The aim was not to teach permaculture to students, but to use permaculture thinking to design an intervention that would improve students' ecological literacy. At the same time, the components of ecological literacy – scientific and ecological knowledge, systems thinking skills, an attitude of care for the environment, and the tendency to take actions for the environment – are embodied by practicing permaculturists, making them ideal candidates to serve as more knowledgeable others (MKO) and examples of citizen scientists.

The aim of a permaculture approach to junior secondary science is to engage students in science learning by making it more experiential, local, relevant and solution-oriented while nurturing systems thinking skills and exposing students to examples of scientifically-based sustainable practices. Whether the students ever utter the word permaculture is less important than the ecological habits of mind it is hoped they would gain as a result of this type of approach to teaching and learning. Those ecological habits of mind are embodied by the concept of ecological literacy, at the heart of which lies the ability to recognize interconnections, as well as both an appreciation for scientifically-based ecological limits to the biosphere, and a hopeful appreciation for the scientifically-based possibilities of ecological design.

A permaculture approach to teaching and learning is not limited to science, but could potentially be applied to any learning area of *The New Zealand Curriculum* (Ministry of Education, 2007). But as a new strategy for teaching and learning that has yet to be researched fully, it appears most appropriate to apply this science-based design system to the science learning area. The decision to conduct this research in a science classroom represents a key component of permaculture: designing around the available resources of a system while keeping in mind potential limits and possibilities. In the case of the intervention design described in Chapter 5, the challenge was to design around pedagogical (rather than ecological) limits and possibilities. The intervention design, along with the literature review, addressed research sub-question 1: What are the characteristics of a permaculture approach to junior secondary science? This question is largely theoretical, and leans more toward pedagogical possibilities than pedagogical limits, although realistic limits on a teacher's time and abilities were considered.

But theoretical limits and possibilities (what's on paper) do not always match what is found through research or real world experience. For example, a permaculture landscape design may recommend certain plants in certain positions on a property and recommend against including other plants due to climatic conditions. But experience may find that the plan was "wrong" because of unexpected micro-climates on the property or changing weather patterns. The same can be said of curriculum plans. What is on paper may not necessarily succeed in classrooms because of the unique character of a school, teacher or community, or shifts in social, cultural or political attitudes over time. It is the role of research to explore what is possible and what those possibilities can lead to.

Permaculturists are known for pushing the boundaries of organic food production, land restoration, eco-home design and construction, renewable energy technology, local currencies and alternative banking systems (Holmgren, 2002). They are inspired by possibilities but refine their designs through the realization of limits. The goal in all cases is to use the greatest possible understandings to create the most robust, sustainable systems. This inquiry is no different. The system in this case is one for providing high quality EEfS in a place where it struggles.

The robustness of this system was evaluated through data collection seeking to address the research question, and particularly sub-questions 2, 3 and 4. Findings for each of those questions were presented in Chapters 6, 7 and 8. This chapter presents a discussion of those findings, as well as conclusions, implications, limitations and recommendations, after a brief discussion of research sub-question 1.

## 9.2 Discussion

### *9.2.1 What are the characteristics of a permaculture approach to junior secondary science?*

Permaculture is a form of ecological design (Holmgren, 2002: Mollison & Holmgren, 1978; Mollison, 1988). Like other eco-design systems, it is *holistic* and *adaptive*. Originally developed to address sustainable agriculture (Mollison & Holmgren, 1978), its holism and adaptability have allowed permaculture design principles to be applied to many human systems unrelated to food production (Holmgren, 2002). In this case, holism and adaptability are characteristics of a permaculture approach to science education. An example of holistic design in this case was the use of ecological design thinking to design learning experiences to promote certain habits of mind associated with ecological design thinking, as well as other components of ecological literacy. While a review of the literature did not reveal similar studies involving permaculture, this characteristic of a permaculture approach to science education is similar to what Holbrook and Rannikmae (2009) argue is the best way to teach scientific literacy: 'education through science' instead of 'science through education.' On one level, the present inquiry can be considered 'science education through permaculture' rather than 'permaculture through science education.'

Another example of holistic design in this case was looking at the science units provided by the teacher and re-ordering them to align with transformative learning theory (Mezirow, 2000). An example of adaptive design was remaining open to teachable moments, which, in this case, turned out to be the Deepwater Horizon accident in the

Gulf of Mexico. After the first newsbyte on the disaster, the teacher told me after class that he thought the students showed keen interest in the story and that we should follow it up by focusing on the science involved.

To practice permaculture is to take stock of available resources, and design for the limits and possibilities of a given system, while, on occasion, testing the boundaries. Traditionally, permaculture focused on ecological limits and possibilities because it was first used to design biological systems considered *cultivated ecologies* (Mollison, 1991). As applied to the teaching and learning of science in this study, permaculture was used in an attempt to create a *cultivated learning ecology*, the characteristics of which were: a permaculturally designed science curriculum; science-based permaculture techniques; permaculture practitioners as MKO; field trips to permaculture properties; and, the transformative nature of permaculture. These five aspects of permaculture were developed through a literature review, along with eight pedagogical practices (Table 5.1) that are recognized as central to promoting ecological literacy, scientific literacy or transformative learning. This section discusses a permaculturally-designed science curriculum by providing examples from the revised unit plans that demonstrate the application of permaculture principles, although – as described in Chapters 3 and 5 – the principles themselves were never explicitly applied to the design of the intervention or the teaching and learning of science. Despite this, the following discussion should demonstrate that they were applied implicitly.

Two design principles that support holism and adaptability can be described as *redundancy* and *multiple-functions* (Mollison, 1988; 1991; Nuttall & Millington, 2008). In other words, each element of a system should serve many functions, and each function of a system should be served my many elements. Combined, these principles support another principle: *increase diversity to increase stability* (Mollison, 1988; 1991; Nuttall & Millington, 2008). In a permaculture approach for junior secondary science, a wide diversity of learning activities were suggested in the revised unit plans, not with the expectation that the teacher would choose to use all of them, but that he would choose those that best suited him and his students. At the same time, many of the proposed learning activities could support a number of the key pedagogical principles. For example, a field trip to a permaculture property could contribute to: making science more relevant to students; highlighting the local application of science; engaging students in experiential learning; and, emphasizing interrelationships. As well, each of these key principles could be supported by different learning activities. For example, watching a science newsbyte or a video clip could potentially help make science appear more relevant to students as much as or even more so than a field trip.

Another pair of design principles that support holism and adaptability is: *work with nature not against it*; and, *see solutions, not problems* (Mollison, 1988; 1991; Nuttall & Millington, 2008). These principles were applied to a permaculture approach for junior secondary science by looking at two problems in education, seeing one solution, and then working within the existing system (Ministry of Education, 2007) to facilitate change. The central argument to this thesis is that both science education and EEfS can be improved at the junior secondary level by thoughtfully combining the two, and that *The New Zealand Curriculum* (Ministry of Education, 2007) provides the structure and freedom to do so.

These principles are supported by another three principles: *cooperation, not competition*; *design to accelerate succession and evolution*; and, *make the least change for the most effect* (Mollison, 1988; 1991; Nuttall & Millington, 2008). As discussed above, the intervention was designed to cooperate with the existing national curriculum, and it will come as no surprise that my role as co-creator with the teacher was one of cooperation, not competition. The next two design principles may appear paradoxical when placed side by side as above. How does one accelerate change by making the least change? In this case, a less-is-more approach was taken with the teacher by making the intervention suggestive instead of prescriptive. A more prescriptive approach is likely to be judged unpalatable by many New Zealand teachers who consider EEfS an add-on to an already over-crowded curriculum (Bolstad et al., 2008; Chapman & Eames, 2007; Eames et al., 2008).

Finally, two more permaculture principles were applied with special sensitivity to this case study: *relative location*; and, *promote self-reliance* (Mollison, 1988; 1991; Nuttall & Millington, 2008). As described above, a permaculturist designs for the limits and possibilities of a given system. Every teacher is different, every school is different, and every community is different. A number of the suggested learning activities in the revised unit plans were based on field trips to those permaculture properties closest to the school. Not only would these rely on the least investment of time and petrol, but they could potentially also increase the probability that the teacher would re-visit them with future classes. A cultivated permaculture learning ecology is not limited to student learning. While it may help students increase their content knowledge, it may also help teachers increase their pedagogical content knowledge (PCK). Authors have argued for nearly a century that pedagogy is as important as content (Dewey, 1916; Freire, 1993; Orr, 1992; Whitehead, 1967). Authors have also argued that EE PCK can help science teachers engage students in science learning that is more relevant, authentic and experiential (Bencze & Hodson, 1999; Gough, 2002; Jensen & Schnack, 2006; Steele, 2011). My position as a former science teacher, permaculture designer, curriculum planner, and education researcher is relatively unusual in the world. Given these skills, it would appear that a meaningful way for me to contribute to sustainability on the planet is to cultivate confidence in science teachers' EEfS PCK.

But cultivation and design signal intent, not accomplishment. In gardens, to cultivate is to prepare the soil to promote plant growth. To cultivate learning is to make the grounds for learning fertile. Permaculture thinking can be used in both cases, but the levels of success are ultimately realized by the system, not the designer. Observation and research can help determine the extent to which design and cultivation influence plants and learners. Findings from this inquiry indicate that a permaculture approach to junior secondary science may: have a positive impact on the teaching and learning of science: enhance students' ecological literacy; and, improve some students' attitudes toward learning science in school. A discussion of each of these possibilities takes place below within the context of research sub-questions 2, 3 and 4.

### *9.2.2 How does a permaculture approach to junior secondary science impact on the teaching and learning of science?*

As described in the previous section, a permaculture approach to junior secondary science is holistic and adaptive. The intervention design included a broad set of suggestions for points of emphasis and learning activities, some of which the teacher implemented. Of those approaches to teaching and learning that were implemented, findings indicate that the most impactful may have been: those relating to big picture thinking; those promoting the relevance of science; and, those emphasizing engagement with science. A discussion of each takes place in the following sub-sections.

#### *9.2.2.1 Big Picture Thinking*

Big picture thinking can be interpreted in many ways. This discussion is limited to two interpretations, which I refer to as linear and lateral. In reference to teaching and learning, linear big picture thinking can be represented by the order in which material in presented to students, and lateral big picture thinking can be represented by emphasizing interconnectedness. In this inquiry, linear big picture thinking involved reordering the three science units to align with transformative learning theory (Section 3.2). Transformative learning is said to be a ten-step process (Mezirow, 1990; 2000), which I distilled down to three fundamental stages in Section 3.2.2: 1) a disorienting dilemma (Mezirow, 2000) or cognitive crisis (O'Sullivan, 2002); 2) looking for and trying out alternative ways of knowing; 3) and, ultimately, changing one's frame of reference by adopting an alternative worldview. I suggest the first two stages may be facilitated by an educator, but the final stage can only be completed by a learner. Therefore, a discussion of the first two stages belongs in this section (9.2.2) while a discussion of the final stage takes place in the following section (9.2.3) on students' ecological literacy.

Because of the disorienting and critical nature of transformative learning, Roberts (1996) warns that facilitating transformative learning experiences in adults may cause adverse effects and could put them off further learning opportunities. An apparent corollary to this study would be the potential for putting students off further science study. But findings suggest that students may have felt less overwhelmed (Section 6.2.2) and more empowered (Section 6.7 and 7.2.1.2), or at least indifferent (Section 7.4), through the intervention that followed a three-stage transformative chronology from a big picture environmental problem – climate change – to small-scale, science-based, local solutions based on permaculture practices. Some students reported that they enjoyed learning science with a focus on the environment more than their usual enjoyment of learning science in school. At the same time, however, some students appear to have expressed greater caution or uncertainty about the use of science and technology. This may have resulted from an unplanned disorienting dilemma – the Deepwater Horizon accident – that occurred midway through the intervention and was the subject of four science newsbytes within three weeks in the class. The caution or uncertainty, however, would be expected when considering the full 10 stages of transformative learning, which include the critical assessment of assumptions (Mezirow, 2000). These findings appear to be supported by the recommendations of some authors to prepare students to critically consider media reports involving science (Korpan, 2009).

As described in the previous section, taking the time to integrate this ecological disaster into lessons is an example of the holistic and adaptive qualities of the intervention design. Pre-planning for something like this is impossible, but allowing for its inclusion, in this case, may have impacted students by: highlighting science and technology in a major news story; revealing limits to science and technology; and, eliciting emotional responses in students by showing images of oiled wildlife. And while the students were responding to the issue, the teacher appeared to respond to the students' responses by revisiting the issue a number of times during different class sessions. Impacts on the teacher's big picture thinking appear to have taken both linear and lateral forms. First, he may have recognized the potential learning interest sparked by a disorienting dilemma such as the Deepwater Horizon accident. Second, he may have recognized how this dramatic news story could be integrated into the topic of study at the time – ecology – rather than being just a passing nod to science in the news. Making links from media reports to immediate classroom learning could help promote relevance, which Korpan (2009) suggests be considered when choosing news stories. Relevance is discussed further in the following section.

Further evidence for the above claims may be found in the words of the teacher himself, as he commented in the final interview on the order of the science units: "It's logical. I do think that was better than going in and teaching about seed germination at the start. That's just basically science-learning names. But this wasn't. This was a whole crazy interwoven web of science: a good idea" (Teacher interview, 26/07/10). While his first sentences express his approval for the linear approach to big picture thinking, the last sentence commends the lateral approach.

Systems thinking is central to ecological literacy (Capra, 2008; Goleman, Bennett, & Barlow, 2012; Orr, 1992; Stone & Barlow, 2005), permaculture (Holmgren, 2002; Mollison, 1988, 1991; Morrow, 2006), and sustainable education (Sterling, 2001, 2003). As described in Section 7.5, the teacher and I employed different strategies for emphasizing interconnectedness, but it was our combined efforts that were the first thing to come to his mind during the final interview session when I asked what stood out for him from the entire intervention. As discussed in Section 6.3, this appears to indicate that a systems approach to teaching and learning that emphasizes interconnectedness – although new to him – was impactful enough to earn top billing for him in our final conversation. One possible result of this impact could have been an expansion of the teacher's PCK, which may prove significant because the literature indicates that teachers may avoid or de-emphasize topics for which they have low PCK (Cutter-Mackenzie & Smith, 2003; Grossman, 1995). As discussed in Sections 6.2 and 6.3The teacher described the linear and lateral big picture approaches to teaching and learning as "logical" and "a good idea" (Teacher interview, 26/07/10). As such, it appears possible that he would continue their use in the future as part of his expanded PCK. If this proved to be the case, the teacher would have developed a level of *self-reliance* for using a more *diverse* set of pedagogies, as suggested by the corresponding permaculture design principles discussed in the previous section. In this way, teacher PCK is transformed from a problem for sustainability education to the *solution* for sustainability and science education: this fits the permaculture principle of *multiple functions.*

Impacts on the teacher's PCK regarding big picture thinking (transformative learning and systems thinking) appear critical to the successful marriage of EEfS and junior secondary science, as the literature indicates the success of any EE program relies on the teacher (Cutter-Mackenzie & Smith, 2003; Robottom, Malone & Walker, 2000). Regarding impacts on students, some said in focus group interviews that they felt they had become better systems thinkers. Findings from the pre- and post-questionnaires suggest this may have been the case for some. (This discussion is continued in Section 9.2.3.) However, the teacher said he thought the concept maps were challenging for some of the students because they were not used to them. Capra (2008) suggests this system thinking is a challenge for older students to pick up because education, and especially science education, has not traditionally emphasized interconnections, and so they are not used to thinking in terms of relationships.

From a systems perspective, one cannot discern between the impacts of the linear and lateral approaches to big picture thinking on the teacher or the students. But between the biggest picture and the smallest detail lay many intermediate layers, sets and sub-sets. In qualitative research, clusters of data emerge such as those that form the three topics of discussion in this section. And while those data clusters influence and are influenced by one another, at some point a line of distinction must be drawn for the sake of intellectual digestability. As a means of transitioning from this point of discussion to the next, I provide a series of links that connect the two. This transition acknowledges the relationship between one data cluster suggesting the impacts of a big picture approach, and another data cluster suggesting the importance of relevance in science teaching and learning.

#### *9.2.2.2 Promoting Relevance*

Relating big picture, global issues to small-scale local solutions, or making connections between various causes and effects, can promote systems thinking skills and help students to 'connect the dots.' Promoting more holistic perspectives can support a greater appreciation of the relevance of science by helping students recognize how science, technology and environmental problems relate to them, their families and communities. Relationship implies relevance. Including popular media reports can help promote the relevance of science (Korpan, 2009), and practicing permaculturists can help promote the relevance of science, and encourage systems thinking by providing a local, yet holistic context for science learning. Bull, Joyce and Hipkins (2007) suggest that contexts and content in science education form an essential pair. As presented in Sections 6.4, 6.5 and 6.6, findings from this study bear that out. The teacher and most students reported to appreciate the environmental and permaculture contexts involved in the intervention.

Literature on science education indicates that relevance can mean importance, usefulness or meaningfulness for learners (Levitt, 2001), and that it can influence students' perceptions of whether certain learning satisfies their personal or professional needs or goals (Keller, 1983). I use relevance as an umbrella term under which fall a number of key pedagogical principles of the intervention (Table 5.1) alongside the key principle of making science relevant: the local application of science; experiential learning opportunities; and, as described above, emphasizing interrelationships. Aikenhead (2010) identifies the importance of relevant content, processes, and contexts. All of these pedagogies have the potential to reinforce importance, usefulness or meaningfulness in learners. The teacher, himself, appeared to recognize a link between some of the literature on science education and the intervention, saying, "I suppose that's a big thing at the moment – trying to make it relevant. And that's what you were saying about this curriculum. Making it relevant to the students" (Teacher interview, 26/07/10). The literature indicates that relevance is important to both promoting scientific literacy (Bell et al., 1995; Holbrook & Rannikmae, 2009; Keller, 1983; Matthews, 2004) and ecological literacy (Balgopal & Wallace, 2009; Goleman et al., 2012; Orr, 1992). Findings from this study suggest that relevance is an impactful aspect of a permaculture approach to science education, and that relevance can take many forms. Although relevance appeared to be a key finding from teacher and student interview data, students self-reporting on their recognition of the relevance of their science learning in school did not change from a relatively high level between the questionnaires. One possible explanation is that because the students' year 9 teacher had embraced a great deal of field work and local ecology in her curriculum (see Section 8.3.1), the emphasis that the teacher and I placed to making science relevant to students may simply have maintained the expectations for relevance that the students may have developed the previous year.

Nonetheless, it appears that students responded favorably to a number of the pedagogical approaches that emphasized relevance (Section 6.4), which may have affected their attitudes toward science and toward learning science (Section 8.3). Some studies have shown that increased relevance improved student interest in learning science (Matthews, 2004; Ramsden, 1998). While findings of this study indicate this may have been the case for some students, a fuller discussion of student learning takes place in Section 9.2.3, while a discussion of attitudes continues in Section 9.2.4.

Although this section on relevance is fairly short, it does not diminish what both the literature and these findings indicate about its importance to students' learning and their attitudes toward learning. Additionally, the role that relevance appears to take in learning fulfills five of the permaculture principles discussed in Section 9.2.1. First of all, the *relative location* of the learner (cerebral, not geographical) is the point of reference of all matters of relevance. This simple acknowledgement (sometimes considered a constructivist approach to teaching and learning) *works with nature* (of learning), is *cooperative* (with much research on learning), and is intended to *accelerate succession* to higher levels of learning. Finally, this central function of promoting relevance is reinforced by many of the key pedagogical principles of the intervention (*redundancy*).

#### *9.2.2.3 Engagement*

As noted above, there is no clear boundary between the three points of discussion in this section. They relate to and reinforce one another. Regarding the third key finding – engagement – there appears to be a close relationship between engaging students in science and their recognition of relevance, although it may be a chicken-and-egg scenario. For instance, during one focus group interview, a group of three boys spoke enthusiastically about both the experiential and contextual aspects of the field trip to Eco-Hostel. This may indicate the synergistic, or regenerative, impacts of a permaculture approach.

Like relevance, I use engagement as an umbrella term to describe not only engaging students in science through experiential learning opportunities, but also engaging students in affective learning experiences, and engaging students with practicing permaculturists. As a transition from the previous discussion to this one, I'll begin with the latter of these in reference to my role as host during the field trip to Eco-Hostel.

As discussed above and in Section 6.5.1, some students' data highlighted the experiential and contextual aspects of the field trip, but findings appear to indicate that for the teacher, my roles as citizen scientist and permaculture MKO were also important (Section 6.5.2). According to social development theory (Vygotsky, 1978), children working at any stage of cognitive development may be able to operate at a higher cognitive level by interacting with an MKO. Approaches to teaching and learning that include engaging with a community of adults - 'Facilitating Shared Learning' – are among the pedagogies encouraged in *The New Zealand Curriculum* (Ministry of Education, 2007). Some authors argue that such social constructivist teaching and learning can promote transformative learning in individuals (van der Veen, 2000), which may have been the case for one special learner in this study: the teacher.

While this inquiry set out to explore learning and attitudes in learners, and teaching by a teacher, one of the most significant findings appears to involve the learning and attitudes of the teacher. While it is unclear whether the teacher in this inquiry experienced a disorienting dilemma or cognitive crisis involving his teaching practice, he appears to have emerged from the experience with transformed views on some aspects of teaching and learning, on permaculture, and on me through my role as MKO. As described in Section 6.5.2, reservations that the teacher reported during the negotiation and early days of the intervention appeared to have been dismissed by its completion. In the final interview he said he would not have been interested in working with a "hippy permaculturist idealist," but that he appreciated working with a citizen scientist. It is possible that he felt he could engage with the latter through the common ground of science but not with the former because he may have felt little or no common ground. As the intervention proceeded, the teacher appeared to exhibit more trust in me and what I could bring to the class as an MKO for permaculture, and perhaps for certain approaches to teaching and learning. After a number of the mini-lessons I taught he commented to me about how engaged the students appeared. The teacher also appears to have been engaged in learning some things about permaculture and passive solar design, particularly during the field trip to Eco-Hostel. Nuttall and Millington (2008) acknowledge that little research has been done on the impacts of permaculture school gardens on teaching practice, but report anecdotal evidence of teachers speaking of "a renewed energy for the teaching task and a welcome increase in ideas for structuring the learning process" (p. 16). During this short intervention, the germination of such feelings appears to have been reported by the teacher involved. These findings may have implications (see Section 9.4) for attracting other science teachers who may be skeptical about including EEfS in their practice.

When engaging students in social construction, Bruner (1986) and Goulah (2007) recommend a process of scaffolding. I prefer the more *biological* images of cultivating a learning ecology and trellising learning, over the *physical* image of a building wrapped in a steel framework. In a garden, cultivating soil usually results in plants that stand on their own, although some gardeners erect structures such as trellises to support vertical growth. The difference between trellising and scaffolding is that the latter constrains the subject within prescribed boundaries while the former allows the subject to *engage with* the framework: to weave in and out, branch laterally, or even reach out and grow onto another trellis. While builders have no choice but to be hands-on, gardeners can choose hands-on or hands-off approaches. Permaculture, for the most part, promotes hands-off gardening through the application of thoughtful up-front design that proactively addresses issues of insect, disease and weed pressure. At the same time, permaculture advocates multi-layered cultivated ecologies that take advantage of pre-existing vertical elements such as walls, fences or trees (Morrow, 2006).

Of critical importance to this inquiry, and the potential implications for improving the ecological and scientific literacy of science students anywhere, is that there already exists a worldwide network of hundreds of thousands of practicing permaculturists that can engage with students and teachers as MKOs. In other words, practicing permaculturists are pre-existing elements that can be used to trellis science and sustainability learning. The distinction between trellising and scaffolding is critical because if permaculturists erect restrictive frameworks, teachers may be less likely to partner with them. Findings from this inquiry suggest that some impacts on the teaching and learning of science may have resulted from using permaculture as a trellis rather than a scaffold, because the growth of the teacher and students were determined by them, and not by me. Literature suggests that for learning to be sustainable, it must be owned by the learner (Sterling, 2001). Findings suggest this may have been the case for the teacher, who was in a position to pick and choose from the suggestions I made in the revised unit plans. In other words, engagement was on his terms.

If we look at the eight key pedagogical principles (Table 5.1) as a trellis provided for the teacher, findings suggest that the tendrils supporting the growth of his pedagogical practice grasped (engaged) some of the rungs but not others as seen in Figure 9.1.

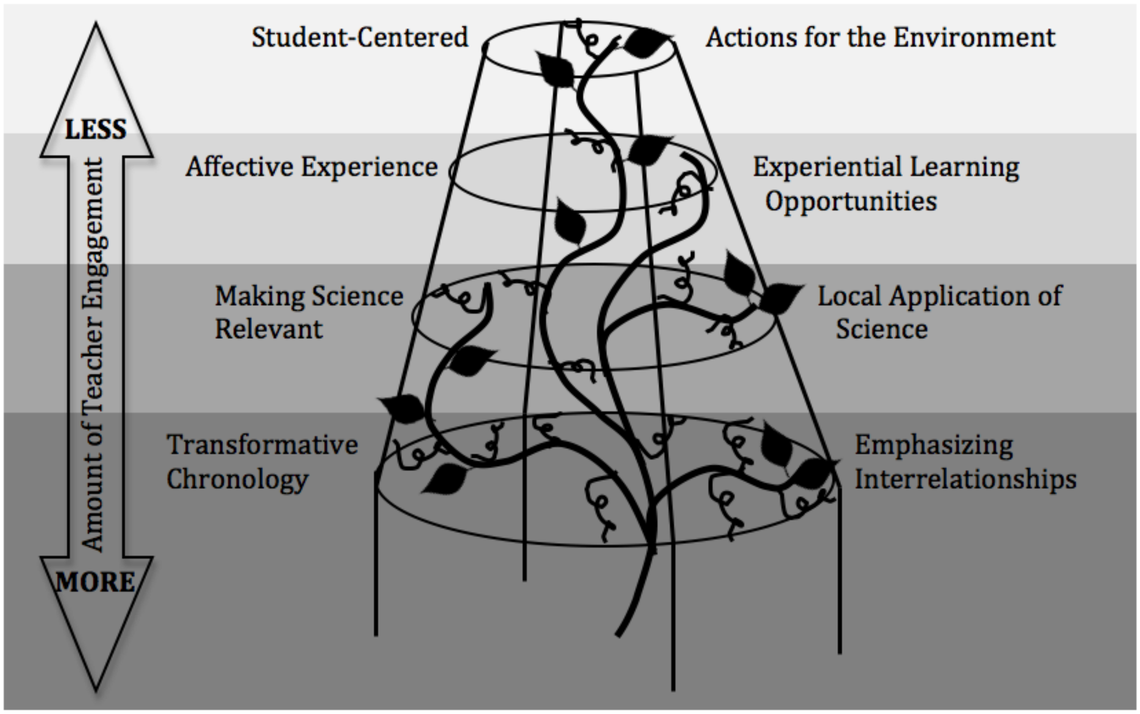


Figure 9.1 The teacher engaged with key pedagogical principles to different degrees

This image of a trellis rather than a scaffold corresponds to the permaculture principle of *working with nature, not against it*. A trellis *cooperates* with growth by providing a suggestion of where to grow, along with support, rather than a rigid prescription for exactly what growth should be. The last century of architecture and building exhibit how most structures are erected with little or no thoughtful reference to the sun. Many of these buildings are cold in winter and hot in summer, appearing to ignore a free source of solar energy. Plants, in every case that I know of, always grow with reference to the sun.

Although the teacher did not engage all of the recommended pedagogies, findings from this study may have significance in that he reflected favorably upon those with which he did engage, in particular some that included eco-social-justice issues, which some authors say pose particular challenges in the traditional science curriculum (Hart, 2003; Steele, 2011). As described in Section 5.4.3, one such issue that caught the attention of the students and the teacher was the prosecution of some American farmers by the Monsanto Corporation for copyright infringement on its GE seed, as depicted in the film, *Food, Inc.*

Pedretti et al. (2008) argue that an issues-based approach to science education "challenges traditional images of a science teacher and science instructional ideologies" (p. 943), yet findings from this study indicate how one science teacher appeared to grow to appreciate some aspects of such an approach.

As discussed in Section 9.2.1, permaculture design is holistic and adaptive. Like any living organism, adaptation relies on feedback. The teacher's apparent engagement with different aspects of the intervention design provides valuable feedback for adaptive re-design of a permaculture approach to junior secondary science as described in Section 9.4.

Engaging students in science and/or the environment through experiential learning opportunities is well documented in the literature of ecological literacy (Goleman et al., 2012; Orr, 1992; 1994; 2002), EEfS (Bolstad, 2003; Chapman & Eames, 2007; Daudi & Heimlich, 2002; Tilbury, 1995) and scientific literacy (Harty, Kloosterman & Matkin, 1989; Mabie & Baker, 1996; Meichtry, 1992; Roth & Roychoudhury, 1993). Findings appear to indicate that students felt engaged in learning during the field trips but less so while doing bookwork in class. Findings also reveal the apparent impacts of engaging students in affective experiences. Learning about two unique socio-scientific issues – the Deepwater Horizon accident and the relationship the Monsanto Corporation has with some American farmers – appeared to have stimulated acute affective responses in some students. The literature indicates that affection for the Earth is critical to ecological literacy (Goleman et al., 2012; Orr, 1989, 1992, 1994), and that affective learning experiences are essential to holistic approaches to EE (Balgopal & Wallace, 2009; Sipos, Battisti & Grimm, 2008).

From an holistic perspective, affective experiences may be able to help promote relevance and interest in learning more on a science topic. Findings from this inquiry indicate this may have occurred for some students regarding the Deepwater Horizon and genetically-modified seeds. Some affective experiences – such as those involving these two issues – might also help promote big picture thinking in students. These findings would support the permaculture principles of multiple functions and redundancy (Mollison, 1988; 1991; Nuttall & Millington, 2008) as discussed in Section 9.2.1. Finally, the teacher described this approach to science education in the final interview as passionate. He even repeated the word. But does passion, or any other aspect of a permaculture approach to junior secondary science, translate into student learning? The next section discusses findings on students' ecological literacy in response to the intervention.

### *9.2.3 How does a permaculture approach to junior secondary science impact on students' ecological literacy?*

While distinct elements of a permaculture approach for the teaching and learning of science were identified and discussed in the previous section, it appears as though synergies were at work that may have created positive feedback between big picture thinking, relevance and engagement. While this would appear to be good news for student learning, it poses challenges to the study of student learning. Systems are complex, especially those involving human beings. This section discusses findings related to apparent changes in students' ecological literacy by addressing those habits of mind associated with ecological literacy: the recognition and appreciation of ecological limits and possibilities, an attitude of care for the environment; and, the tendency to take action for the environment.

Section 2.2.3 described the recognition of ecological limits and possibilities as special types of knowledge that allow individuals to critique systems and practices that are unsustainable, and then to design more sustainable ones based on the most appropriate applications of science and technology. These habits of mind are fundamental to ecological literacy (Orr, 1992), and are among the primary components of scientific literacy (AAAS, 1993; Norris & Philips, 2003; OECD, 2003). *The New Zealand Curriculum* suggests that scientific literacy is best nurtured when: "students explore how both the natural physical world and science itself work so that they can participate as critical, informed and responsible citizens in a society in which science plays a significant role" (Ministry of Education, 2007, p. 17).

This type of thinking can be discussed on two levels. The first level may be described as a developed stage of scientific literacy where an individual can view socio-scientific issues along a broad spectrum from identified problems to proposed solutions from a discerning scientific perspective (AAAS, 1993; Ministry of Education, 2007; Norris & Philips, 2003). This discussion, however, takes place in Section 9.2.3 because of its relationship to students' attitudes toward science. The second level separates the recognition of ecological limits from the recognition of, and appreciation for, ecological possibilities, because there appear to be distinct habits of mind unique to each as well as some they hold in common. A discussion of each takes place in the following two sections.

#### *9.2.3.1 Recognizing Ecological Limits*

The recognition of ecological limits can serve as the first stage of transformational learning: a disorienting dilemma or cognitive crisis (Mezirow, 2000; O'Sullivan, 2002). In the 1970s, it was the recognition of perceived limits of food and energy supplies that led to the development of permaculture (Mollison & Holmgren, 1978), and it is likely that in the interim the recognition of limits (ecological, energetic, economic) has prompted many to study permaculture to learn about ecological possibilities.

The recognition of ecological limits is one expression of a habit of mind known as the 'precautionary principle.' This habit of mind – a cautionary approach to decision-making – represents a different way of thinking than some of the more creative habits of mind associated with recognizing and appreciating ecological possibilities. There are critics in this world who are good at recognizing limitations, and there are creators who explore possibilities. It's often easier to be a critic, but the aim of a permaculture approach to teaching and learning is to develop critical creators.

Findings from this inquiry indicate that some students appear to have recognized more limits after the intervention than before it (Section 7.2.1.1). For example, data from the pre- and post-questionnaires indicate a shift in students' recognition of limits to human population growth and limits to the use of science and technology. Findings from classroom observations and focus group interviews appear to indicate students also gained awareness of limits to non-renewable mineral and energy resources. While these findings appear to have the potential to overwhelm some students – as found by Hillcoat, Forge, Fien and Baker (1995) – the transformative chronology of the intervention highlighted examples of science-based eco-design strategies intended to inspire as well as educate them.

#### *9.2.3.2 Recognizing and Appreciating Ecological Possibilities*

If recognizing limits to the Earth's capacity to provide (and the limits of science and technology to overcome those limits) can represent the first stage of transformative learning, then recognizing and appreciating ecological possibilities may represent completion of the process. I include the word appreciate here to express a higher level of cognition that is closer to honoring and engaging with than to simple recognition. Transformative learning results in an alternative worldview (Mezirow, 1990, 2000), and in the context of this inquiry that worldview could be called ecological literacy or a permaculture perspective. In both cases, that worldview involves habits of mind that include scientific literacy, systems thinking, and sustainable thinking. Each of these is discussed below.

As argued in Section 2.3.3, scientific literacy boosts ecological literacy, and may be particularly valuable in helping students understand some potential sustainable applications of their science knowledge. Findings on some aspects of scientific literacy indicate that some students developed a greater appreciation of socio-scientific issues – such as deep sea oil drilling and genetic engineering as discussed above – and that many students increased their use of science and sustainability vocabulary on the concept mapping exercise on the post-questionnaire (Section 7.2.2). Also, as mentioned above, Section 9.2.4 discusses findings on students' attitudes toward science that appear to indicate greater caution or uncertainty for potential benefits and dangers of the use of science and technology. All of these findings appear to align with literature on scientific literacy that advocates some of the pedagogical approaches used in this inquiry such as promoting relevance (Bell et al., 1995; Holbrook & Rannikmae, 2009; Keller, 1983; 2004; Korpan, 2009; Matthews) and engaging students in science (Harty, Kloosterman & Matkin, 1989; Mabie & Baker, 1996; Meichtry, 1992; Roth & Roychoudhury, 1993).

Systems thinking is suited to decision-making on complex socio-scientific issues (Goleman et al., 2012; Sterling, 2001). Literature indicates that appropriate learning experiences can help students understand systems interactions (Assaraf & Orion, 2005;

Hipkins, Bull & Joyce, 2008). Findings on students' systems thinking indicate that some students may have improved their ability to recognize interrelationships, while others showed no improvement (Section 7.5). A similar gap between students was observed in findings relating to sustainable thinking. In both cases, data were triangulated from the concept mapping and SOLO Taxonomy exercises on the pre- and post-questionnaires, and focus group interviews. Regarding sustainable thinking in the context of permaculture education, the literature documents some cases where permaculture gardens were used to teach the values of sustainability, stewardship and resourcefulness (Gunderson & O'Day, 2008; Lewis, Mansfield & Baudains, 2008; Praetorius, 2006). Although this inquiry did not involve school gardens or gardening, the students were exposed to examples of permaculture gardens and food forests in their community.

Regarding apparent changes in both systems thinking and sustainable thinking, findings indicate that those students with higher scores on the pre-questionnaire generally experienced greater improvements on the post-questionnaire than students with lower scores on the pre-questionnaire (Sections 7.2.2.3 and 7.5). While it is natural for students to learn at different rates, these findings indicate that some of the stronger science students may have been learning at higher rates than weaker science students. Although the small sample makes data from the questionnaires indicative only, and these findings could be attributable to differences in test-taking ability rather then differences in learning, they deserve further discussion because one of the aims of this inquiry was to narrow the achievement gap in a country with a "long tail" of underachievement among science students (Telford & Caygill, 2007).

As the questionnaires were coded in order to identify individual students, I was able to identify a correlation between some of those students who showed small or no improvement on the concept maps and the SOLO Taxonomy exercises between the pre- and post-questionnaires, and more negative attitudes toward learning science in school. However, many of these students – represented by Natalie's case story in Section 8.4 – reported greater enjoyment of learning science with a focus on the environment than their overall enjoyment of learning science in school. Put simply, the findings on student learning appear to be at odds with what might be expected given the findings on students' attitudes toward a permaculture approach to science education. In other words, it might be expected that those students who reported greater enjoyment of learning science with a focus on the environment than their usual enjoyment of learning science in school would show greater advances in their learning and narrow the achievement gap. Crooks, Smith and Flockton (2008) have noted a decrease in New Zealand students' attitudes toward learning science paired with a decline in some conceptual areas of primary-level science, and Caygill (2008) indicates that students who reported higher engagement with science generally achieved higher in science than students who reported low engagement.

As a possible explanation, in Section 8.4 I used a swale as a metaphor to suggest possible relationships between attitudes toward learning science, science and sustainability learning, motivation to act for the environment, and actions taken or not. But what is below the surface cannot be seen until it springs forth – literally in terms of a re-hydrated watershed and figuratively in terms of evidence for student learning. Groundwater movement can be influenced by: bedrock material, porosity and permeability, fractures and veins, or the presence of impermeable lenses. Student learning can be influenced by attitudes, motivation and effort. Seismic studies and core samples can help explain the dynamics of an aquifer while education research probes the dynamics of learning. Findings from this study indicate that a permaculture approach may have positively affected some students' enjoyment of learning science. This is discussed in Section 9.2.4 after a discussion on the final two components of ecological literacy.

#### *9.2.3.3 Caring and Acting for the Environment*

Other ways in which students might be functioning like swales involve the complex dynamics between caring about and acting for the environment. Findings from this inquiry indicate that many students expressed strong feelings about the protection of wildlife and issues of justice and injustice in human power relationships. These findings are supported by literature indicating that biology lessons can affect students' attitudes toward wildlife (Adams, Thomas, Newgard & Cooper, 1987), and significant correlations between New Zealanders' reported levels of concern for environmental and social justice issues (Carroll, Casswell, Huakau, Perry & Chapman, 2009).

Findings also indicate a small shift in students' feelings about protecting the environment over making money. However, when students reported their feelings of personal obligation to act for the environment, there was no apparent corresponding shift. As suggested in Section 7.3, the seeming contradiction in data may be explained by the way the semantic differential statements were phrased. The paired statements on personal obligation to act included the pronoun I, while the paired statements on setting economic and environmental priorities in general did not. It is often easier for one to point the finger at others and say they should do this, than look in the mirror and say I should do this. The literature indicates that the dynamics at work are complex, but that a sense of responsible environmental behavior includes: an understanding of the issues and action strategies; locus of control, personal attitudes, and one's own sense of responsibility (Hines, Hungerford & Tomera, 1987).

An apparent disconnect is also suggested by data involving students' self-reporting on their motivation to take actions for the environment (Table 7.11) and their actual taking actions for the environment (Table 7.12). Kollmuss and Agyeman (2002) indicate that the dynamics involved in action-taking are complex, conflicting, competing, and poorly understood, but that they agree with Grob (1991, as cited in Kollmuss & Agyeman, 2002) "that the stronger a person's emotional reaction, the more likely that person will engage in pro-environmental behavior" (p. 254). As described in Section 8.4.2, despite Natalie's reported strong agreement with feeling motivated to take actions for the environment on the post-questionnaire, her self-assessment of personal actions dropped between the pre- to post-questionnaires. A potential explanation was that with a wider view of ecological problems and possibilities, students such as Natalie might have viewed their own actions with a more discriminating eye when compared with some actions taken at Eco-Hostel. This may have complicated an already complex dynamic. Drawing on the work of German researchers (Fietkau & Kessel, 1981; Fliegenschnee & Schelakovsky, 1998, as cited in Kollmuss & Agyeman, 2002), Kollmuss and Agyeman (2002) suggest that a combination of ecological knowledge, values, attitudes and emotional involvement form a complex they call 'pro-environmental consciousness' that is embedded in a wider set of personal values, personality traits, and other internal and external social and cultural factors.

Given the multiple factors, feedback loops and a potential time delay between developing a 'pro-environment consciousness' and engaging in sustainable behaviors, it seems appropriate to return to the swale and watershed metaphor. The use of swales fulfils *multiple* permaculture principles discussed in Section 9.2.1. The *relative location* of a swale high on a property is important. If the location is correct, and the swale *works with nature* (hydrology in this case), then there is likely to be a *great effect with the least change* to the property. However, immediately following earthworks, it is possible for a swale to result in a short term drying out of the landscape directly below, while water goes initially to recharge underground aquifers rather than pooling in previously flooded surface reservoirs. This temporary impact on the watershed may be similar to what some findings in this study appear to indicate about some students' affective and psychomotor responses. For example, while Natalie – and other students like her – reflects on her learning, her attitude toward science, and her motivation to act, there may be a period of inaction. As discussed above, one of the intermediate stages of transformative learning is the critical assessment of assumptions (Mezirow, 2000).

O'Sullivan (2003) insists that transformative learning involves changes in thought, feelings, and action. From this perspective, it can be argued that in this case a permaculture approach to junior secondary science was not transformative with regards to sustainability. Sipos, Battisti and Grimm (2008) advocate a head, hands and heart approach to transformative sustainability learning, but time constraints prevented the action (indirect or direct) projects scheduled for the end of the intervention. Another possible explanation for apparent inaction involves locus of control (Newhouse, 1991; Kollmuss & Agyeman, 2002). It is possible that children in their early and mid-teens may feel an external (rather than internal) locus of control regarding sustainable behaviors because for most of their lives their parents or guardians have made the majority of decisions regarding purchasing decisions, waste management, home gardening, or energy conservation.

But the ultimate aim of EEfS is personal action (Barker & Rogers, 2004; Bolstad, 2003; Breiting & Mogensen, 1999; Chapman & Eames, 2007; Jensen & Schnack, 1997). Each EEfS program, or a brief intervention such as this one, may not yield significant sustainable behavior change, but their combined effects, over time, could be like the recharging of an aquifer drop by drop. As with the discussion on student learning above, it may be worth considering the time delay to be like a physiological swale that collects and stores learning and motivation until they are in sufficient abundance to spring forth in action. The decision to act may be considered a personal tipping point – or series of tipping points – where confidence and caring overcome complacency. But confidence to act can and should be cultivated through action learning experiences (Jensen and Schnack, 1997), which, unfortunately, were not included in the intervention as planned. In their absence, it appears that the cumulative effects of cognitive, affective and experiential learning *activities* involved in the intervention contributed to a 'pro-environment consciousness' (Kollmuss & Agyeman, 2002) in students rather than immediate behavior change. As discussed above, different students appeared to *soak in* some of the learning experiences in different ways and at different rates. Some students, like some soils, may have become hardened against absorption of sustainability or science learning. In both cases the solution may be breaking the surface, as discussed in the next section.

#### *9.2.4 How does a permaculture approach to junior secondary science affect students' attitudes toward learning science?*

Section 8.4 presented findings on two students, Edward and Natalie, who appeared representative of other students in the class. Edward, and those students most like him, reported on the pre- and post-questionnaires to like learning science in school, and reported to be neutral or positive about "learning science with a focus on the environment" (Post-questionnaire, 22/06/10). Although some of the students in this cohort complained about the large amount of bookwork and fewer experiential learning opportunities compared with the year before, those complaints did not appear to have affected their general attitude toward learning science. For the purposes of this discussion, a permaculture approach to junior secondary science appears to have had little or no impact on these students' attitudes toward learning science. As discussed below, however, this approach does appear to have had an impact on some of these students' attitudes toward science itself.

The second cohort, represented by Natalie, reported a greater enjoyment of learning science with a focus on the environment than their general enjoyment of learning science in school. Their general science learning experiences in school could be described as similar to those listed by Fensham (1985) and echoed by Gough (2004) as explained in

Section 2.3.1. These findings appear to indicate that these students enjoyed those times in class when they perceived that they were learning science through environmental problem-solving and permaculture, but not enjoyed the overall experience of learning science during the intervention because of what many of them considered to be boring bookwork. This criticism is consistent with findings that indicate students to be critical of science teaching methods dominated by memorization, lists, facts and figures (Keysar & Pasquale, 2008), which are some of the characteristics of science education criticized by Fensham (1985) and Gough (2004).

These findings may be attributable to students like Natalie gaining a better recognition of the relevance of science to them and their world, and feeling more engaged in science learning through the permaculture approach. Natalie reported a slight increase in her recognition of the relevance of her science learning, and only one of the 16 students reported not to recognize relevance in their school science learning (Tables 8.5 and 8.6). Relevance appears to be an important factor in students' attitudes toward learning science (Holbrook & Rannikmae, 2009). Some authors suggest that relevance influences motivation (Keller, 1983; Levitt, 2001), and others equate relevance with student interest (Matthews, 2004; Ramsden, 1998). The combined sum of relevance, interest and motivation may have resulted in the positive attitudes toward learning science through the permaculture approach reported by Natalie and her cohort.

The literature indicates that relevance for students has four aspects relating to school science: personal, professional, social and personal/social (Van Aalsvoort, 2004). Although data was not collected on the specific aspects of relevance to students, it is likely that most students may have recognized all of those above, apart from perhaps the professional relevance for students unlikely to pursue science as a career like Natalie. For her and students like her, it appears possible that personal and social relevance may have contributed to a greater interest in science but that may not have translated into higher motivation to learn, perhaps because the class was still heavily reliant on transmissive pedagogies and bookwork. In the case of Edward and students like him, who may have been considering careers in science due to their affinity for it, professional relevance may already have been high enough that the intervention did not significantly impact on their interest or motivation, and robust enough to provide them with a greater tolerance of large amounts of bookwork. But for Natalie and her cohort, traditional transmissive science pedagogy does not appear to be effective. These students may be like those that Keysar and Pasquale (2008) studied who expressed a desire for fewer lectures and more hands-on approaches to science teaching and learning.

As expressed by the theoretical framework of this study, the aims of the intervention were to improve students' ecological and scientific literacy, as well as their attitudes toward learning science in school. What I did not anticipate was the extent to which a permaculture approach could be applied on so many levels of this inquiry, and particularly to the ways students appear to function as learners. One of the unique functions of permaculture is that it can be used to restore overused, degraded or damaged landscapes, and findings from this study appear to indicate that it may have the potential to restore interest and motivation to learn in some students who have become disengaged with science learning over their years of schooling.

One permaculture strategy for releasing compacted soils is the use of a chisel plow that mechanically aerates the earth without overturning it like a traditional plow. In some cases, a chisel plow is used in conjunction with swales to help them perform to their full potential as soon as possible. Without the chisel plow, water may overtop the swales during rains and stand stagnant for days afterward. With the chisel plow, both air and water are allowed to enter into the previously compacted soils. Since air and water are essential to life, soil biota is encouraged, which further aerates the soil in a positive feedback loop: the presence of more life in the soil creates conditions that favor more life in the soil. This is a prime example of the regenerative nature of permaculture on the land. And it is through mimicking these types of positive feedback loops in learners that a permaculture approach seeks to improve students' ecological and scientific literacy, and their attitudes toward learning science.

But in the case of students who may have become hardened against learning science, it appears critical to break the glazed surface, or patina, of attitude. This is at the heart of both regenerative eco-design and regenerative education. A journal search for 'regenerative education' produces results only for articles on regenerative medicine, but I was able to locate a theoretical dissertation on the philosophy of regenerative education and living schools (Nielsen, 2008) that draws on literature from the field of holistic education, and highlights themes of the environment, spirituality and holism. Nielsen (2008) identifies that the philosophy of regenerative education includes four types of education: understanding-based, self-revealing, systems and spiritual. In regenerative learning environments, students engage in self-actualization and self-realization, as well as system-actualization and system-realization (Nielsen, 2008). While I am in agreement with the philosophy presented above, in the case of science education I would place special emphasis on the reparable capacity of a permaculture approach. Before we reach a sustainable state of human-environment relationships or student-science learning relationships, remediation appears to be required in some cases. In this way, permaculture can serve as both pathway and destination. Gentle cultivation for those students who have become hardened against science may allow them to learn like swales and, ultimately, use their science and sustainability learning to act like swales: re-invigorating overused landscapes, and redesigning for a truly sustainable future. Rathzel and Uzzell (2009) insist that learning to live sustainably on the planet is non-negotiable. Such learning would aim to promote ecological literacy (Orr, 1992), which I argued in Section 2.3.3 is enhanced by advances in scientific literacy (Figure 2.4). Some aspects of scientific literacy were discussed in Section 9.2.3, save for a discussion of students' attitudes toward science.

For the purposes of this discussion, a mature attitude toward science aligns with two components of scientific literacy identified by Norris and Philips (2003): understanding the benefits and risks of science; and, the ability to think critically about science. In Section 9.2.2 I described this as a developed stage of scientific literacy where an individual views socio-scientific issues along a broad spectrum from identified problems to proposed solutions from a discerning scientific perspective (AAAS, 1993; Norris & Philips, 2003). Bybee (1997) calls this multidimensional scientific literacy, and Holbrook and Rannikmae (2009) maintain that this is the goal of researchers and educators who take a long-term view of scientific literacy.

As presented in Section 8.2, findings from this study appear to indicate that some students developed a greater sense of the risks of science and technology over the course of the intervention, but some may have become more uncertain about their potential benefits. While the use of science and technology were presented as both villain and hero during the intervention, the overwhelming emphasis was on science as a hero, or according to the teacher, a superhero: Science Man. Despite these concerted efforts, however, it appears that not all students were convinced of the power of the science of sustainability and ecological design.

As discussed in Section 8.2, a move toward neutrality in one's opinion could mean different things. Some students may have accepted both sides of the science and technology story and become more undecided in their opinions. The apparent neutrality may, in fact, represent greater confusion about the whole issue, or that the students think that some, but not all, science and technology can be used for better or worse. Or it may indicate an even a more sophisticated understanding of the many shades of grey involved in most socio-scientific issues.

This discussion concludes with a final point on students' attitudes toward science: relevance. As discussed above, relevance can mean importance, usefulness or meaningfulness for learners (Levitt, 2001), and it can influence students' perceptions of whether certain learning satisfies their needs or goals (Keller, 1983). Findings from this inquiry appear to indicate that the relevance of a permaculture approach to science teaching and learning had an impact on students, but that it was closely related to their engagement with science at local permaculture properties. It would appear that the synergy of the two could improve students' recognition of, and appreciation for, science. Findings indicate that this may have been the case for students such as Edward, who latched on to the concept of the swale as a way to use science knowledge to re-hydrate arid landscapes. (He had recently moved to New Zealand from Australia.) But Olivia, who sat next to Edward in the focus group interview, replied, "I don't want it to," when asked if science was relevant to her life (Focus group interview, 25/06/10). After some probing, Olivia admitted that she might like science more if it wasn't so hard for her to understand and learn.

While a permaculture approach to science education does not aim to make science *easier* to learn, it does aim to engage students more by making it more relevant, experiential and solution-oriented. These aims have the dual potential of improving some students' attitudes toward science and toward learning science in school. In a classroom, all students respond differently to personality and pedagogy. One without the other represents incomplete design and unfulfilled potential. Some students can learn when one is weak or missing, but others need both. This recalls the advice given by a colleague early in my teaching career that I related in Section 8.5: "The cream will always rise to the top. Where we need to work is with the skim milk." With this in mind, it appears that a permaculture approach to junior secondary science may have the potential to *cultivate* healthier attitudes of some students toward science and science learning, while *trellising* science and sustainability learning in all students. In both cases, the aim is a form of regenerative science education that results in independent, life-long learners who understand science, how it works, and how to apply it to create a more sustainable human presence on the Earth.

## 9.3 Conclusions

One permaculture principle not discussed in Section 9.2 is *use edges and value the marginal* (Holmgren, 2002). Permaculturists use natural edges, or ecotones, to great productive advantage. In formal schooling, sustainability education is often marginalized (Blumstein & Saylan, 2007; Chapman, 2011; Daudi & Heimlich, 2002; Gruenewald, 2004). This study indicates that EEfS can be used to enhance a core learning area of *The New Zealand Curriculum* (Ministry of Education, 2007): science. Having discussed the findings in relation to the research questions, there are five main conclusions drawn from this thesis with regard to a permaculture approach for junior secondary science in New Zealand.

1. A permaculture approach to junior secondary science in New Zealand is characterized by holism, adaptability, cooperation and transformation.

   Permaculture principles can be used to design a *cultivated learning ecology* that aims to be transformative by encouraging habits of mind associated with eco-design thinking, ecological literacy, and scientific literacy. A holistic, adaptive design strategy involves considering the limits and possibilities of a given system, while remaining open to unanticipated opportunities. Major design factors include: *The New Zealand Curriculum* (Ministry of Education, 2007), previous research in ecological and scientific literacy; transformative learning theory (Mezirow, 2000); and, a familiarity with permaculture (in general) and permaculturists living close to a school. The aim is not to teach permaculture, but to use permaculture to improve the teaching and learning of science.

2. **A permaculture approach to junior secondary science in New Zealand can impact on teachers' and students' big picture thinking.**

   Science units can be ordered to promote a 'think globally – act locally' frame of mind in two ways. The first involves a transformative chronology, which presents a global, anthropogenic environmental problem, followed by a study of how nature 'avoids' or 'solves' problems (ecology), and finally the application of ecological design to address the problem in the local community. The second involves pedagogies that emphasize interconnectedness to help students recognize how things are connected to one another and to themselves. A carefully planned field trip to a permaculture property can be like walking through a concept map. Whether on paper or on the ground, the emphasis is on interrelationships, all of which must ultimately relate to an individual human being who recognizes his or her own relationship to the greater whole.

3. **A permaculture approach to junior secondary science in New Zealand can impact on the relevance and engagement of learning.**

   Certain science learning activities can be used to *cultivate* interest in students and *trellis* their learning by focusing on relevance and engagement (cognitive, affective and psychomotor). At the same time, a permaculture approach can *cultivate* interest and *trellis* learning for teachers with regards to sustainability and EEfS by emphasizing the science of sustainability (relevance) and allowing them to take on new learning on their own terms (engagement). The most holistic learning activities that both engaged learners and emphasized the relevance of science were field trips to local permaculture properties.

4. A permaculture approach to junior secondary science in New Zealand can improve **some aspects of students' ecological literacy.**

   Most students showed improvements in systems thinking, sustainable thinking, scientific literacy, and an attitude of care for the environment, although there was insufficient evidence on changes to students' acting for the environment. Most students showed greater recognition and respect for ecological limits and possibilities, although the transformative nature of this approach takes into account the potential for delayed learning in students who have soaked in new information – like a swale soaks in water – but did not exhibit changes during the course of the intervention.

5. A permaculture approach to junior secondary science in New Zealand can **improve some students' attitude toward studying science.**

   While most students' attitude toward science appeared to change during the intervention, the attitudes of only a small number of students toward learning science seemed to change as a result of a permaculture approach to teaching and learning. These students did not generally like learning science in school but enjoyed learning science with a focus on the environment and sustainability. In this case, a permaculture approach can be used to *cultivate* more positive attitudes toward learning science that could lead to greater interest, motivation and effort in a *regenerative* positive feedback cycle.

These conclusions are based on the research sub-questions that guided this inquiry. The implications of these conclusions focus on the groups, or stakeholders, for whom those questions were written, and for whom this inquiry was undertaken.

## 9.4 Implications

There are three primary stakeholders in a permaculture approach to junior secondary science: students, teachers, and permaculture practitioners. Peripheral stakeholders include teacher educators and school administrators. While education researchers may also be considered peripheral stakeholders, implications for them take the form of recommendations in Section 9.6. This section describes the implications of this study on each of the primary stakeholders, and then combines the peripheral stakeholders into a final sub-section.

### *9.4.1 Implications for Students*

A permaculture approach to junior secondary science has implications for cultivating students' attitudes and trellising students' learning. Such attitudes include those toward science, toward learning science in school, and toward the environment. Such learning includes science, sustainability, and systems thinking. This study has shown that the attitudes and types of learning listed above can be improved by increasing students' engagement with science and their perception of its relevance using various aspects of permaculture.

From an holistic perspective, changes in attitudes and learning occur simultaneously and reinforce one another through positive feedback. However, findings from this study show that attitudes can precede or preclude learning, the implication being that the cultivation of positive attitudes toward science and the environment can have regenerative effects on students' ecological and scientific literacy. In other words, when students enjoy learning science in school, and that learning comes with a focus on the environment, they may develop attitudes of care for the environment closer to that of *kaitiakitanga*, the Māori concept for guardianship/stewardship.

If attitudes are the foundation, or fertile soil, of a sustainable future, learning is the growth, or development, that will help young people make it a reality. A permaculture approach to science education both cultivates attitudes and trellises learning relating to science, sustainability and systems. In permaculture, this is sometimes referred to as stacking functions. For students, this means that learning science can be engaging and relevant, and although few may pursue a career in science, all may become lifelong science learners and practitioners of the science of sustainability.

### *9.4.2 Implications for Teachers*

A permaculture approach to junior secondary science has implications for science teachers who are: interested in but unsure about incorporating EEfS into their practice; looking for ways to engage students in relevant science learning; or, eager to improve some student attitudes toward learning science. While every teacher is different, many experience similar challenges in their classrooms. Findings from this study indicate that the multiple-functions of a permaculture approach to science education may have broad appeal among teachers in any of the three conditions above. The implication being that even teachers who are not necessarily interested in sustainability or EEfS, or feel they are too busy to incorporate them, may still embrace a permaculture approach because of the general learning benefits for students.

For those science teachers who want to incorporate sustainability and EEfS into their practice but lack confidence, a permaculture approach can facilitate the process by providing an holistic, adaptive and cooperative model. A trellis that is suggestive but not prescriptive allows teachers to control the speed and scope of their own learning. Within the permaculture approach, teachers' EEfS PCK development is relevant and engaging on two levels. Regarding sustainability content knowledge, teachers can learn alongside their students from a permaculture MKO. Regarding transformative pedagogies, teachers can learn by slowly integrating the eight key principles (Table 5.1) and observing how their students respond.

A permaculture approach also has implications for teachers looking for ways to engage students in relevant science learning, whether or not they have a parallel interest in EEfS. The implication is that a permaculture approach to teaching and learning is not just high quality sustainability education, it is high quality science education. Maximizing student learning is theoretically at the forefront of teachers' minds, regardless of their attitudes toward the environment. As such, this approach may attract teachers into EEfS who may not otherwise take that direction. By implication, teachers inexperienced with EEfS could develop their EEfS PCK without any formal or compulsory professional development training.

Finally, a permaculture approach has implications for teachers eager to improve some students' attitudes toward learning science, whether or not they have a parallel interest in

EEfS. As stated above, students' attitudes toward learning can precede or preclude their learning. Findings from this study show that students who do not normally like learning science in school enjoyed learning science through a permaculture approach. Considering international trends in students' disengagement with science in schools, this implication would appear to have especially broad reach.

However, the greatest implication for teachers is that a permaculture approach to science education can accomplish all of the above simultaneously. Busy teachers who may feel overwhelmed in their work may be attracted to the multiple-functions of a permaculture approach or to the opportunity to work with a permaculture MKO as a science colleague. Where a teacher's role is normally that of coach and cheerleader for students, in the presence of an MKO the role can become that of team-mate, or co-learner. These instances can provide the unique opportunity for teachers to share their enthusiasm for learning, which may have waned over years at the head of a class. All of these implications for teachers create implications for teacher educators, school administrators, ministries of education, and education researchers as discussed in Section 9.4.4. They also have implications for self-identified practicing permaculturists, as discussed next.

### *9.4.3 Implications for Permaculture Practitioners*

To call oneself a permaculturist is to abide by a set of ethics: care for the Earth; care for people; and, share surpluses (Holmgren, 2002; Mollison, 1988). While individual permaculture practitioners may express these ethics in different ways, the opportunity exists to exercise all three ethics simultaneously by partnering with a science teacher to enact a permaculture approach to teaching and learning. By sharing their stories, properties, knowledge and enthusiasm, permaculturists can care for people and the planet by educating for a sustainable future in which human kind and all of life may thrive. The implication is that self-identified permaculturists can be called upon to approach their local science teachers and suggest classroom visits or field trips. A key issue raised in this thesis is that of the synergistic and regenerative potential of partnership between an expert in eco-design and sustainability, and an expert in student learning. A permaculturist and a teacher can come together within a common understanding of science, and a common desire for children to learn.

Critical to cultivating this relationship is *not trying to teach permaculture*, but using permaculture to teach science better. Unless the permaculture community can convince teachers that it can help them improve *student learning* and *attitudes toward learning* and that *it will not be too much work*, educators are unlikely to go for it. As pragmatic as permaculturists tend to be when applying permaculture on their land, I have observed that many of them tend to be dogmatic when talking about or teaching permaculture. When it comes to education, they appear not to see the food forest for the fruit trees. I submit this has held the movement back, and the time may be right for the permaculture community to make the move from second order change (doing better things) to third order change (seeing things differently) (Sterling, 2001) regarding *permaculture education*. The implication is that many permaculturists may need to transform their perspective on the design principles toward education to that of *means*, rather then *ends*. Applied to junior secondary students, I suggest that end be ecological literacy, not new permaculture recruits. As ecologically literate adult citizens, they will likely gravitate toward permaculture, but if they don't, they will still think and act in permaculture ways that benefit the Earth. In other words, cultivating ecological literacy and trellising science and sustainability learning may lead to a burgeoning population of self-identified permaculturists, but it does not matter if it doesn't because actions are 'heard' by the planet, not words or names.

Moving forward on these implications (see Recommendations, Section 9.6), however, must also acknowledge the limitations of this study as described in Section 9.5, and some implications for the peripheral stake holders as discussed next.

### *9.4.4 Implications for Teacher Educators and School Administrators*

While not directly involved in a permaculture approach to science education, teacher educators, school administrators, ministries of education, and education researchers can take lessons from this case study. Implications for each group are explained below.

Teacher education usually takes two forms: pre-service and in-service. In both cases, teacher educators can include various aspects of a permaculture approach to the teaching and learning of science. At the university level, permaculture practices can be used to provide real life examples of *relevance* and *engagement*, which may seem like abstract ideas to some science teacher students who may have been taught science in traditional, transmissive ways. A field trip to a local permaculture property would accomplish the above, along with highlighting the potential of a citizen scientist as MKO, and work toward demystifying the potentially intimidating word, permaculture. The implication is for the development of a permaculture approach to tertiary science teacher education.

Implications for in-service teacher educators are similar to those described above, but a lack of university structure provides a unique set of challenges and opportunities. For instance, taking the 'class' on a field trip on a certain day may not be as feasible due to scheduling and time constraints on full-time teachers. However, opportunities exist for more individual learning experiences catered to a teacher's interests and needs. In some ways, greater opportunities may exist for working with experienced teachers who are scattered around the country the way permaculturists are. Exploring some of these opportunities are explained in Section 9.6.

Principals and Trustees are charged with implementing *The New Zealand Curriculum* (Ministry of Education, 2007). As described in Section 3.4, a permaculture approach to junior secondary science supports some of the *Curriculum's* Vision, Principles, Values and Key Competencies. Additionally, it aligns with the Nature of Science strand in the science learning area, and provides the opportunity for the type of "responsive curriculum" (p. 41) called for year 10 students by the Ministry of Education (2007). The implication is that findings from this thesis may be used to help school administrators recognize that EEfS does not compete with the *Curriculum*, but supports and enhances it. As a result, they may be more open to EEfS professional development programs for their staff, or even take on a permaculture perspective for whole school management.

## 9.5 Limitations

Although there has already been significant discussion of limits and possibilities in this chapter, this section addresses the limitations of the study itself, while the next section explores possibilities for future research. While measures were taken to enhance trustworthiness in this study, there are always limitations in education research. Many of the limitations associated with the methodology and methods of this inquiry were discussed in Chapter 4.

Further limitations involved the extent to which the intervention design was implemented (see Table 5.1). Roth (2005) suggests that a design experiment be carried out with best practice and in a best-case scenario, which may preclude other teachers from carrying it out. If those are the parameters of a design experiment, this was not one. I have grown to see this not so much as a limitation, however, but as one of the most valuable findings of the study. Permaculturists are known for turning problems into solutions, and after a certain amount of anguish, I was able to take that perspective on the intervention. In some cases, investigating the real may be more valuable than investigating the ideal. I would suggest that because the intervention was implemented by a real teacher in a real classroom instead of me, not only did I learn more from the inquiry, but it also makes a greater contribution to the field and offers more opportunity for further research.

However, because the intervention unfolded the way it did, I was less able to answer those research questions most focused on the impacts on students' learning and their attitudes toward studying science. In other words, I could only report on what happened and not on what did not happen, or what might have happened. This limitation is addressed further in the third recommendation in the following section.

More significant limitations had to do with my ability as a researcher to observe significant occurrences in the classroom. The subjective nature of naturalistic research ensures the potential for bias toward certain outcomes. As the designer of the intervention and a rookie researcher, the potential for bias would have been significant, and may have influenced my early notes on classroom observation because I thought I was looking for certain things. It was not until I listened to the focus group and teacher interviews over and over again that I realized that in many cases minor notes from my classroom observations were more valuable data than some of the long, detailed passages I'd written. Examples include some students' reactions to the newsbyte on elephant poaching, and Scott's exclamation after the first newsbyte on the Deepwater Horizon accident: "What a waste of oil!" At the time these were taken, they were minor notations quickly scribbled, but after reviewing other data they became important points for triangulation.

Using interviews and observations to address the research sub-question on ecological and scientific literacy also had limitations. In the focus group interviews, most students self-reported on their perceptions of their own learning, although a few of the more vocal students were able to demonstrate new learning through accurate descriptions. In the classroom, observations on students' engagement in learning were more easily made than on students' learning. Document analysis was considered as a method for data collection that may have provided insights into students' learning, but in this class the students' notebooks were almost always in their possession. In other words, the teacher did not collect the notebooks and hold them overnight for marking, but usually did a quick check of students' homework at the beginning of class. As the notebooks were used during class and for homework, there appeared to be no non-disruptive time for me to take possession of them, even for photocopying.

This type of research can be humbling, and I was humbled many times during this inquiry. But I believe that humility made me less expectant and more open to unexpected possibility. For me, the most interesting findings of this study are the ones I least expected.

Additionally, my role as researcher, co-teacher, *and* permaculture MKO, may have caused the students and teacher to respond differently than if the permaculture MKO role was played by other people in the community. I asked four local permaculturists to serve as site hosts at the food forest, and one other to visit the class on a day we were conducting a soil permeability comparison between the school's playing fields and the native bush adjacent. None were available on the scheduled days. In terms of the field trip to Eco-Hostel, I was the most qualified to serve as host and permaculture MKO because it had been my home for a year and a half, and I had been involved with design work as well as garden installations, building swales and planting fruit trees. However, the question remains, will permaculture practitioners who are not EEfS doctoral students be effective sustainability MKOs for science teachers and their students? This question influences two of the recommendations in the following section, after one final note.

The results of this study should be considered indicative only, and not a definitive inquiry into a permaculture approach to junior secondary science in New Zealand. The sample size of this inquiry was small, with data collection ranging from 10 in the focus group interviews to 24 in classroom observations. This can be considered a limitation of the study, and findings should not be considered comprehensive. The transferability of the findings is left to the reader.

Given these potential limitations and the implications discussed in the previous section, a set of recommendations is made in the following section.

## 9.6 Recommendations

Figure 2.1 showed a learner whose feet are planted on the ground but is reaching for the stars. That figure represented EEfS, but could easily represent EEfS research or permaculture design. In all cases, strong groundings, or roots, support ambitious endeavors. Some of those endeavors may bear fruit and some may not. In all cases, cultivation and trellising support new learning, and new knowledge can be used to *extend the trellis*. Doctoral research extends the trellis by making incremental advances in the field and recommending areas of further inquiry.

Findings from this study lend support to Gough's (2004) argument that EE be conjoined with science during the early secondary years as a way to rekindle students' interest in science and an attempt to combat attrition beyond the compulsory years. Although this thesis covers a lot of ground from science education to sustainability education, and transformative learning to permaculture, findings can be viewed by education researchers from the same perspective that informed the research, which has been described as holistic, adaptive, and cooperative. Some researchers may view this inquiry in its entirety and pursue further research in a permaculture approach to science education. Some researchers may find parts of this thesis that appeal to them, and adapt some of the ideas presented to their own work. And other researchers may be interested in entering into cooperative studies with local permaculturists, which is where I believe the next steps should be taken to further develop this approach to science education. As such, recommendations from this thesis include: creating and piloting a 'common ground' document for permaculturists and science teachers; researching the willingness of self-identified practicing permaculturists to engage with science teachers; and, further developing a permaculture approach to science education at other year levels in New Zealand or in other nations.

Conspicuously absent from this list is the recommendation for further professional development for teachers, as it would likely be hollow for two reasons. First, time constraints, funding constraints, and priority constraints are likely to preclude it from happening. Second, pre-determined teacher training sessions do not place teachers in the position to own their learning, putting into the question the sustainability of their learning. Instead, it is my position to call on the permaculture community to put their ethics into action and share their science practice with local schools. The first two recommendations speak to this position.

1. A permaculturist with science education experience could create and pilot a document for permaculturists and science teachers that provides a common ground between them using the common language of science and the common aim of student learning.

   Permaculturists tend to favor systems that are de-centralized, low-input and high-performance (Holmgren, 2002; Mollison, 1988). The idea behind creating a *common ground* document is that it has the potential to meet these criteria. By necessity, it would be short (low input) and distributed nationwide via networks of permaculturists (de-centralized). Its performance will ultimately be based on how it is interpreted and implemented by a teacher and a permaculturist working together: the expert in education and the expert in sustainable practices. But its performance can be influenced by sound design that is holistic, adaptive and cooperative. Feedback on drafts should be sought from the permaculture community and science teachers. The design should emphasize the pragmatic over the dogmatic, and seek to cultivate and trellis learning for both participants.

2. A permaculturist with science education experience could research the willingness and ability of self-identified practicing permaculturists to engage with science teachers and students, either with or without a *common ground* document.

Among the limitations of this study was my role as researcher *and* permaculture MKO in all of the learning experiences outside of the classroom. Although self-identified local permaculturists were invited to engage with the science class, none could do so because of reported scheduling conflicts. While this is understandable because many of them had full-time jobs, families, and potentially other commitments, the ethical grounding of permaculture as discussed in the implications section suggests that self-identified permaculturists would be more willing to make time to practice their ethics in their community than a member of the general public, and equally as willing as some ethically-guided religious practitioners who make time regularly for charity work. But this is theoretical only. For a permaculture approach to science education to be widely embraced, self-identified practicing permaculturists must voluntarily engage with their local schools. No research has been done on whether this is a reasonable expectation, or on the ability of permaculturists to engage students in relevant science-based sustainable practices. Therefore, I recommend that such research be carried out following the development of the *common ground* document described above. Using the document and an on-line advisor for support would help to ensure that the best possible result might be achieved.

3. An education researcher could further develop a permaculture approach to junior secondary science, as well as permaculture approaches for other year levels in New Zealand, or in other nations.

Among the limitations of this study was the extent to which some recommendations in the modified unit plans were implemented by the teacher (see Table 5.1). As a result, data on some of the key pedagogical principles were incomplete or inconclusive. In order to better understand how these pedagogical practices can impact on ecological and scientific literacy, and students' attitudes toward learning science at the junior secondary level, I recommend another intervention building upon the findings from this thesis. Additionally, research could be carried out on how a permaculture approach could be applied to other year levels in New Zealand, or to other nations such as Australia, which has a similar curriculum and a large population of practicing permaculturists.

On a final note, teaching and learning in permacultural ways may one day lead to humanity acting in permacultural ways by caring for the earth, caring for others, and sharing surpluses. But such radical change requires hope. For me there is tremendous hope in Natalie's reported high enjoyment of, and inspiration to act because of "learning science with a focus on the environment," and the little heart she drew in the margin next to these Likert scale statements on her post-questionnaire (Natalie, post-questionnaire, 22/06/10).

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Appendix A: Sustainable Propositions from Expert Concept Maps

Sustainable Propositions:

1) a sustainable food system is local
2) a sustainable food system reduces reliance on petrol
3) a sustainable food system reduces use of nitrogen fertilizer
4) a sustainable food system consists of farms…&
5) a sustainable food system consists of gardens
6) petrol should be used sparingly in transportation
7) transportation of food should be mostly local
8) farms produce food
9) gardens produce food
10) farms strive to be organic
11) gardens strive to be organic
12) plants grow on farms
13) plants grow in gardens
14) plants can be weeds
15) plants can fix nitrogen
16) plants are fed to animals
17) plants produce food
18) sunlight powers plants
19) water is essential for plants
20) water is essential for animals
21) water should be conserved on farms
22) water should be conserved in gardens
23) weeds can be made into compost
24) weeds can be fed to animals
25) compost is used on farms
26) compost is used in gardens
27) insects pollinate plants
28) insects can damage plants
29) insects can harm animals
30) insects both benefit and harm farms
31) insects both benefit and harm gardens
32) animals can be used for transportation
33) animals can help reduce reliance on petrol
34) animals should only occasionally be used as food

Additional concepts: 3 big categories, with synonyms accepted.

• Diversity: This concept would relate to the resilience of a bio-diverse farm/garden to insects/disease pressure (ie, reduced use of pesticide/fungicide) by 1) inter-planting a diverse complimentary set of plants (big picture) and 2) choosing cultivars for disease resistance/LISA-compatibility (small picture) rather than high productivity or aesthetics; also consider plants suitable to weather fluctuations, soil conditions, beneficial relationships, plant-animal systems, 'whole-farm organism', etc.

• Soil: This concept emphasizes the role and value of soil in a sustainable food system. Emphasis would be on building soil fertility through the use of legumes, compost teas, etc.
• Integrated Pest Management (IPM)/ Low-Input Sustainable Agriculture (LISA): This concept emphasizes the use of organic methods up to the point of potential crop loss before using minimal chemical inputs. The concept would extend beyond the traditional IPM focus on 'pests' to include whole farm management that would allow non-organic inputs so long as they: a) are used sparingly on a case by case basis as with IPM; b) are used as a transitional strategy to quickly get a farm/garden on the path to LISA; c) consider the proximity and availability of off-site inputs (ie; the closer the more sustainable).

Permaculture emphases:
Reducing fossil energy use
Plants and animals playing multiple roles
Turning problems into solutions
Legumes
Complimentary systems
Decentralized food production
Local food production
Water conservation
Holding energy on site
Holding nutrients on site

Appendix B: Teacher Interview Schedules

## 1st Interview – Pre-Intervention

Tell me about why you became a science teacher?

What do you think about the role of the teacher in education?

What do you think about the role of the student in education?

Please give me an example where you felt that teaching year ten science went really well.

Please give me an example where you felt that teaching year ten science did not go well.

Tell me about whether you think children should be learning science. SL

Do you have a view on the role of science in sustainability?

I noticed the Enviroschools sign in front of the school. Can you tell me about that program in this school?

Can you tell me what sustainability mean to you?

The revised curriculum emphasizes systems. For example in the 'Planet Earth and Beyond' and Ecology strands. What are you thoughts on this emphasis?

How familiar are you with permaculture?

## 2nd Interview – Mid-Intervention

How is this approach working for you?

How do you think the students are responding to the intervention?

What activities do you think have worked well?

How do you think the order of the units is progressing?

What content material do you think students were most enthusiastic about?

Have you noticed any changes in the students with regards to attitude or behaviour change?

Do you have any other thoughts?

## 3rd Interview – Post-Intervention

Did this approach work for you?

Theme of 'saving the planet.' Why choose those words?

Describe the connectionss we were able to make between the 3 units.

What do you think might have helped students make connections?

What activities in the units do you think worked well?

What do you think didn't work well?

What would you have liked to know more about before teaching these units in this way?

Which aspects did you enjoy?

What do you think the students enjoyed?

How do you feel about the progression through the units?

Did you experience any particular problems or challenges in these units?

What content material do you think students were most enthusiastic about?

What content material do you think students were least enthusiastic about?

How do you think the students responded to the constant theme of saving the

Can you identify bright spots of light bulb moments for the students?

Have parents/guardians or other teachers mentioned any differences in the students with regards to attitude or behaviour change?

Have you noticed any changes in the students with regards to attitude or behaviour change?

What happened to that girl that disappeared from class?

Would you teach these units with these activities again?

Would you do anything differently?

How important do you see it is to teaching school students about sustainability?

Do you think that there is enough sustainability education happening in schools?

Do you  have any final thoughts?

# The University of Waikato

## Centre for Science and Technology Education Research

## Pre-Study Questionnaire

This questionnaire asks about your knowledge and opinions about science and the environment. Please take your time and give your best answers to the questions.

Do not put your name on this questionnaire.

Your answers will be anonymous during the entire unit.

Your teacher won't ever see your answers.

Thank you for taking part in this research.

#___

1) Use these concepts to make a concept map to show what you know about **a sustainable system for producing food**.

• Add other concepts that you think belong.
• Be sure to circle all concepts on the map.
• Be sure to label all of your links between concepts with words or phrases.

| | | | |
|---|---|---|---|
| Plants | Fertilizers | Water | Weeds |
| Sunlight | Nitrogen | Compost | Transportation |
| Animals | Gardens | Farms | Insects |
| Petrol | Organic | Local | Food |

Added Concepts:

____________________ ____________________ ____________________

A Sustainable
Food System

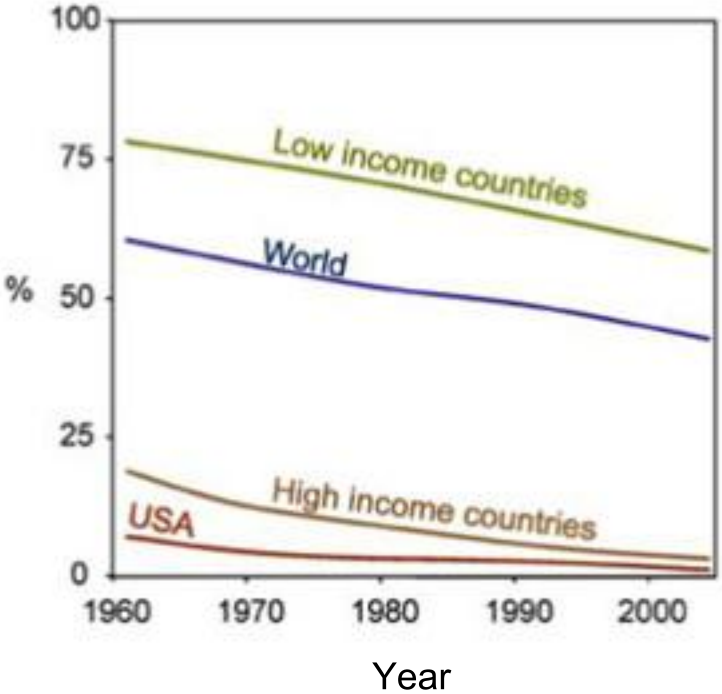
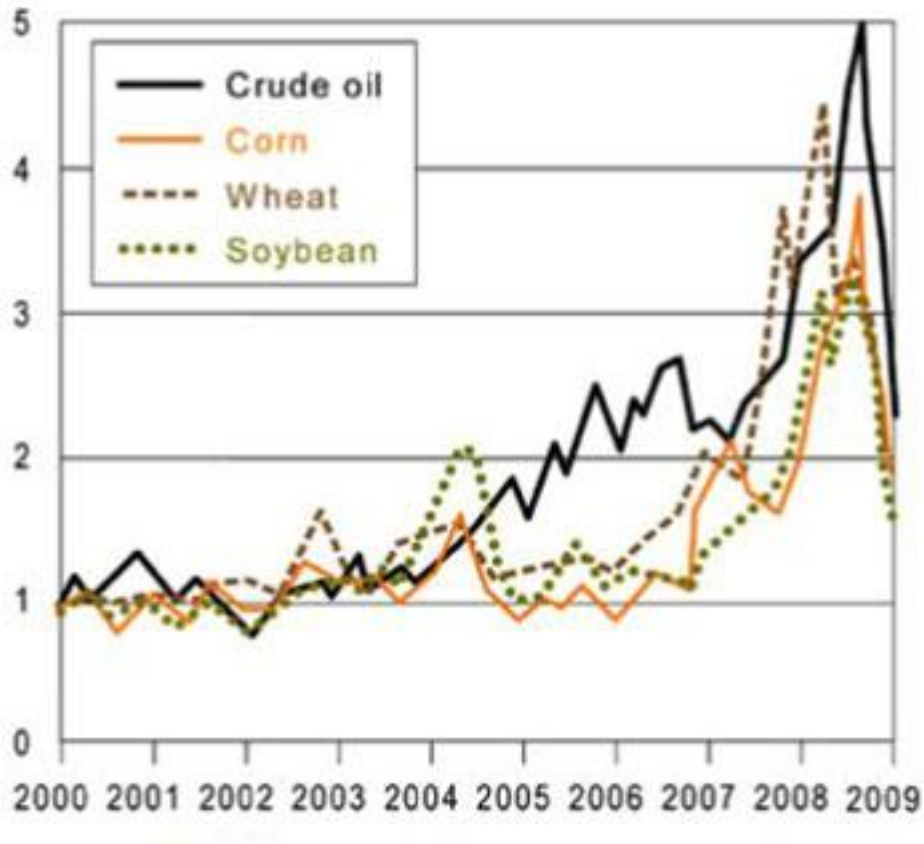



Figure 1. Percentage of people working in agriculture, 1961-2004

Use the graph above to answer these two questions.

2) What changed about the percentage of people in the world working in agriculture from 1961 to 2004?

3) Do low income countries or high income countries have a higher percentage of people working in agriculture?




Year

Figure 2. Price relationship between crude oil, corn, wheat, and soybean, 2000 - 2008.

Use the graph above to answer the next question.

4) Why might corn, wheat and soybean prices have gone up and down so much in 2007 and 2008? Give reasons for your answer.

5) Over time, growing food relies less on people working and more on oil. What might be the **economic, social and environmental** impacts of this?

**Economic impacts**

S**ocial impacts**

**Environmental impacts**

6) What might your community do to protect against a rapid rise in food prices (like New Zealand had in 2008) and also help reduce climate change?

These are 11 pairs of statements. Each pair has two different points of view on a topic.
Place your view along the scale by circling a number between 1 and 7.

- 1 means you strongly agree with the statement in Column A.
- 4 means your views are evenly balanced between the two statements.
- 7 means you strongly agree with the statement in Column B.

| | Column A | Strongly Agree Balanced Opinion Strongly Agree | Column B |
|---|---|---|---|
| 7 | Scientific ideas change over time. | 1 2 3 4 5 6 7 | Scientific ideas do not change over time. |
| 8 | Science and technology can be blamed for environmental problems. | 1 2 3 4 5 6 7 | Science and technology cannot be blame d for environmental problems. |
| 9 | Science and technology can be used to help solve environmental problems. | 1 2 3 4 5 6 7 | Science and technol ogy cannot be used to help solve environmental problems. |
| 10 | Making money should be given priority over protecting the environment. | 1 2 3 4 5 6 7 | Protecting the environment should be given priority over making money. |
| 11 | There is no limit to the number of human beings who could live on Earth. | 1 2 3 4 5 6 7 | There is a limit to the number of human beings who could live on Earth |

| | Column A | Strongly Agree Balanced Opinion Strongly Agree | Column B |
|---|---|---|---|
| 12 | I take the environmental impacts of food production into account when buying food or asking my parents or guardians to buy food for me. | 1 2 3 4 5 6 7 | I do not take the environmental impacts of food production into account when buying food or asking my parents or guardians to buy food for me. |
| 13 | I feel I should take actions to help the environment. | 1 2 3 4 5 6 7 | I do not feel I should take actions to help the environment. |
| 14 | Science classes I've been in have given me a better understanding of the way the world works. | 1 2 3 4 5 6 7 | Science classes I've been in have not given me a better understanding of the way the world works. |
| 15 | I understand why the science topics covered in school are taught. | 1 2 3 4 5 6 7 | I do not understand why the science topics covered in school are taught. |
| 16 | I like learning science in school. | 1 2 3 4 5 6 7 | I do not like learning science in school. |
| 17 | I take actions to help the environment. | 1 2 3 4 5 6 7 | I do not take actions to help the environment. |

18) If you take actions to help the environment, please give examples.

## Additions for Post-Questionnaire

These questions relate to the units on ecology and permaculture.
Circle the number that best applies for you for each statement.

| 1. Strongly Disagree | 2. Disagree | 3. Neither Agree nor Disagree | 4. Agree | 5. Strongly Agree |
|---|---|---|---|---|

I enjoyed learning science with a focus on the environment.

1 2 3 4 5

I learned about interconnections in nature and human communities.

1 2 3 4 5

Permaculture is a good way to solve environmental problems.

1 2 3 4 5

This science unit has motivated me to take actions for the environment.

1 2 3 4 5

* Only answer this question if you went on the field trip to the Raglan Food Forest.
The field trip helped me learn about environmental projects in my community.

1 2 3 4 5

* Only answer this question if you went on the field trip to Solscape.
The field trip helped me see permaculture in action.

1 2 3 4 5

Appendix D: Concept Map Quality Scoring Rubric and Protocol

Concept Map Quality Scoring Rubric and Protocol (CMQSRP)

Quality Scoring Descriptors

| | |
|---|---|
| 0 None | Represents no evidence of understanding/development of concept |
| 1 Minimal/little | Represents novice/beginning level of development of concept |
| 2 Fair/moderate | Represents an emerging level of development of concept |
| 3 A lot | Represents a great deal/high of development of concept |
| 4 All parts of concept | Represents an expert level of development of concept |

Quality Scoring Decision Rules

0 Uses the concept words provided but forms no sustainable propositions
1 Uses some sustainable propositions and some logical organization.
   Main sustainability aspects:
   Reducing the use of fossil fuels in production and transportation
   An emphasis on local markets
   Building and maintaining soil fertility
   Multiple roles of insects and weeds and their control when necessary
   The role of humans and human labour
   Reducing meat consumption
   Water use and conservation
2 Demonstrates a recognition of 3 or more of the main sustainability aspects, and the potential addition of appropriate concept words
3 High quality of linking words and phrases to form clearly understood sustainable propositions, recognition of relationships and micro-cycles within the map, overall map organization, and the addition of appropriate concept words
4 All of the main sustainability aspects are included along with appropriate additional concept words falling within the additional concepts identified on expert maps, high level of organization including the recognition of relationships, micro-cycles and feedback loops.

Based on:
Miller, K., Koury, K., Fitzgerald, G., Hollingsead, C., Mitchem, K., Tsai, H-H, & Park, M. (2009). Concept mapping as a research tool to evaluate conceptual change related to instructional methods. *Teacher Education and Special Education*. 32(4) 365-378.

Appendix E: Focus Group Interview Schedule

Can you tell me some of the things you learned during this unit on permaculture?

Were there any memorable parts of this unit, good or bad?

Do you feel differently about the environment now than you did before the unit?

Do you do anything differently now, such as recycling (more or less)
or started a compost pile? Anything else?

Do you talk more about the environment with your friends or family?

Do you think you are better at seeing interconnections than before the
unit? Can you give me an example?

Was there anything different about the teaching style in this unit?
How did it differ from other science teaching you have had in school?
Were the differences good or bad?

Do you feel any differently about learning science now? Please explain.

| Environmental Chemistry Unit | | | |
|---|---|---|---|
| Is global warming happening? | | | |
| **Learning Objectives** | **Possible Teaching Activities** | **Learning Outcomes** | **Points to Note** |
| • to use secondary sources to answer scientific questions<br>• how to decide whether evidence is good enough to answer a question<br>• to evaluate evidence put forward by others<br>• to discuss and evaluate conflicting evidence to arrive at a considered viewpoint | • **Present pupils with recent newspaper articles on climate change. Ask students what they know about it. Why has it been in the news so much lately?**<br>• **Fire lane activity. A series of questions to bring up discussion and debate, and to identify any misunderstanding. (Questions to be determined.)**<br>• Ask groups of pupils to use it to prepare answers to questions, *eg*<br>– *Have there been climate changes in the past?*<br>– *What were the effects of these?*<br>– *Is the Earth warming up? What evidence is there for this?*<br>– *If the Earth is warming, what are the possible causes of this? What role does the burning of fossil fuels play? What evidence is there?*<br>– ***What are the predicted effects on the local area?***<br>• Ask pupils to make brief presentations of their answers to the questions, making clear the evidence on which they are based. Ask other pupils to ask questions about the evidence.<br>• Discuss pupils' presentations with them and examine the ways in which fuel is used and the impact of this on the environment and ways in which fuel consumption might be usefully limited. Use concept mapping<br>• **Use concept mapping to explore the interconnections between causes and effects. (This concept map will be used as a link to the next topic, 'Acid Rain' and potential links to 'Peak Oil' that may come up through discussions with permaculturists.)** | • identify key trends in data and draw conclusions from these<br>• explain how they used the evidence to draw conclusions<br>• recognise where data is not sufficiently strong to support conclusions or can be interpreted in another way | • **'The Age of Stupid' is a film produced this year by a Dunedin woman. It is about an archivist living in the future and looking back at the present era.**<br>• **This film can be used to develop a visioning activity.**<br>• **Permaculture founder David Holmgren has just written a book called 'Future Scenarios.'** |

## Environmental Chemistry Unit (continued)

What causes acid rain?

| Learning Objectives | Possible Teaching Activities | Learning Outcomes | Points to Note |
|---|---|---|---|
| • that the atmosphere contains carbon dioxide from natural sources and the burning of fossil fuels, and this gas can dissolve in rainwater, causing it to be weakly acidic<br>• that dissolved oxides of sulphur increase the acidity of rain<br>• that oxides of sulphur in the air can arise from human activity and geological activity | • **Revisit the concept map developed in the global warming section and add acid rain to explore more interconnections.**<br>• Ask pupils what they know about the importance of carbon dioxide in the air to plants and animals from their work on photosynthesis, and remind them that the atmosphere contains carbon dioxide from natural sources. Provide pupils with a range of solutions, *eg rainwater, water with dissolved carbon dioxide, water with dissolved sulphur dioxide*, and ask them to carry out tests to rank them according to pH.<br>• Help pupils make a summary of the processes involved, *eg as a flow diagram.* Use video clips to illustrate how sulphur dioxide and oxides of nitrogen get into the air, *eg through volcanic eruptions, burning of fossil fuels*, and are transported away. | • identify which solutions are acidic<br>• recognise that solutions with lower pH will be more corrosive<br>• identify burning of fossil fuels, *eg in vehicles*, and volcanic activity as leading to acids in the environment<br>• represent, *eg by drawing flow diagrams or equations*, a sequence of reactions in which acid rain is formed | • **Cover the learning objectives from 'What happens to rocks and building materials over time?' as part of the concept mapping exercise.**<br>• Pupils will have learnt in unit 7F 'Simple chemical reactions' that oxides are formed when materials burn. This may need to be reinforced in the context of burning carbon and sulphur.<br>• Carbon dioxide as a raw material for photosynthesis is covered in unit 9C 'Plants and photosynthesis'. It is important that pupils realise that carbon dioxide in the air is essential for food production.<br>• Some internet sites provide information about, and pictures of, recent volcanic eruptions.<br>• Extension: pupils will already have represented some combustion reactions by word equations. It may be appropriate to introduce symbol equations to some pupils.<br>**Safety**<br>**–** sulphur dioxide is toxic and corrosive. Solutions should be left in stoppered bottles. Warn pupils with asthma not to inhale |

## Environmental Chemistry Unit (continued)

What are the effects of acid rain and how can they be reduced?

| Learning Objectives | Possible Teaching Activities | Learning Outcomes | Points to Note |
|---|---|---|---|
| • about the effects of acid rain on rocks and building materials<br>• why acid rain will dissolve some building stones<br>• that acids in the environment can lead to corrosion of metal<br>• to make careful observations over a period of time | • Provide pupils with named samples of a number of rocks, including some sandstones and some carbonates, *eg chalk, marble*, and metals, *eg zinc, iron, lead*, together with a very dilute solution of sulphuric acid (to represent acid rain), and ask pupils to investigate the effect of the acid on the materials. Ask them to suggest how to make and record careful observations of small changes over a period of time. Ask pupils to contribute results to a class record and bring together all the results. | • identify that acid rain affects some metals and carbonate-containing rocks<br>• record observations accurately, indicating the time intervals between them | • Lime-cemented sandstone, *eg Cotswold type*, should be used. The sand grains fall apart as the cement dissolves. Before pupils use them, clay-cemented sandstones need to be investigated to see if water causes as much effect as 'acid rain'.<br>• Pupils will have encountered the reactions of acids with carbonates and metals in unit 7F 'Simple chemical reactions' and unit 9E 'Reactions of metals and metal compounds'.<br>• Extension: pupils could be asked to suggest what would happen if acid rain were to run into a stream passing through carbonate rocks, and to find out about the formation of limestone caves.<br>**Safety:** a very dilute solution of sulphuric acid (0.005 mol $dm^{-3}$) is suitable for this activity |
| • that acid rain damages living organisms and materials<br>• about ways in which emissions of oxides causing acid rain can be reduced<br>• to use secondary sources to find information about key questions | • Ask pupils to use reference materials to identify the effect of acid rain on plants and animals in a particular location, and to identify the source(s) of the acid rain.<br>• Ask them also to find out about ways, *eg catalytic converters, sulphur precipitators,* in which acidic emissions can be reduced. Summarise both sets of information in a class display or set of information cards. | • identify a source of acid rain and its effect on living organisms within a particular environment<br>• describe how emissions from a particular source causing acid rain could be reduced | • Information about the effects and origins of acid rain can be found on the internet, *eg www.epa.gov/acidrain/student*<br>• Extension: pupils could use very dilute acid to investigate the effect of acid rain on the germination of cress seeds. |

## Environmental Chemistry Unit (continued)

Is pollution worse now?

| Learning Objectives | Possible Teaching Activities | Learning Outcomes | Points to Note |
|---|---|---|---|
| • to decide what evidence should be collected<br>• to collect evidence to answer a question<br>• how to decide whether evidence is good enough to answer a question<br>• to appraise texts quickly and effectively for their usefulness<br>• to recognise the author's standpoint and how it affects the meaning | • Review with pupils ways in which quality of air and/or water is monitored or controlled and ask them whether they think there is more pollution, *eg of air or of water*, now than there was at a specific time in the past. Ask them to suggest the basis for their answers and then to think what evidence might be collected, *eg photographs, public records, paintings, individual medical records showing outbreaks of disease, descriptions of domestic and working environments, Clean Air Act and other legislation.* Consider a selection of available evidence and compare it with today's evidence. Ask pupils to decide whether the evidence is good enough to come to a firm conclusion, and to explain their decisions. | • identify and evaluate sources of information about the past, *eg photographs of city centres, contemporary descriptions of domestic/urban/rural life*<br>• identify and evaluate sources of information about the present, *eg local and national monitoring records, media reports*<br>• identify and describe differences between evidence from the past and present-day evidence<br>• explain the strengths and weaknesses of present-day and past evidence | • Alternative questions relating to pollution in different localities could be investigated.<br>• In this activity the emphasis should be on pupils' decisions about the strength of the evidence, rather than on the answer to the question about pollution |
| • how air or water pollution is monitored and controlled | • Invite an adult responsible for environmental matters, *eg an environmental health officer*, to talk about their work. Ask pupils to prepare questions to ask, *eg about the way in which air quality and water pollution are monitored, how the information is made public, what is done when air pollution rises.* Using the information from the talk and other sources, ask pupils to compile a summary sheet of what is done to protect their local environment, *eg the air and water quality.* | • describe ways in which pollution in their locality is monitored<br>• identify steps taken to reduce pollution | .•**Save some of these questions for the soils field trip below with a permaculturist. They are likely to be aware of changing local conditions.** |

## Environmental Chemistry Unit

How are soils different from each other?

| Learning Objectives | Possible Teaching Activities | Learning Outcomes | Points to Note |
|---|---|---|---|
| • that different soils have different characteristics, including pH ranges, and that this affects the plants that grow in them<br>• to locate information about plants and preferred soil types in secondary sources<br>• to use knowledge about acids, alkalis and neutralisation to suggest ways of reducing the acidity of soils | • **Cover as much of this topic on a field trip with a local permaculturist.**<br>• Use secondary sources, *eg photographs, video clips,* to remind pupils about sedimentation and ask them what else they think plays a role in soil formation. Establish that vegetation and soil animals are also important.<br>• Present pupils with information about different soils and show them soil-testing kits. Ask them to use secondary sources to find out why soils are acidic or alkaline, and to identify problems that this might cause and suggest possible cures.<br>• Ask pupils to use the kits to test local and other soils. Use secondary sources to identify plants often found in particular soil types, *eg in the locality of the school,* the implications of soil type for agriculture and effects on some plants, *eg hydrangea colour.* Help pupils to summarise what they have found out in a database and use this to produce an information sheet. | • identify a range of differences between soils<br>• use the results from work with soil-testing kits to rank soils in terms of acidity<br>• identify and make a record of plants that are likely to grow well in a particular soil, *eg in the locality of the school*, and some that are not<br>• suggest suitable methods of reducing acidity or alkalinity of soils | • **The field trip serves as an introduction to permaculture for the students. It will also emphasize the importance of soils in permaculture.**<br>• **Alongside any chemical testing of soils, make sure to include the emerging use of biological soil testing. Many permaculturists are interested in the 'Soil Food Web' work of Dr. Elaine Ingham.**<br>• **The 'Soil Food Web' will provide a good link to the next unit, 'Ecological relationships.'**<br>• See unit 3D 'Rocks and soils' and unit 6A 'Interdependence and adaptation' in the key stage 2 scheme of work. Unit 8G 'Rocks and weathering' covers the formation of sediment. The pH scale is introduced in unit 7E 'Acids and alkalis'.<br>• It is important to make sure that pupils do not attribute all acidity in soils to acid rain. Contact with vegetation (roots) amplifies acidity.<br>• Extension: pupils could survey wild flowers found in their immediate locality, relating this to preferred soil type, and exchange information with other schools via e-mail or the internet.<br>**Safety**<br>– if soils collected locally are used, check they are not contaminated with dog faeces. Wash hands after |

## Environmental Chemistry Unit

What happens to rocks and building materials over time?

| Learning Objectives | Possible Teaching Activities | Learning Outcomes | Points to Note |
|---|---|---|---|
| • that rocks and building materials change over time<br>• about factors that affect the way in which materials change | • As a quick introductory activity, remind pupils of earlier work on local rocks and building materials and ask them to describe changes and compile a list of possible causes. Reinforce by showing video clips and/or photographs of a wide range of non-local weathered buildings and/or rocks and ask pupils to suggest a range of factors affecting weathering, *eg nature of rock, climate, local conditions of air, water, soil, position, vegetation cover*.<br>• Ask pupils to identify factors that lead to extensive chemical weathering. | • describe how the appearance of landforms and/or buildings may change over time<br>• identify factors, *eg low pH of air and rain together with high rainfall,* that favour chemical weathering | • **Cover these learning objectives while concept mapping with acid rain in the previous section.**<br>• Pupils could be shown photographs of Cleopatra's Needle in London and a corresponding obelisk in Egypt to compare the two.<br>• The effect of vegetation could be illustrated by showing a photograph of a boulder of granite that has not weathered above the surface but beneath the soil and vegetation has been eaten away. |

## Ecological Relationships

How do living things in a community depend on each other?

| Learning Objectives | Possible Teaching Activities | Learning Outcomes | Points to Note |
|---|---|---|---|
| • that all feeding relationships within a habitat are interconnected<br>• that food webs are made up of a number of food chains<br>• to make predictions about the effect of different environmental factors on plant and animal populations<br>• to use ICT to model population changes<br>• that plants benefit from waste products and the decay of other organisms | • **Use the 'Soil Food Web' to link to other food webs**. Ensure that they can identify the food chains within a food web, and that they understand the terms 'producer' and 'consumer' and the flow of materials through the food chain.<br>• Challenge pupils to predict the effects of making changes to the numbers of one type of organism. Encourage pupils to go beyond simple relationships by considering knock-on effects of a single change, *eg as the number of rabbits decreases, more grass will grow, providing more food for other grass-eating animals, whose numbers may increase as a result.* **Systems thinking activities and further concept mapping can be used here.**<br>• **Ask pupils to consider a range of examples of such changes in communities and their consequences. Introduce the concept of 'Tragedy of the Commons.' Various activities and case studies can be employed here.** | • identify the food chains which make up a food web<br>• use the terms 'producer', 'consumer' and other terms related to feeding<br>• describe how a food web shows the feeding relationships within an environment<br>• predict how changing the size of one population will affect the numbers of other species<br>• present data from simulations as graphs and make predictions from patterns in these | • **Emphasize interconnectedness. The Linking Thinking curriculum has many high quality activities.**<br><br>• **A case study of DDT in Borneo illustrates knock-on effects and interconnectedness very well.** |
| • to identify patterns in data<br>• that a pyramid of numbers describes the numbers of food plants, herbivores and carnivores in a habitat<br>• that there is a flow of energy from the producer to the final organisms in the food chain | • Provide pupils with data on the numbers of animals and plants in a community and what they feed on. Ask them to count up numbers of producers, herbivores and carnivores, and to look for patterns in the results and to repeat for a different set of data. **Compare a natural community with the town of Raglan. How are human communities similar and different to natural communities?** Ask pupils whether the pattern in the two sets of data is the same. Show them how to represent the data as a pyramid of numbers and explain the usefulness of this model in considering the interdependence of living things.<br>• Show pupils examples of inverted pyramids of numbers, *eg involving an oak tree,* and ask them to explain how these are different. | • draw pyramids of numbers from data provided<br>• explain how a pyramid of numbers describes the number of producers, herbivores and carnivores in a habitat<br><br>• describe how there is a flow of energy from the producer to the final organisms in the food chain | **The comparison between human and natural communities can be put off until the section ''Why do the communities differ in different habitats?'**<br>• The term 'trophic level' is not required at this stage.<br>• Data on numbers of animals in the community studied in the field should be used for this activity, if available. This can then be built on using secondary data. |

## Ecological Relationships (continued)

How can animals be classified?

| Learning Objctvs | Possible Teaching Activities | Learning Outcomes | Points to Note |
|---|---|---|---|
| • that organisms only survive in a habitat where they have all the essentials for life and reproduction | • Review what pupils recall from previous work on living things in the environment by providing stimulus pictures of different habitats and asking pupils to suggest what types of animal and plant live there. Ask pupils to suggest reasons why the animals and plants differ, focusing on environmental factors. Use the opportunity to encourage pupils to think about how organisms get all the things they need to survive in these habitats. **How do people in Raglan meet their needs?** | • suggest how organisms living in different habitats obtain the essentials for life and reproduction<br>• identify organisms likely to be found in a habitat | • The first two activities are intended to find out what pupils know and understand about living things in habitats. Teachers will need to bear this in mind in later work. |
| • that animals can be divided into vertebrates and invertebrates and that these groups can be further subdivided | • Remind pupils of the work they did in year 7 on classification and using, *eg photographs, ICT resources,* as stimulus material, establish that it is helpful to classify organisms into plants and animals and that animals can be subdivided into vertebrates and invertebrates. | • describe differences between vertebrates and invertebrates<br>• name some groups of invertebrate and give examples of these | • The number of vertebrate and invertebrate groups introduced is likely to depend on the habitats to be investigated in the next part of the unit. At this stage it is not necessary for pupils to distinguish between levels of subgroup, *eg phylum, class.* |
| How can green plants be classified? | | | |
| • that green plants can be subdivided into those with vascular tissues (xylem and phloem) and complex leaves with a waterproof cuticle, and those without | • Show a selection of common living plants, *eg mosses, liverworts, ferns, conifer branches, pelargonium and grass in flower.* Ask pupils to suggest where, and in what environmental conditions, each might be found. Show how plants are subdivided into two groups: plants without waterproofing layers, *eg mosses, which are confined to damp environments,* and plants with waterproof cuticles, which inhabit a wider range of habitats. **Weigh the pros and cons of specialization vs. adaptability.**<br>• Ask the pupils about other features shown by the plants. Use their suggestions to form the basis of classification, *eg ferns, cone-producing plants and flowering plants.* | • recognise that plants are subdivided into groups based on characteristics such as vascular tissue and seed- or spore-bearing reproduction<br>• explain why mosses are found in places that are damp | • **Emphasize the unique ability of legumes to fix nitrogen in the soil. This will come up in later units on growing food and the importance of legumes in permaculutre.**<br>• **Classify different varieties of vegetables. This will come up in later units on growing food and the importance of legumes in permaculutre.** |

## Ecological Relationships (continued)

How do plants, animals and environmental conditions interact in a habitat?
a) How can we collect data to answer questions about a habitat?

| L. Objectives | Possible Teaching Activities | Learning Outcomes | Points to Note |
|---|---|---|---|
| • how to frame questions that can be investigated<br>• to use scientific knowledge and understanding to raise questions about habitats<br>• to decide what data might be collected and how to present data<br>• how to use ICT to measure and record environmental factors | • **Start with a short video clip of permaculture founder Bill Mollison talking about how he spent lots of time observing nature to come up with the permaculture principles. Encourage students to think about how humans can learn from nature to be more sustainable. Do some plants and animals fit better into certain habitats than others?**<br>• Organise fieldwork in a suitable location, *eg woodland, pond, stream, school grounds, wall, paving stones, park, sand dunes, rocky shore*, and discuss with pupils the questions they will try to answer during the work, *eg*<br>– *What lives there?*<br>– *Why do communities differ in different habitats?*<br>– *How can we measure sizes of populations of living things?*<br>• Ask pupils for ideas about data they will need to collect to answer the questions, how they will go about it and what they will do with the data collected when they return to school.<br>• Remind pupils of how to use dataloggers to collect remote data when outside, *eg temperature variations, dissolved oxygen, light intensity and humidity*, and how to produce graphs from the data collected. Discuss the formats to be used for presenting results in the fieldwork activity.• Challenge pupils to explain how plants benefit from the other organisms in the community. | • decide on questions to be investigated<br>• suggest data to be collected | • It is helpful if the locality chosen allows two contrasting habitats to be studied. **The second habitat to be studied can be the town itself. How does a human community function like a natural community? How does it differ? Given what we have learned about global warming, acid rain and peak oil, should we be concerned about the current structure of human communities?**<br>• Pupils are likely to have used environmental sensors and computers to collect and display environmental data in unit 7C 'Environment and feeding relationships'. |
| • about the importance of sampling in biological studies<br>• about the use of quadrats as a sampling technique for investigating populations<br>• to sample using quadrats | • Ask pupils to suggest how they might go about finding out the size of a population of a plant or animal living in a habitat. Help them to realise the limitations of simply counting in some situations, *eg where the animals are difficult to find, or where they occur in large numbers.* Explain the principles behind sampling as a means of collecting this type of data in biological studies. Describe different methods of sampling populations including the use of quadrats.<br>• Provide groups with trays of sand, in which small steel tacks have been buried. Show them how to use small wire square quadrats to sample areas of the tray, using a magnet to remove the tacks within a quadrat. Ask them to estimate how many tacks are hidden, by taking ten quadrat samples, and to explain why taking ten samples gives more reliable data than taking one.• | • explain why it is sometimes necessary to use sampling methods to get information in biological studies<br>• use data from quadrat sampling to give information about population size<br>• explain why one sample might provide misleading results | • Detailed mathematical treatments are not required in this key stage.<br>• This activity illustrates how a sample can be taken. It is not a substitute for sampling within a natural habitat. |

## Ecological Relationships (continued)

b) What lives there?

| Learning Objective | Possible Teaching Activities | Learning Outcome | Points to Note |
|---|---|---|---|
| • to observe and record the organisms which comprise the living community in a habitat<br>• to work safely with living things<br>• to show sensitivity to living things in their environment | • Agree with pupils what data they are going to collect and show them ways of finding and observing living things in the habitat being studied. Make sure they understand issues relating to safe working and care for living organisms.<br>• Show pupils ways of collecting specimens of animals, *eg using pooters.*<br>• Provide pupils with resources, including keys, field guides to help them find, collect, and identify typical animals and plants that they may come across. If possible, help pupils to use a digital camera to make a record of the habitat and organisms found. | • observe and record the organisms which comprise the living community in a habitat<br>• work safely with living things and show sensitivity to them<br>• make records in an appropriate way, *eg using a digital camera* | • A prepared spreadsheet template on a portable computer can help with the collection of data in the field.<br>• If small invertebrates are removed from their habitat, ensure they are treated with care and returned as soon as possible. Avoid disturbing the habitat. Plants should not be removed unnecessarily. Stones or logs should be replaced if they are turned over.<br>• Pupils could be reminded that most micro-organisms within a habitat will not be found in this kind of activity.<br>**Safety** -wash hands after handling animals. Pooter mouthpieces should be disinfected each time they are used. Wipe benches |
| • that different habitats support different living things<br>• to describe and evaluate how the work was undertaken and what led to the conclusions | • If possible, ask different groups of pupils to make and collect data about the communities in two different habitats within the same locality, and share findings as a report in the classroom. **Use the local human community as the second habitat. Ask students a series of questions such as:**<br>- **where does the energy come from for each?**<br>- **What resources does each use? Where do they come from?**<br>- **What does each produce? Where do those products go?**<br>- **What are the nutrients of each system? Where do they come from?**<br>- **What is the level of diversity of each system?**<br>• Ask pupils to produce a report of their findings, describing what they did, comparing the communities and saying what led to their conclusions.. | • describe how the communities in two habitats differ<br>• describe, *eg in an OHT/ Powerpoint presentation*, how they carried out their work and explain how they came to their conclusions | • **After brainstorming about how human communities are different from natural communities, have them go down town and observe as if they were doing a field study of a natural habitat. See what they come up with.** |

## Ecological Relationships (continued)

c) Why do the communities differ in different habitats?

| Learn Objectives | Possible Teaching Activities | Learn Outcomes | Points to Note |
|---|---|---|---|
| • to use ICT to measure, record and describe environmental factors<br>• that different habitats have different environmental features | • Agree with pupils what data they are going to collect about the environmental factors of the habitat, *eg temperature variations, light intensity, dissolved oxygen.* Provide them with the appropriate apparatus, including dataloggers. Ask pupils to make a record of environmental conditions. | • collect data, *eg temperature variation, light intensity within a habitat*, using ICT<br>• use data collected to compare different habitats | • **This section is applied to the ongoing comparison of the natural habitat and the human habitat.**<br>• It may be helpful to decide beforehand on the format for recording environmental conditions. If a spreadsheet is used, pupils could investigate the data and produce graphs.<br>• Many CD-ROMs and internet sites are good sources of information on environmental conditions and on the organisms associated with different habitats |
| • to group sentences into paragraphs that are clearly focused and well developed | • Ask pupils to write a report, including graphs of the data, about ways in which the two environments are different and encourage them to make associations between some of these conditions, *eg in ponds, warm conditions and abundant plant growth can result in low oxygen levels, fast-flowing water in streams leads to cooler conditions.* | produce a report comparing two environments, incorporating appropriate data and other information | The term 'habitat' refers to a place; 'environment' refers to the surroundings. In this activity, pupils are comparing the environmental features of two habitats and are therefore comparing two environments. Pupil records of comparisons of environments could be combined |
| • that organisms show adaptations to environmental conditions<br>• that both plants and animals are adapted to ensure the survival of the species | • Ask pupils to make suggestions about how the conditions in each habitat influence the communities of organisms living there, *eg by asking why there is more of this here than over there,* and ways in which animals and plants are adapted for the problems of living within those environmental conditions, *eg pond communities contain rooted plants on the fringe and floating plants in the middle of the pond, and an abundance of free-swimming animals, while fast-running streams may have plants with long, flexible stems, and animals adapted to holding on to a stony substrate.*<br>• Help pupils to present their work as a wall display, including images of animals and plants showing relevant adaptations. | • describe organisms which show adaptations for particular habitats, and explain how these help the organisms to survive<br>• explain that both plants and animals are adapted to ensure the survival of the species | • As a classroom-based alternative, ask pupils to search secondary sources of information, or use real data about the environmental conditions of the two habitats being compared, *eg*<br>*– temperature at different depths, flow rate, light intensity, availability of dissolved oxygen for two aquatic habitats*<br>*–temperature, moisture, organic content, mineral content, pH for two soils*<br>*–air temperature, humidity, light intensity, wind, for two terrestrial habitats* |

## Ecological Relationships (continued)

d) How big are the populations in the habitat?

| Learning Objectives | Possible Teaching Activities | Learning Outcomes | Points to Note |
|---|---|---|---|
| • how to use quadrat sampling techniques to collect information about populations of organisms<br>• how to record data in appropriate ways | • Remind pupils about quadrat sampling and help them to collect quantitative data about number and distribution of organisms, *eg count and find out about distribution of weeds on a school field, limpets on a rocky shore or earthworms in the soil; estimate percentage cover of different plant types in different habitats or in different areas of a habitat, such as along a transect.* Arrange for pupils to collect comparative information from two habitats, or different parts of a habitat for which environmental data has also been collected. | • collect information about the number and distribution of organisms in a quadrat sample<br>• use sample data to estimate a population<br>• record data in appropriate ways | • **Continue the comparison of human and natural habitats**. |
| • that abundance of organisms in habitats is affected by environmental factors such as availability of light, water and nutrients<br>• that distribution of organisms in an environment is affected by environmental factors<br>• that the size of a population depends on resources | • Ask pupils to represent the data graphically, to make comparisons of the data and to suggest reasons for the distribution of organisms. Encourage them to consider the range of resources needed by animals, *eg nesting sites, mates,* and how environmental differences affect numbers and distribution of organisms. **Consider the resources needed in human communities, particularly energy. Recall the concept maps on climate change, acid rain and peak oil.** They should also be able to suggest ways in which organisms may influence each other, *eg a large tree shading the area below it, preventing other plants from growing; availability of food influencing animal distribution.* ***Starting to think ahead to how human food systems can be designed on ecological principles. What are the challenges to look out for and what are useful lessons learned?***<br>• Help pupils to bring together all the work resulting from their field trip as a classroom display. | • suggest how environmental factors, *eg availability of light, water and nutrients,* affect numbers of organisms<br>• describe how the distribution of organisms depends on environmental factors<br>• explain how the size of a population depends on resources | • Data collected in the field may need to be supplemented by data from secondary sources.<br>• If possible, compare results with those from a previous year. Building up long-term data can help to make sense of some of the variables noted.. |
| Reviewing work | | | |
| | • **Field trip or overnight trip to Solscape to look at how one human habitat is trying to follow ecological principles.** | | |

## Plants For Food (continued)

How do fertilisers affect plant growth?

| Learn Objectives | Possible Teaching Activities | Learning Outcomes | Points to Note |
|---|---|---|---|
| • to use ideas about feeding relationships in a new context<br>• to combine ideas from different sources | • **Watch the new film, 'Food, INC' and use the discussion guide to get students talking about the film.** | • construct a food web showing feeding relationships of humans<br>• explain the meaning of terms, *eg producer, consumer, energy source, herbivore,* in relation to food chains | |

## Plants For Food

Where does our food come from?

| Learning Objective | Possible Teaching Activities | Learning Outcome | Points to Note |
|---|---|---|---|
| • to observe and record the organisms which comprise the living community in a habitat<br>• to work safely with living things<br>• to show sensitivity to living things in their environment | • Agree with pupils what data they are going to collect and show them ways of finding and observing living things in the habitat being studied. Make sure they understand issues relating to safe working and care for living organisms.<br>• Show pupils ways of collecting specimens of animals, *eg using pooters.*<br>• Provide pupils with resources, including keys, field guides to help them find, collect, and identify typical animals and plants that they may come across. If possible, help pupils to use a digital camera to make a record of the habitat and organisms found. | • observe and record the organisms which comprise the living community in a habitat<br>• work safely with living things and show sensitivity to them<br>• make records in an appropriate way, *eg using a digital camera* | • A prepared spreadsheet template on a portable computer can help with the collection of data in the field.<br>• If small invertebrates are removed from their habitat, ensure they are treated with care and returned as soon as possible. Avoid disturbing the habitat. Plants should not be removed unnecessarily. Stones or logs should be replaced if they are turned over.<br>• Pupils could be reminded that most micro-organisms within a habitat will not be found in this kind of activity.<br>**Safety** -wash hands after handling animals. Pooter mouthpieces should be disinfected each time they are used. Wipe benches |

Appendix G:   Permaculture Document for the Teacher

Introduction:
Permaculture is about recognizing and cultivating networks of beneficial relationships. To do this, it uses ecosystems as model examples of networks of beneficial relationships. The science unit on ecological relationships can emphasize what we can observe in, and learn from, nature in terms of sustainability. Suggested activities and emphases are on the unit plan I sent last week. I can provide more information for you as well as arrange all guest ‘citizen scientists.’

There are two types of permaculture in practice.

1) ‘Original permaculture’ seeks to imitate ecosystems in a direct way. Key characteristics include plant and animal diversity, perennial crops, no dig/ no till agriculture. A food forest is a classic example of this. There is a food forest in Raglan West.

2) ‘Design permaculture’ seeks to place elements of a system in relation to each other to maximize beneficial relationships in highly functional design. Solscape is in the process of applying design permaculture to the property and business.

In terms of permaculture in school science, I see 4 ways in which it can align with the ecological relationships and plants for food units:

a) Ecological Thinking, aka systems thinking and holistic thinking.
This takes the form of emphasizing the interconnectedness of human systems that we observe in natural systems. Concept mapping can be used to help students practice recognizing interconnectedness. Other activities that do the same include: DDT in Borneo case study activity; Web of life/Ball of yarn activity; Talking about the new film ‘Avatar,’ which many students will have seen, and the emphasis on a forest ‘network’ on Pandora.

b) Bio-mimicry.
This is literally about imitating nature for more sustainable design and manufacturing processes and materials. It can be done on a small scale or a large scale.

Small scale: Last year when I visited your class you played a newsbyte about researchers who were trying to mimic optic lenses in shrimps’ eyes. There are heaps of other examples in the news (I listened to a 2 minute podcast about one today), and I have a DVD on bio-mimicry as well. I would be happy to scour the internet for this type of newsbytes for your class.

Large scale: A food forest like the one in Raglan West would be an example of larger scale bio-mimicry. Solscape is in the process of mimicking nature as a human ecosystem.

c) Using an understanding of science for local environmental problem-solving.
Good examples of this revolve around energy issues. For example, how the second energy law (thermodynamics) can help someone design an energy efficient home.
I have an age appropriate activity that involves students making small, paper and plastic passive solar houses, setting them in the sun with thermometers inside, and comparing one house 'with the drapes open' and another 'with the drapes closed' (a piece of paper covering the window). This also demonstrates how one version of the 'greenhouse effect' can be beneficial to saving energy, and making more comfortable and healthy homes for New Zealanders.

Another example that somewhat relates to the flaming tea bag experiment you did in class is the use of a 'solar chimney' to create negative pressure inside a 'cool cupboard' which draws in cool air from the shady side of a home to reduce the need for refrigeration.

Indirectly, changes in air pressure globally generate winds that can turn a spinning vent atop a chimney on a composting loo so that air is continually drawn into the chamber and up the chimney to keep smells out of the house.

Also, an understanding of particle sizes of sand and gravel, combined with a knowledge of wetland plants can lead to the design and construction of 'artificial wetlands' to cleanse waste water on individual or community scales.

In the garden, understanding predator/prey relationships aid integrated pest management and the promotion of 'beneficial insects.'

d) Permaculturists as practicing citizen scientists.
This includes organic farmers like Kaiwaka and Lynne, and Rick and Liz, who make careful observations, keep records, note unusual happenings, draw on the work of others, carry out experiments with controls, independent and dependent variables, etc.

On a final note, as a design permaculturist myself, my challenge is to design the permaculture approach to science specifically to the resources and patterns of your year 10 science class. The last two weeks have been extremely valuable for me to observe those patterns and resources. Although funding for transportation may limit the role of field trips in the design, I see great potential for the role of daily newsbytes in echoing the themes of the ecological relationships unit and plants for food unit. As I mentioned above, I am happy to glean appropriate newsbytes that introduce/reinforce each daily lesson and provide them to you in advance.

As I wrote in the first sentence above, permaculture is about cultivating beneficial relationships. One might say symbiosis. You are helping me tremendously, and I'd like to support you as much as I can while remaining in the background of the classroom.

# Mission Possible: Using Science to Save the World

## Field Trip on 19th March to Food Forest

In science class, we have been studying ecology. In permaculture, people use scientific knowledge to build a ‘cultivated ecology.’ The Food Forest is a good example of ‘cultivated ecology.’ Lets go find out what this is all about…

Some definitions:

Permaculture: Permaculture uses science and ethics to design and build sustainable human communities.

Sustainable: Something that can go on and on forever.

Sustainability: When the *environment*, *society* and the *economy* work together so that people and nature can live in harmony for decade after decade.

Permaculture Ethics:

Care for the Earth
Care for people
Share the surplus

• Meeting someone who practices permaculture.
After listening to the guest, write down the science words they used in their talk.

Why did they say they wanted to make a food forest?

What is a food forest?
• At the Food Forest. Ask anyone to help you answer these questions.
What do you notice is different between a food forest and a fruit orchard?

What covers the ground in the food forest? Why?

How many different trees are planted? Why?

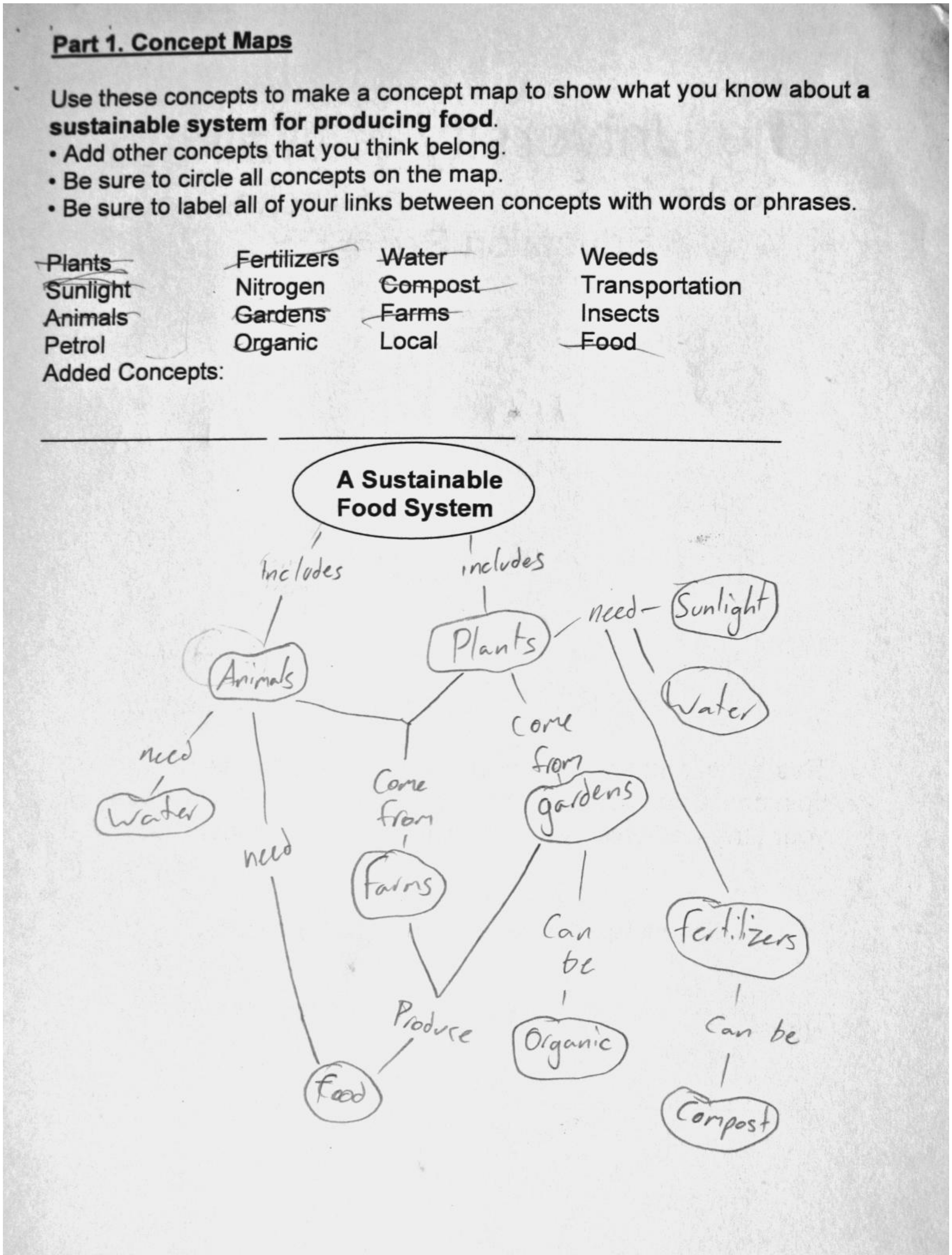
Organic? What does that mean?

• Soil & Water Experiment:
1) Have a watch ready to time.
2) Quickly pour 400 mL of water into the can and start timing.
3) Stop timing when all of the water has soaked into the ground.
4) Repeat with the other can.

Homework: Please answer these questions in your notebook:
What did you do?
What happened?
Why do you think it happened?
What did you learn in class today?

Appendix I: Scott's Concept Map

Pre-questionnaire:



**Part 1. Concept Maps**

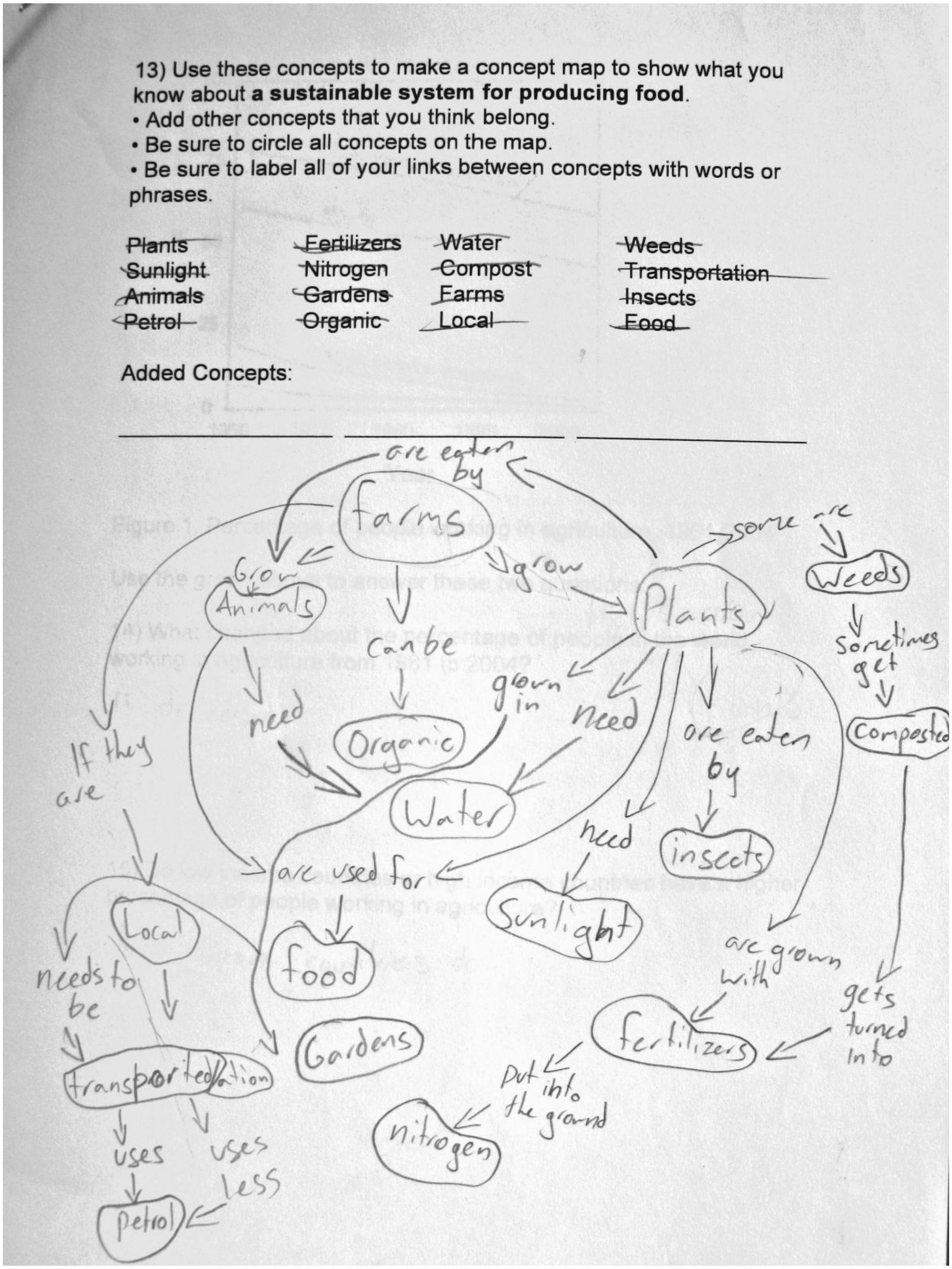
Use these concepts to make a concept map to show what you know about a **sustainable system for producing food**.

- Add other concepts that you think belong.
- Be sure to circle all concepts on the map.
- Be sure to label all of your links between concepts with words or phrases.

| | | | |
|---|---|---|---|
| ~~Plants~~ | ~~Fertilizers~~ | ~~Water~~ | Weeds |
| ~~Sunlight~~ | Nitrogen | ~~Compost~~ | Transportation |
| Animals | ~~Gardens~~ | ~~Farms~~ | Insects |
| Petrol | Organic | Local | ~~Food~~ |

Added Concepts:

Post-questionnaire:


13) Use these concepts to make a concept map to show what you know about **a sustainable system for producing food**.
• Add other concepts that you think belong.
• Be sure to circle all concepts on the map.
• Be sure to label all of your links between concepts with words or phrases.

| | | | |
|---|---|---|---|
| ~~Plants~~ | ~~Fertilizers~~ | ~~Water~~ | ~~Weeds~~ |
| ~~Sunlight~~ | ~~Nitrogen~~ | ~~Compost~~ | ~~Transportation~~ |
| ~~Animals~~ | ~~Gardens~~ | ~~Farms~~ | ~~Insects~~ |
| ~~Petrol~~ | ~~Organic~~ | ~~Local~~ | ~~Food~~ |

Added Concepts: