Ecological Concept Development at the Elementary School Level

by

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Masters Thesis

Submitted to the Graduate Faculty of Education

Lakehead University

In Partial Fulfillment of the Requirements

for the Degree of Masters of Education

Acknowledgements

In this journey I was blessed to be working with someone I admire so much. Dr. Tom Puk, I am deeply indebted to you. A HUGE thank you from the bottom of my heart for the *endless* hours you gave in helping me produce this thesis. Your patience, guidance and wisdom lead me to complete what seemed like a never-ending process. How much you care about your students and the natural world is truly inspirational. Your teachings sparked a passion in me and this passion became the catalyst for my thesis topic, and now influences the way I view and interact with the world. As always, it was a pleasure working with you.

Next, I would like to acknowledge committee members Dr. Rahim, and Dr. Brady for your time, effort, and suggestions. Your suggestions were a tremendous help in the creation of this thesis. I thank you for sharing your knowledge and expertise with me.

To my children, Trysten, Keegan and Braya I cannot thank you enough for being so patient and understanding as I pursued this aspiration of mine. I am truly blessed to have such remarkable children; the three of you are definitely the force that drives me. I love you always xo. To my life partner, Ryan, now where would I be without your continual support? Thank you for being my rock, listening to me vent when I needed to, and for always believing in me. I will never forget that and I love you too. Also to my best friends Shannon and Keri, I thank you both for grounding me when I lost sight and filling me with your encouraging messages to keep me moving forward. It meant more to me than you know, and I am blessed to have you both in my life xo. And naturally to my mother Connie (Wayne), my father Randy (Suzie), and my two brothers Ryan and Joey, thank you for your constant support throughout this whole process and throughout my entire academic career. It did not go unnoticed. I love you all xo. My message to you the reader: challenge yourself, step outside your comfort zone, and you may be pleasantly surprised with what you can achieve; I was. Enjoy!

Abstract

This case study of one school was designed to examine the level of knowledge and understanding elementary students (ages 9 – 13) have for key ecological concepts that are found in the Ontario 2007 science curriculum guidelines for grades 4, 6, and 8. This study utilizes the research design technique of concept analysis to investigate the level of maturity of understanding found in elementary students‟ definitions for these ecological concepts. The study revealed that a majority of students possess a limited understanding of the concepts of *photosynthesis*, *decomposition*, *greenhouse gas*, *recycling* and *biodiversity*. The study also found that students possess quite varied meanings for the concepts of *the environment*, *sustainability* and *green*. This limited understanding of concepts and the variability of meaning demonstrated that there was limited growth in concept development from grade 4 to grade 8. The results of this one study may encourage educators to consider further the importance of focusing on ecological concept development in elementary education.

Table of Contents

List of Tables

List of Figures

Chapter 1: The Nature of the Problem

Chapter Overview

This chapter begins with a discussion about the background influences impacting this study. This is followed by a description of the purpose and need for the study that involved collecting and analyzing elementary students‟ ecological concept meanings. A third section provides a review of the concepts used in the study and explains where they can be found in the Ontario Ministry of Education *Science and Technology* (2007a) curriculum guidelines. The final section outlines the design of the study including assumptions, definitions of key terms and limitations.

Background Influences of the Study

According to Hodson (2003) environmental problems exist because of our internal view of the world. Our choices reflect our inner thoughts. If humans continue to make decisions negatively affecting other living organisms and natural systems on this planet, then the result will be detrimental. Tolle (2005) articulates how "the unprecedented violence that humans are inflicting on other life-forms and the planet itself..." is "[d]riven by greed, ignorant of their connectedness to the whole, humans persist in behavior that, if continued unchecked, can only result in their own destruction" (p. 11). Humans blindly assist in the perpetual loss of natural systems; it will not only affect these systems, but also threatens other natural systems which are dependent upon the organisms, creating a succession of destruction. Tolle (2005) refers to this sightlessness as "[d]ysfunction of the human mind" (p. 11).

Human innovations starting from the industrial era to more recent innovations such as the computerization of economies (Kasa, 1973) forever changed the dynamics of the human-earth relationship. Human dependence on machines increased fossil fuel consumption,

extraction of natural resources, and pollution of water systems at an exponential rate. Some of the innovations designed to aid humans are slowly deteriorating the health of the earth and putting all living species into jeopardy. "Human pressures on the Earth‟s ecosystems and climate, unless mitigated substantially, will cause dangerous climate change, massive species extinctions, and the destruction of vital life-support functions" (Sachs, 2008, p. 6). Therefore, the onset of the 21st Century has illuminated ecological challenges facing humankind. Climate change, biodiversity disruption, deforestation, land and water resource depletion, alongside a rising global population, are all contributing to the degradation of the natural world.

The Earth is home to numerous interconnected organisms. Despite this, humans‟ intellectual capability to understand this, critics claim that we habitually take this planet for granted.

> The biospheric membrane that covers Earth, and you and me, is the miracle we have been given. And our tragedy, because a large part of it is being lost forever before we learn what it is and the best means by which it be savored and used.(Wilson, 2002, p. 21).

We depend on the health of the planet and organisms we coexist with. However, many years of harmful human activities has driven the atmospheric carbon dioxide levels up to a dangerous point of disrupting natural systems (Speth, 2008, p. 2). Another ecological problem is deforestation, i.e. the permanent removal of forests, also negatively contributing to the acceleration of the previous problem. Approximately17% of the total greenhouse gas emissions are a result of deforestation (Tacconi, 2007, p. 6). The continuance of climate irregularities may lead to a loss of biodiversity (Pimm, 2009, p. R595). Wilson (2002) predicts that "at least a fifth of the species of plants and animals would be gone or committed to early extinction by 2030 and

half by the end of the century" (p. 102). Conkin (2007) suggests that in this century the earth is in a new era of massive extinctions with the possibility of surpassing the number of previous geologic extinctions (p. 132). Abuse of land and water resources drastically disrupts and accelerates changes in the ecosystem, resulting in biodiversity loss. "Human impacts have pushed estuarine and coastal ecosystems far from their historical baseline of rich, diverse, and productive ecosystems" (Lotze et al., 2006, p. 1809). Similarly, Scherr (2000) discusses agricultural productivity, particularly in poverty stricken countries, having an increase in disease and pest problems due to a declination in agrobiodiversity (p. 480). Additional consequences of land use changes cause disruptions of hydrological systems and soil degradation (Meyer & Turner, 1992, p. 39).

Rapid growth of the human population is another integral factor affecting natural resource depletion. As a result of "… the population explosion, never before have so many environmental problems been global in their implications …" (Conkin, p. 28). The demand continually grows and nature simply struggles to repair itself. Rees (1992) explains that natural resources are life-support functions of the ecosphere and their depletion is unacceptable. This perpetual behavior towards earth is only diminishing the quality of life for all species. "Humanity has so far played the role of planetary killer, concerned only with its own short-term survival. We have cut much of the heart out of biodiversity" (Wilson, 2007, p. 102). However, remedial measures wait in the milieu for a critical mass to address the global ecological crisis.

Many studies have examined the impact of harmful human behaviours and attitudes which are affecting earth"s health and longevity. (Hoffman & Sandelands, 2005; Hunter & Rinner 2004; Zakri & Kambu, 2007). When humans begin to face cold hard facts that are a direct result of our anthropocentric behaviour, such as deforestation (Houghton, 1991), rising

atmospheric carbon dioxide levels (Hansen et al., 1981) and a perpetual increase of fossil fuel usage, then there is potential for a reconceptualization of attitudes that might reduce ecological degradation.

Senge and Carstedt (2001) claim that moral and social values are contributing factors to ecological insensitivity. Hoffman and Sandelands (2005) go further by suggesting that social and cultural values are fundamentally assisting in environmental degradation. Sadler and Zeilder (2003) state that "people are lulled into doing whatever is deemed best by authority simply because we ought to" (p. 261). Bowers (2003) explains that there is a connection between displaced moral values and long term ecological consequences. He suggests that this displacement is attributed to mankind‟s desire to progress, whether it‟s to grow economically or to obtain more material items. Either way there is a disregard of the effects on natural processes.

In order to face the serious challenges of ecological degradation, we need to visualize nature as an extension of oneself (Bonnett, 2002). Humans must be willing to embrace an eco-friendly transformation in both their personal and professional lives (Morris, 2002, p. 582). The question that remains is exactly how do we accomplish this? Puk (2010) highlights the need for developing a critical mass of ecologically literate citizens through an intense emphasis on ecological education in public schooling. It is postulated that a resulting ecologically literate citizenry would decrease the risk of ecosystem destruction, before it is pushed beyond our control.

Ecological literacy during the formative years is crucial to providing future adults with the knowledge to protect natural systems. However, there is little research on what elementary students know about key ecological concepts. Previous studies have focused on the misconceptions of scientific concepts (Amaudin & Mintzes, 1986; Smith, DiSessa & Roschelle,

1993; Thompson & Logue, 2006), but these studies do not concentrate on assessing definitional understanding of ecological concepts. It is important to assess elementary students‟ knowledge of ecological concepts because concepts are a key component in becoming ecologically literate. According to Orr (1992) “knowing, caring, and practical competence constitutes the basis of ecological literacy” (p. 92). Whereas, Berkowitz, Ford and Brewer (2005) define it “as the ability to use ecological understanding, thinking and habits of mind for living in, enjoying, and/or studying the environment” (p. 228). For this study, I have chosen to adopt Puk‟s (2010) definition of ecological literacy as “the capacity to make informed decisions about the future of life based on a comprehensive, gestalt-like understanding of the reciprocal relationships among and between natural systems (air, water, soil, energy, biodiversity and population) and human systems” (p. 115). I have chosen to focus on one aspect of ecological literacy, that is, the understanding of ecological concepts.

In essence, ecological concepts are the building blocks of ecological literacy. Once the learner has obtained an understanding of a concept, she can use this knowledge to transfer and expand her level of comprehension to more complex concepts and systems. The learner can then begin to understand the interconnectedness between natural systems and human systems and begin to develop a systematic understanding of the world.

In examining university students‟ definitions of key ecological concepts, Puk and Stibbards (2010) found that a majority of teacher-candidate participants had immature definitions and extensive variability in meaning when defining key ecological concepts found in the Ontario secondary curriculum and that the level of maturity of these definitions was limited (Puk & Stibbards, 2011). Although these studies provide us with insight into the understanding preservice teacher candidates have for key ecological concepts, it would also be beneficial to

know what understanding elementary students have for similar ecological concepts. This would be particularly important to know in light of the numerous recent changes made by the Ontario Ministry of Education to incorporate environmental education into policy frameworks and initiatives such as "*Acting Today, Shaping Tomorrow: A Policy Framework for Environmental Education in Ontario Schools*" (2009), *Science & Technology* (2007a)", and "*Shaping our Schools, Shaping our Future*" (2007b). All of these documents are designed to infuse environmental material across all subjects. What is missing from this equation is empirical data pertaining to elementary students‟ current level of understanding for key ecological concepts. This study provides some preliminary evidence of elementary students‟ ecological concept understanding that can be used to aid teachers in the implementation of these initiatives in fostering students‟ knowledge of these ecological concepts.

Purpose of the Study

First, it will determine what ecological concept knowledge children have at different ages and grades in the elementary sector. In doing so, it would create a collection of ecological concept definitions of elementary students in grades 4, 6 and 8. Secondly, the study would result in a concept development sequence to illustrate the maturation of concepts in terms of robustness and complexity as children progress through the elementary grades. Thirdly, it will inform teachers‟ instructional strategies with the primary goal of establishing definitions and meanings for concepts essential to understanding our relationships with the natural world.

The following questions guide the research process:

1) What level of understanding do elementary school students‟ share in regard to key ecological concepts?

2) How do these definitional understandings mature at different ages and grade levels?

Need for the Study

This proposed research study is driven by a combination of two influences I feel most passionate about. First, this research aligns with my dedication and concern for the health of the natural world, for without the existence of a healthy earth, human existence too, is comprised. Secondly and most importantly, the research embraces my role as a mother. Being a mother and a role model for three children I am aware that the actions and decisions I make today, indirectly impact their tomorrow. That alone provides me with enough motivation to advocate change by seeking a transformation in people‟s perspectives in what I view as a distorted societal reality, which separates humans from nature. I believe a mother‟s role is to shield her children from harm, provide a safe nurturing atmosphere for them to grow, and to hope for a thriving future for their children. This research taps into a fundamental component of motherhood: protection. I learned a lot about childhood education in watching my children grow, and in watching my children become conscious of the natural world around them. It was then that I realized the potential influence of my study and practice of education in real human life and the natural world.

In the fall of 2009, I enrolled in a graduate course titled “Outdoor Ecological and Experiential Education” at Lakehead University taught by Professor Tom Puk. This course had a positive influence as the teachings resonated with me. The awareness that this class stimulated within me has morphed into a deeply rooted passion driven by a heightened awareness of the natural world and how education plays a pivotal role in our impact on this world. As Dr. Puk eloquently states when referring to being exposed to ecological literacy for the first time, “it‟s like the gum stuck to the bottom of your shoe, once it‟s there it is hard to remove” (T. Puk, personal communication, October 5, 2009). This statement illuminates a whole new perception

about being introduced to ecological literacy, and that means that once learned it is not easily discarded because of the lasting impression the information has on the learner. After the knowledge gained in this course, I decided to orient my studies according to ecological literacy, because this could contribute a new insight to our practices of elementary ecological education and our ecological practices.

I wholeheartedly believe the key ingredients to change are awareness, self-reflection and willingness. In our westernized society education is associated with power and has the capacity to control the type of information that is being delivered in schools. Apple (1995) and Giroux (1983) criticize how institution‟s culturally reproduced structures of modernity and the effect this has on society and the environment. In other words, schools are part of the problem. Apple (1995) describes the external pressures on schools to produce and reproduce students with personality and dispositional traits that mirror societal beliefs (p. 62). Giroux (1983) supports this by stating that "we have accounts of schooling that illuminate how cultural resources are selected, organized, and distributed in schools so as to secure existing power relations" (p. 4). Despite this, it is necessary to ecologically educate, and part of the modern school‟s mandate is to do this. As students become more ecologically literate schooling should encourage them to question societal values.

I feel that as an educator myself, we are contending with a wide range of external forces outside the classroom domain. In my opinion, technology removes us from nature and makes it harder to see the natural impact of our actions. Take, for example, the rich variety of natural voices of all earth‟s creatures that cannot speak, to the wonderments of the world that our anthropocentric way of life takes for granted. Learning to appreciate nature, and learning to appreciate it daily, is a powerful and direct way to establish ecological literacy, and learn about

our very nature. If, we were stripped away from all of our amenities, what would remain? Overall, I believe that there is a need to reform the public school curriculum in order to provide a more intense focus on ecological literacy.

I enter this research domain fully knowing I hold strong ideals and values regarding this subject. I feel that the younger generation should be taught how to respect, preserve, care for and understand their relationship with Mother Earth. When educators show a genuine interest in the natural world it has the potential to create a contagious atmosphere sparking children‟s natural curiosity. Ideally, I believe in the value of spending more time teaching outdoors, but I realize not all educators share this perspective.

A search of the current literature indicates that a sizeable research gap exists in regard to what is known about elementary students‟ understanding of key ecological concepts i.e. there are few studies that have examined this area in any depth, especially in terms of student definitions. Thus, to minimize the sizable gap in this area it would be beneficial to gather data which might provide evidence of the level of understanding students have for key ecological concepts in order to give feedback for implementation initiatives. To better assist elementary students‟ acquisition of ecological concept meaning, we need to find out first of all what meaning they possess for key ecological concepts.

Secondly, teacher instruction would benefit by having a sequence of student definitions. Knowing the ecological definitions that students possess can empower teachers to prepare appropriate activities that will help students to acquire more age appropriate understanding of these concepts.

Over a decade ago, the Ontario Ministry of Education decided to eliminate Environmental Science courses from the secondary level of the curriculum (Ontario Ministry of

Education, 2000) by integrating the subject matter into other subjects such as geography, chemistry and science. Due to the removal of the Environmental Science courses, Puk and Behm (2003) conducted a study of Ontario secondary science and geography teachers in order to establish how much time was devoted to teaching topics with ecological concepts. Their study revealed weaknesses in the Ontario Ministry of Education proposal to integrate environmental science into other subject areas. This study verified that integration reduced the amount of exposure students receive in environmental science, hence, decreasing the likelihood of establishing ecological literacy.

A further investigation was carried out by Puk and Makin (2006) exploring Ontario elementary teachers‟ opinions about ecological literacy and the students they instruct. The survey found that "[s]eventy-one percent of teachers said they did not believe that the students they taught were ecologically literate ..." (p. 271), again indicating possible limitations to integrating ecological subject matter. Moreover, "[o]nly 5% of respondents said that they received extensive training in ecological literacy at a Faculty of Education ..." (p. 272). All things considered, this study confirmed the limited degree of ecological literacy in both teachers and students in Ontario schools. These studies suggest that instructional and experiential barriers are limiting the development of ecological literacy in publically funded education in Ontario.

The current study endeavours to provide insight into what elementary students understand about key ecological concepts. By doing so, it will contribute to the existing literature by providing a developmental sequence in terms of maturity of students‟ ecological concept definitions from K - 8. Assessing what level of understanding and knowledge students presently possess might allow for curriculum recommendations to be put in place and thus ensure that measures are identified to improve students‟ understanding of key concepts. Additionally, the

study presents preliminary evidence about the degree of conceptual growth of key ecological concepts as children mature intellectually. The assumption being made in this study is that concept maturity is developmentally construed (Piaget, 1964).

The Concepts

Ontario curriculum guidelines are designed to guide teachers in their classroom instruction and to familiarize parents with curriculum expectations. Prior to the construction of the concept survey for the current study, the Ontario Ministry of Education *Science and Technology Grades 1 - 8* curriculum guideline (2007a) was thoroughly examined to extract familiar ecological concepts that were appropriate for each grade level. Grade 4 survey concepts consisted of *the environment, photosynthesis, decomposition and greenhouse gas* (see Figure 1). Grades 6 and 8 survey concepts included *the environment, photosynthesis, decomposition, greenhouse gas, biodiversity, recycling, sustainability* (see Figure 2) which were chosen from the *Science and Technology* (2007a) curriculum guidelines. The concept of *green*, although not in the provincial curriculum was also selected because of its popular use in the media as in the "green economy" or "green lifestyle practices". Grade 4 participants received a shorter concept list because consideration was given to the age of the participants to ensure that the survey would not cause undue stress by asking for too many definitions in a short period of time. In addition, there are a limited number of ecological concepts found between grades one and three. More importantly, the inclusion of grade 8 students in the survey captures their prior knowledge as they were at one point grade 4 students.

The term *the environment* is found throughout the *Science and Technology Grades 1 - 8* curriculum guideline, beginning in the Grade 1curriculum expectations (Ontario Ministry of Education, 2007a, p. 45). References are made to *the environment*, *environment*, and *the natural*

environment which are used repeatedly throughout the document in a variety of different contexts (e.g. p. 46, p. 67, p. 74). It is interesting to note that of all the concepts in the survey, only *the environment* is not defined in the curriculum guideline. *Photosynthesis* is a concept introduced in grade 3 under the strand and topic of "Understanding life systems: Growth and changes in plants" (p. 70). The concept of *decomposition* is presented in grade 3 within "Understanding earth and space systems: Soils in the Environment" (p. 79). *Greenhouse gas*, like photosynthesis and decomposition, is also found in grade 3 within "Understanding life systems: Growth and changes in plants" (p. 70). *Recycling* is first introduced in grade 5 within the unit "Understanding matter and energy: Properties of and changes in matter" (p. 104). The concept of *biodiversity* is presented in grade 6, where an entire strand entitled "Understanding life systems: Biodiversity" is dedicated to teaching this concept (p. 112). Similar to *the environment*, *sustainability* is found throughout numerous grade levels, including the section of fundamental concepts such as "sustainability and stewardship" (p. 112). Lastly, the only concept that is not found in the Ontario *Science and Technology Grades 1 - 8* curriculum guideline (2007a) is the concept of *green*. The decision to include this concept was based on the popularity of this word in our social media messages and product marketing campaigns. The inclusion of this concept does indicate to some degree that advertizing media has power to influence children"s concept formations too. However, examining this assumption in greater detail goes beyond the scope of this study.

Overview of the Design of the Study

This qualitative study involved ten elementary classrooms in a North-Western Ontario public school. There were 87 elementary students in total participating in the study: thirty-four

grade 4, twenty-eight grade 6, and twenty-five grade 8 students. A mix of female and male students existed across all grades.

Data collection involved participants completing a concept definition survey. When necessary, individual follow up questioning took place to clarify the concept definition responses. The survey asked participants to define concepts that are found in grades 1 to 8 of the *Science and Technology* curriculum guidelines sections (Ontario Ministry of Education, 2007a) with the exception of the concept green which is not from the curriculum. The follow up questioning occurred during school hours and on the research site. The researcher asked students individually to explain or expand on the definitions in a manner that is understandable to the child in order to provide clarification of the participants‟ written concept definition response(s). The clarification responses were recorded by the researcher on the participants‟ original surveys ensuring that confidentiality and anonymity was retained.

Assumptions

1. It will be assumed that the participants in the study answered the definitions to the best of their ability.
2. It will be assumed that the participants were honest in their answers provided in the survey and in their responses provided in the follow-up questioning.

Definition of Key Terms

For the purpose of this study, the following definitions apply. These definitions best capture my own meaning of the terms. A more comprehensive exploration of these terms is provided in the literature review.

Ecological Literacy: as "the capacity to make informed decisions about the future of life based on a comprehensive, gestalt-like understanding of the reciprocal relationships among and between natural systems (air, water, soil, energy, biodiversity and population) and human systems" (Puk, 2010, p. 115).

Ecological Consciousness: "a consciousness that is based on value attitudes oriented toward the preservation, restoration, and rational use of the natural world" (Biriukova, 2005, p. 34).

Concept Development: "is a process in which old concepts are enhanced, made more sophisticated, through experience, either by adding new criterial attributes to the concept, or by making connections to other existing concepts, to handle newly encountered situations" (Puk & Stibbards, 2011, p. 193-194).

Limitations

The following outlines the limitations of the study:

1. The validity of information from the students is dependent upon how well they can articulate knowledge of the concepts in a written format and their willingness to respond to the definitions being asked in the concept definition survey along with the assumption that concept growth is developmentally configured (Piaget, 1964).

2. The quantity of information gathered is dependent upon the cooperation of each teacher. Each teacher must give access to their students and be willing to disrupt their instructional time, so the researcher can successfully conduct the research study.

3. The sample size and composition of the study was dependent upon the number of students who took the parental consent form home and subsequently returned the form to their teacher with their parent"s signature.

4. The fact that this is a case study involving one (albeit large) elementary school may limit the degree to which we can generalize the findings that a larger study might accomplish.
5. The concepts were chosen specifically by the researcher and her thesis advisor and this could potentially shape the interpretations of the study.

Overview of the Thesis

The balance of the thesis is devoted to the following: Chapter Two provides a review of the related literature and theoretical influences. Chapter Three, the design of the study and documentation of the methodology and research designs are discussed. Chapter Four, an analysis of the data is provided, while a discussion of the findings, recommendations, and conclusions are examined in Chapter Five.

Chapter 2: Literature Review and Theoretical Influences

Chapter Overview

This chapter consists of four sections. The first provides a brief overview of ecological education with a specific emphasis on ecological literacy and ecological consciousness. The next section examines the challenges of teacher training regarding the preparation of teachers to implement ecological education in their classrooms. The third and fourth sections outline concept development and the role of instruction in ecological concept development. In this final section, there will be an emphasis on Puk and Puk & Stibbards' previous research as it addresses ecological concept development most directly.

Ecological Education

Ecological education can be interpreted with varying degrees of understanding and forms of instructional implementation. Although this section may be narrow in scope, its purpose is to draw attention to several fundamental instructional components and illustrate the importance of ecological education.

Kamel (2000) suggests that ecological education involves being cognizant of four environments: physical, natural, social and cultural. Ecological learning experiences begin by linking all „environments" and discussing the implications of human involvement (p. 22). Similarly, Nikolaeva (2008) claims that ecological education should consider involving the aspect of interconnectionism amongst organism and environment. Secondly, ecologically based programs help shape children"s attitudes toward nature. Cherif (1992) believes that ecological education programs should aim to foster positive attitudes and genuine concern toward the environment. According to Biriukova (2005) "[t]he purpose of ecological education in schools is

to shape a system of scientific knowledge, views, and convictions that enable school students to form a responsible attitude about the world around them in all types of activity" (p. 39).

Tilbury (1995) suggests introducing ecological education to children as young as six years old. Young children should be involved in lessons that reach beyond the classroom by investigating surrounding natural and human communities in order to understand the interconnectedness between the communities. Place-based learning (Gruenewald & Smith, 2008) is a prime example of this type of approach. "Our children should be properly introduced to the world in which they live … to the entire range of natural phenomena" (Berry, 1988, p. 13). Certainly a goal of ecological education is to extend beyond the scope of the classroom as a continual lifelong learning process (Cherif, 1992; Puk, 2002).

Studies concerning ecological education in Ontario have revealed a weak and narrow scope present in the curriculum at both elementary and secondary levels (Howard, 2008; Puk & Behm 2003; Puk & Makin, 2006; Wien & Dudley-Marling, 1998). Puk and Makin (2006) proposed that by making ecological education a priority, it would allow for the natural world to become a part of the classroom. They also recommended that ecological education should be recognized as a distinct subject area and not just integrated into existing subject matter. A policy change made in 1998 by the Ontario Ministry of Education removed the Environmental Science courses from the secondary curriculum by dispersing environmental expectations into other subjects (Puk & Behm, 2003). Puk and Behm‟s (2003) study collected survey data from Ontario science and geography teachers to determine the level of integration of Environmental Science topics. They found that ecological topics were not being taught enough when integrated in subjects such as science and geography. Russell and Burton‟s (2000) case study goes further by

revealing that the integration of environmental studies has too often relied upon science and geography subjects only, rather than integrating into the arts.

A recent initiative by the Ontario Ministry of Education has taken remedial steps to incorporate environmental education into the provincial curriculum. The *Environmental Education* (2011) document has been designed to assist teachers in integrating environmental education into their lessons. Once again the Ministry‟s approach advocates for an infusion and integration method across almost all subjects with exceptions such as mathematics. Although this policy may be well meaning, Knapp (2000) argues that integrating environmental education into existing subject matter lacks the depth that a dedicated curriculum would provide. He suggests that creating a dedicated curriculum would provide the depth that is missing in the integrated method (p. 36). Sobel (1996) supports this further by stating that "most environmental education in schools gets translated into isolated activities where depth is sacrificed and there is little opportunity for students and teachers to make meaning of their experiences with the environment" (as cited in Gruenewald, 2004, p. 74). However, the debate persists as to whether it is best to integrate ecological education or to offer distinct foundational courses linked to the rest of the curriculum. Whichever method is utilized in schools, the development of "a critical mass of ecologically literate citizenry" (Puk, 2002) will require an intense emphasis on ecological literacy and ecological consciousness.

Ecological literacy is an essential component of ecological education and ecological consciousness is shaped by an individual‟s understanding of the information they are learning on their journey to becoming ecologically literate. Each topic will be addressed in the subsequent sections.

Ecological literacy. The following section provides a selective overview of an otherwise broad field of approaches to ecological literacy. The selection criterion was based on how succinct and robust the definitions were according to their meaning and in particular how they integrate effectively within an educational reference.

Several studies emphasize the importance of ecological knowledge and understanding as fundamental factors in the formation of ecological literacy (Berkowitz et al., 2005; Curthoys & Cuthbertson, 2002; Puk, 2010; Puk & Stibbards, 2010; 2011; in press; Stibbards & Puk, 2011). Puk (2010) defines ecological literacy as "the capacity to make informed decisions about the future of life based on a comprehensive and gestalt-like understanding of the reciprocal relationships among and between natural and human systems" (p. 115). Balgopal and Wallace (2009) refer to ecological literacy as an understanding about ecological concepts and the range of functions concerning the ecosystem whereby students can apply their knowledge of ecological concepts for a deeper understanding of human impacts on flora and fauna.

Orr (1992) cites Garrett Hardin"s definition of ecological literacy as the ability to ask "What then?" (p. 85). He appends to this by stating that "[k]nowing, caring, and practical competence constitutes the basis of ecological literacy" (p. 92). This is then expanded through a series of steps. First, ecological literacy "… implies a broad understanding of how people and societies relate to each other and to natural systems, and how they might do so sustainably". Second, ecological literacy involves knowing "something of the speed of the crisis that is upon us … to understand the human enterprise for what it is: a sudden eruption in the enormity of evolutionary time". Third, ecological literacy "requires a comprehension of the dynamics of the modern world". Fourth, it "… then, requires a thorough understanding of the ways in which people and whole societies have become destructive" (p. 92-93). Orr also provides reasons for

western culture"s resistance to accepting ecological literacy. First, citizens lack the ability to conceptualize broadly, in terms outside of the conventional domain. Second, western culture tends to apply instructional time predominantly in indoor settings. Third, a reduction in aesthetic appreciation is working against ecological literacy.

Various studies emphasize the relevancy of becoming ecological literate (Chambers 2007; Cutter-Mackenzie & Smith 2003; Daudi, 2008; Puk & Stibbards, 2010; 2011; in press; Stibbards & Puk, 2011) with a focus on interconnectedness. The significance of exploring the natural world through an ecological lens provides an opportunity to become reacquainted with the interconnectedness of the natural systems that we are seamlessly a part of. Orr (1992) believes one should have an affinity for the living world by paying attention to nature and our landscapes and "to see things in their wholeness" (p. 92). He proposes that "ecological literacy is driven by the sense of wonder, the sheer delight in being alive in a beautiful, mysterious, bountiful world" (p. 86). Berkowitz et al. (2005) define ecological literacy "as the ability to use ecological understanding, thinking and habits of mind for living in, enjoying, and/or studying the environment" (p. 228). According to Disinger and Roth (1992) environmental literacy provides an opportunity for individuals to understand the health of ecosystems and the ability to identify suitable actions for improving the health of those systems (p. 2). Duailibi (2006) also believes that ecological literacy facilitates a connection with the natural world, while ecological illiteracy may instead promote a disconnect. This disconnect may then hinder humans in understanding how they fit with other species. He suggests that ecological literacy is a key component in the survival of the human race.

Wilson (1996) takes it one step further by describing the concept of "ecological self" as one who can identify with nature by acquiring attitudes and having the capacity to connect with

the natural environment. She draws attention to the fact that childhood is where one develops attitudes, beliefs, and dispositions that have a tendency to carry forward into adulthood. These ideas support the need for intense implementation of ecological literacy at the elementary level to ensure ecological attitudes are formed before adulthood.

For this study, I have chosen to adopt Puk‟s (2010) definition of ecological literacy as described above. This is to ensure that there is a linkage in this study to previous concept development research. To which this current study might complement, and provide further insight into this topic. As well there is a strong linkage with ecological consciousness in that this view of ecological literacy is seen as "a stage along the way to ecological consciousness and represents extensive knowledge and understanding of complex natural systems ... [w]ithout this specific knowledge, one can easily be misled" (p. 4).

Ecological consciousness. O‟Sullivan and Taylor (2004) generalize consciousness as a mental structure disseminating our reality to explore meaning and discover ourselves, in essence our ontological presuppositions. Puk (2010) describes ecological consciousness as a "„weltanschanuung,‟ that is, a world-view and a lifestyle. "Ecological consciousness fills our whole being and guides us in our daily decision making …" (p. 4). Whereas, Biriukova (2005) simplifies ecological consciousness as having a conscientious attitude about "preservation, restoration, and rational use of the natural world" (p. 34). For an individual to achieve a desirable attitude requires active effort, enthusiasm, and willingness to learn.

A benefit of developing an ecological consciousness is suggested by Morris (2002) as she describes a visible shift in attitude altering our human perception by bringing us back to what is truly important: modifying our anthropocentric thinking to include the entire ecosystem. The development of ecological consciousness is not only beneficial to the person adopting this

awareness but could produce a positive ripple effect impacting the natural world. Puk (2002) regards ecological consciousness as a means to change behaviours in every facet in one‟s life, particularly within our educational and societal endeavours. At the same time, Morris (2002) describes that there is a dual purpose behind ecological consciousness for it not only educates individuals but "hopefully will re-integrate us back into the wilderness" (p. 580). Hill, Wilson, and Watson (2004) believe the development of ecological consciousness will result in an influx of self-identified environmentalists among the population.

Raghunandan (1987) sees ecological consciousness as being intrinsically social. He stresses the fact that further clarity is required to view ecological issues from both cognitive and social levels. Drawing attention to the existing absence where "… ecological consciousness is not necessarily inherent even in communities wholly dependent on the maintenance of ecological balance in their environment" (p. 547). As he suggests, we are too occupied with social classes and community-based manifestations of ideologies usually driven by the need to control natural resources then to be concerned with becoming ecological sound. "[A] truly ecological consciousness is directly linked to such a transformation in production and production relations" (p. 548).

Moving away from economically based arguments Agwan (1993) proposes a multi-religious understanding of the environmental crisis creating a deeper ecological view resulting in an ecological consciousness. This view urges humanity to be cognizant of our actions as "humanity has now reached the point at which it must change its attitude towards nature, or else nature will continue to thrust ever-harsher catastrophes upon it" (p. 243). Humans have adopted lifestyles that require a significant amount of resources, than ever before at an exponential rate. We live in an era with an insatiable appetite, disrespecting the very source that provides the

luxuries we have become accustomed to. “We now control forces that once controlled us, or, more precisely, the earth process that formerly administered the earth directly, is now accomplishing this task in and through the human as its conscious agent” (Berry, 1988, p. 42).

With that being said, one way to begin the transformation is to teach with a purpose in mind by raising ecological consciousness. Hill et al. (2004) promote educational curricula, programs, and learning processes that foster the development of an ecological framework to deepen, broaden, and raise ecological consciousness. The intention behind forming an ecological consciousness is to offer individuals an alternative way to interpret the world by using an ecological lens. An example of applying this lens can be found in the decision to buy locally grown food instead of imported foods and/or buying fruits and vegetables that are in season, instead of consuming produce from other countries which places a higher demand on exporting items (e.g. bananas) increasing the amount of global travel. Applying an ecological lens to our food consumption behaviours helps people make ecologically friendly decisions, which in this example, helps to reduce carbon dioxide emissions. However, although these steps are outlined in a systematic fashion, Puk (2010) reminds us that “[t]here is no perfect state of ecological consciousness” (p. 123). Achieving ecological consciousness is a complex, non-linear undertaking (Puk & Stibbards, 2011). “We may be each starting from different points on the continuum, but where we are headed in our ecological behaviors should be more important than where we have come from” (Puk, 2010, p. 123).

Teacher Training

One critical avenue for the development of ecological literacy and ecological consciousness is through teacher training. Barraza (2001) indicates the importance of teacher training by stating that “[t]he pedagogical approach and the teacher‟s interest in environmental

issues seem to affect children‟s learning processes” (p. 34). However, various studies have questioned the adequacy of teacher training programs to prepare new teachers to teach ecological education.

Dove (1996) conducted a study to ascertain student teachers‟ understanding of three environmental problems: the greenhouse effect, ozone layer depletion, and acid rain. The results exposed misconceptions, low familiarity, and little understanding about each concept. Dove (1996) suggested that this problem might be dealt with by first identifying both teachers‟ and students‟ misconceptions. This would not only reduce the amount of erroneous information, but also uncover the reasons behind the misconceptions. Thompson and Logue (2006) conducted a preliminary investigation identifying science misconceptions with a sample size of six participants ranging between 6 and 15 years of age. Their discussion focused on the importance of misconceptions, questioning how students acquire and uphold their misconceptions as they mature. On the whole, Thompson and Logue (2006) advise that teachers should attempt to minimize the development of misconceptions by integrating knowledge in such a way that valid concepts are maintained (p. 558). By understanding misconceptions in their own understandings, educators can improve instructional practices by reducing confusion, thus increasing comprehension (Chi, 2005; Chi, Slotta, & de Leeuw, 1994). It is the responsibility of the educational system to provide ample training in this regard. This then leads us to question exactly how much ecological concept knowledge does the average elementary teacher possess?

Karrow and Fazio (2010) discovered a correlation between teachers‟ subject knowledge and students‟ learning opportunities when it was found that teachers were unable to provide answers to students‟ questions concerning identification of worms. From this study one can speculate that teacher subject knowledge appears to have a direct impact on learning. Swanepoel,

Loubser and Chacko (2002) express concerns with teacher comprehension stating that "[t]eachers can, however, hardly assist learners to become environmentally literate if they themselves lack environmental literacy" (p. 282). Additional studies strengthen the above notion as Summers, Kruger, and Childs (2000) explore primary school teachers‟ understanding of environmental issues. Their study produced comparable findings as teachers‟ understanding of key concepts were far less understood or even absent altogether.

Cutter-Mackenzie and Smith (2003) examined teachers‟ ecological knowledge. These authors were concerned with the level of ecological literacy each participant had, in order to understand possible reasons behind environmental education deficiency. Out of the 26 primary school teachers participants "… 78.1% indicated that they had never undertaken in-service training in environmental education …" (p. 506), furthermore "… 84.5% also indicated that they had never undertaken pre-service training in environmental education …" (p. 507). In a province-wide study of 132 K-8 teachers in Ontario, Puk and Makin (2006) found that 95% had never received extensive preservice training in ecological literacy. Although 62% felt they were very knowledgeable about ecological topics, 71% scored poorly when asked basic ecological facts. This false self-efficacy mimics a similar finding that Puk and Stibbards (2011) found with teacher candidates who felt they were quite capable of defining ecological concepts but actually scored poorly in doing so.

Zak and Muson (2008) stress that "[t]eachers play a critical role in creating a society in which people develop an understanding of ecological concepts" (p. 32). Thus, identifying teachers‟ knowledge or lack thereof is a crucial piece of the larger puzzle. Unfortunately, it is currently left in the hands of educators to integrate such a vast subject matter with little to no prior knowledge themselves. This imbalance and unfair expectation placed upon pre-service and

in-service teachers can be resolved by revisiting current teacher training practices, especially in regard to ecological concept development.

Concept Development

"Concepts are mental categories for objects, events, persons, places, or ideas that have a common set of critical attributes" (Birbili, 2007, p. 143). Concepts are considered to be an inseparable entity of human thoughts, because "concepts are so fundamental to our own functioning that the notion of a thought without concepts is hardly conceivable" (Schyns, 1991, p. 462). Concept acquisition begins in the early years of life and becomes more mature as we age. Rosemberg and Silvia (2009) discuss concept acquisition as "precisely one of the aspects in child development where the connection between language and cognition is most obvious" (p. 573). A number of theorists have supported the idea that we have the innate capacity to learn and develop concepts shortly after birth and throughout childhood (Johnson, Amso, & Stemmer, 2003; Keil, 1994; Nelson, 1974; Piaget, 1926; Vygotsky, 1986).

Piaget"s (1926; 1964) extensive research theorizes and identifies four stages of cognitive development as humans intellectually mature. From birth to two years of age children generally exhibit characteristics from what Piaget identified as the "sensori-motor stage" (Birth – 2) (Piaget, 1964, p. 20-21). The second stage begins at a time where children are able to communicate orally and ends around the age of seven. Piaget called this phase the "pre-operational stage" of cognitive development (Age 2 – 7) (Piaget, 1964, p. 21). A transition in cognitive structures begins to evolve during the third phase of development referred to as the "concrete stage" (7-12) (Piaget, 1964, p. 21). In the fourth stage called "formal or hypothetic-deductive operations" cognition acquires its maturity (Piaget, 1964, p. 21). It is important to be

cognizant of what cognitive stage children are at in order to assist in teaching strategies and instructional guidelines that are in accordance with the child‟s cognitive development.

Contributing to the theoretical paradigm in cognitive growth, Vygotsky (1986) developed somewhat different views than that of Piaget. Vygotsky constructed developmental structures to include the intricacies of thought and speech along with the „cognitive zone of proximal development‟ to support the notion that children require adult guidance to aid in their cognitive development. According to his theory, Vygotsky concludes that children utilize five cognitive functions: language, thinking, perceptions, attention, and memory.

Vygotsky‟s (1987) theoretical assumptions also contributed to the area of concept formation. He described two kinds of concepts: spontaneous everyday concepts, and non-spontaneous scientific concepts- scientific concepts are characterized by being formulated in systematic relationships. For example, Vygotsky theorized that where spontaneous concepts are concerned, without the influence of social agents, a child‟s thinking would linger at this level unchanged and would never mature to the level of scientific concepts (as cited in Puk & Stibbards, in press, p. 4).

A primary objective then, as loosely indicated above, is to guide children in their development from spontaneous concept understanding towards achieving scientific concepts formation as “[t]hese complex psychological processes cannot be mastered through the initial learning alone” (Vygotsky, 1986, p. 83). Numerous studies conducted by Simons and Keil (1995) explored children‟s perceptions of various living and non-living entities to understand how children classifying objects. The results demonstrated that children use their personal viewpoints of an object to assist them in the categorization process. This reinforces the importance for educators to recognize that children too, have assumptions and expectations of

concepts that they are learning which is often linked to previous experiences and naïve understandings.

Puk (in press) provides a post-Piagetian/post-Vygotskian model for cognitive development based on the influence of neurobiology. Specifically Puk describes three stages of growth to acquire ecological consciousness based on neurocognitive development: (a) pre-puberty/birth to grade 3, (b) the boundary space/grades 4-9 and (c) post-puberty/grade 10-lifelong. The implication for educators is that we need to understand how each [neurocognitive] stage of life (i.e. early childhood to adult) is dependent on preceding stages and interconnected with all stages as opposed to focussing only on individual stages of cognitive development (Puk, in press, p. 2).

According to neuroconstructivist research (Goswami, 2008; Puk, in press), the „plastic" brain is entirely shaped by the external world up to puberty. Post-puberty, the brain resists the influence of the external world and attempts to maintain the meta-values it has already laid down previously. Puk believes that educators should take advantage of this natural phenomenon and adjust the manner in which ecological concepts are taught particularly during the Boundary Space of grades 5-7 which lead up to puberty. According to this theory, if this pre-puberty ecological emphasis is weak, absent or faulty (and specific to the current study, if critical ecological concepts are misunderstood), it is much more difficult to change the meta-values of adults based on a kind of „neuro-rigidity" (p. 8).

Driver, Asoko, Leach, Mortimer and Scott (1994) investigated the construction of knowledge by analyzing the impact of teachers" instruction on concept formation. What was discovered is that it is largely dependent upon how eager and interested the learner is when learning new concepts. If the learner is engaged in the process it helps with knowledge

acquisition as opposed to only learning the material because they are obliged to do so. This emphasizes the importance of instruction in the teacher - student relationship.

The Role of Instruction in Ecological Concept Development

Ecological studies at the elementary level provide an opportunity to develop students‟ ecological knowledge. Bowers and Flinders (1990) refer to a classroom as being "an ecology of mind" (p. 104). Instructional processes, nonverbal communication and teachers‟ ideologies play an intricate role in student learning. Berry (1988) suggests educational processes communicate some fixed form of cultural ideologies that can become a means for self-transformation for both the human community and the planet. However, if there is ineffective integration of ecological instruction in classrooms it could produce future citizens who are not only disconnected from the natural world but illiterate in terms of the impact that humans have on natural systems (Puk & Makin, 2006). A reintegration of human processes and natural processes as Berry (1988) describes could be difficult to achieve and this detachment has the potential to accelerate ecological degradation.

Fundamentally, educators‟ decisions regarding what concepts to teach, when to teach, and how to teach them have an impact on student learning. Rosemberg and Silva (2009) suggest "[t]he way adults use words to indicate objects refines and reorganizes those first concepts formed by children" (p. 573). In the case of ecological concept development it could lead to potential problems because children may be acquiring conflicting meanings for ecological concepts. Our cultural pattern of thinking is reinforced by the curriculum being taught and the school teachers‟ deliverance of the material (Bowers, 2006, p. 5).

Concepts can be taught in various ways. One way is through socio-dramatic constructive play (Gennari, Langley, & Fisher, 1989). This includes a style of instruction that consists of

using physical movement to learn concepts which can help students associate and retain what they have learned. Another approach for educators is explored by Boulware and Crow (2008) as they applied Jerome Bruner‟s concept attainment technique. “The strategy focuses on the meaning or understanding of a concept, rather than on what the concept is called” (p. 491). The authors explain that each application has a common theme: an introduction of the concept, attainment of the concept, and analysis of the concept. This process applied by Boulware and Crow can be duplicated by educators to enhance their instructional approach.

Another approach advocated by Puk (2010) describes the use of “ecological macro models” as one way to assist the learner in understanding ecological concepts and systems. Ecological macro models are:

> collaborative learning activities that are organized around macro, analogous representations of the interactions between natural systems (e.g. air, water, soil, energy, biodiversity) and human systems (e.g. hydrogen fuel cells, nuclear energy, landfills) in which the learner…plays an active role to better understand and internalize how these systems work (Stibbards and Puk, 2011, p. 21).

These macro models are designed around the elements of complexity, emergent design and embodied experience (Puk, 2010). Macro models are typically used outdoors to provide a multi-sensory learning experience. Surrounding the learner with natural systems creates a rich context where embodied experience can flourish. Learners are given roles to play and then interact with other roles in order to re-enact how natural systems and human systems work. This interaction indirectly aids in one author‟s understanding of the concepts under study. The types of macro models represent different ecological literacy components (e.g. water contamination and photosynthesis), they vary in complexity in terms of rules, concept meaning and resources and

they try not to waste resources such as water usage (e.g. using water from the natural sources rather than the tap). These activities provide an alternative to the traditional classroom instruction in which the learner passively receives information through lectures or reading. Stibbards and Puk (2011) demonstrated the self-efficacy that teacher candidates reported in regard to learning through this teaching/learning process. In a second pre-post study with the same cohort, Puk and Stibbards (2011) also demonstrated that as a consequence of utilizing the macro-model approach in contrast to more traditional approaches to concept development, teacher-candidates achieved significant growth in developing more mature definitions for key ecological concepts as well as acquiring a more discerning attitude towards the general usage of these concepts by the media, government, industry and general public.

Conclusion

This literature review discusses various theoretical perspectives of ecological literacy and ecological consciousness and how these perspectives might influence the implementation of ecological education in schooling. It is postulated that emphasizing ecological education in the elementary grades with a particular emphasis on concept development can provide children with a fundamental understanding and appreciation of the interconnectedness of natural systems and human systems.

Chapter 3: Methodology

Chapter Overview

The following chapter provides a detailed summary of my research methodology. It is divided into two sections. Section one is the overview of research methodology and design. This section reviews the qualitative research paradigm and then explains and justifies the composite research design of case study, including survey design, and grounded theory. Section two discusses data sources, collection and analysis. In this section it provides an overview of the data collection method, reviews the survey concepts, and describes the research site and sample. Within this section, I will also summarize data reliability and validity along with data analysis procedures- discourse and concept analysis.

Overview of Research Methodology and Design

Qualitative research methodology. The qualitative research paradigm is rooted in the exploration and understanding of human behavior, process, and actions. It is largely investigative, with a focus on individual meaning behind social or human problems (Creswell, 2009). Within this paradigm interpretive inquiry is a method where the researcher interprets the data using their history, contexts, and prior understandings. In addition, the reader of the study is also able to freely interpret the data within their understanding, which can create a multiple view of the research inquiry (Creswell, 2009). Typically, qualitative research uses an inductive approach with the goal of developing theories, building abstractions and concepts (Merriam, 1988), instead of a deductive approach of testing theories or hypotheses.

Qualitative researchers are interested in capturing a particular perspective of a social phenomenon with the intent of gaining a better understanding of the viewpoint of the participants involved (Merriam, 1988). The overall premise of the current study is investigative as it looks into the phenomenon of students‟ ecological concept knowledge from grades 4, 6, and 8. The

design of the study resonates with the qualitative paradigm because it examines a social phenomenon in order to provide further insight into ecological concept development. The data collection process of this paradigm can involve one or a variety of empirical materials such as observations, interview, fieldwork, personal experience, to name a few (Denzin & Lincoln, 2005, p. 375). In the current study, the empirical material consisted of fieldwork. The method of data collection consisted of a concept survey and asking follow up questions. And, analysis of the data proceeded with interpreting the participants‟ meaning-making by creating a compilation of emergent themes, determining the maturity of the definitions, and developing a growth sequence in order to advance the knowledge base of this research field.

Research design. A research design is used as a logical blueprint of a study, as it consists of initially starting with research questions and then arriving at some set of conclusions, which is directed by the logical plan (Yin, 2003). For this study I incorporated a fusion of research design methods. Foremost, the qualitative research paradigm acts as the philosophical orientation for the overall study, in which I carefully chose to combine case study, survey design, and grounded theory to answer the underlying questions for this research study. When selecting a research design the researcher is presented with many choices and must consider a range of strategies for collecting and analyzing data (Yin, 2003). This is to ensure that the strategy used will be a best fit to explore the research problem. Even though survey design is often associated with the quantitative paradigm, the purpose it serves in this study is structured upon a qualitative approach.

Case study. The case study research method is influenced by the qualitative paradigm regarding how research is conducted and how the findings are reported. The case study itself can be complex, impacting or bounded (Merriam, 1988). According to Merriam, a

case study design "is the best plan for answering one's questions" as "it offers insight and illuminates meanings that expand its readers' experiences" (p. 32). In addition, the researcher's prominent interest and her adopted theoretical stance influences the type of case study used (i.e. longitudinal vs. cross-sectional vs. case-control) (Merriam, 1988). This case study applied a cross-sectional approach because it gathers participants' information at one specific point in time.

Case studies are based on inquisitive inquiries, for example, the researcher may want to describe a certain characteristic of a population (e.g. illness). The current qualitative case study was based upon an empirical investigation of students' ecological knowledge from one elementary school using a single-case design (Yin, 2003). This case study is particularistic in nature as "[t]he case itself is important for what it reveals about the phenomenon and for what it might represent" (Merriam, 1988, p. 11). In essence, this interpretive case study develops conceptual categories to "illustrate, support, or challenge theoretical assumptions held prior to data gathering with the intent of interpreting or theorizing about the phenomenon" (Merriam, 1988, p. 28). The specific purpose of this case study was not to collect thick, rich descriptions of the phenomenon because I investigated only one particular aspect of the case. Yin (2003) supports this by stating that it is not always necessary to record detailed observations as evidence for case studies. It is important to mention that other external factors could have been explored to enrich the understanding of the case. However these factors were beyond the means of the individual investigator as time and resources were significant influences, in drastically reducing the scope of the case.

Survey design. Fink (2003) defines a survey as a system typically used in research and evaluation for gathering information about people's knowledge, behavior, and attitudes.

Survey questions are considered the research instrument of the survey. Alreck and Settle (2004) state that one chooses to use a survey because it is often easier and less expensive to attain the information desired. Time and resources were definite concerns for this study and the survey approach fit well with the research objectives.

Based upon Fink‟s definition of a survey and the research questions underlying this study I conducted an in-person questionnaire to find out students‟ ecological concept knowledge. The nature of the survey is cross-sectional (Fink, 2003) as the data will be collected at one point in time. Survey research involves a variety of sampling methods commonly divided into two types: probability and non-probability sampling. This survey uses a non-probability sampling strategy because it targets a certain population for the needs of the study (Fink, 2003). The sample size was not determined at the onset of the study because it was dependent upon the number of willing participants in each of the designated grades within one particular school. Furthermore, external variables posed complications to identify the population (e.g. teacher cooperation and parent/guardian approval) because the survey respondents are children. Bartlett, Kotrlik, and Higgins (2001) acknowledge that the sample size of survey research should be representational of the population, whereby generalizations surfacing from the research data are accurately reflective of a population. Creswell (2009) suggests that generalizations are possible from a questionnaire sample while at the same time recognizing the limitations of a case study approach.

Although, survey research design is often grounded in the quantitative paradigm (based upon the type of questions found in the survey), this general rule does not apply for every survey instance. Yin (2003) describes how "… some survey questions (such as those seeking categorical responses) rely on qualitative and not quantitative evidence" (p. 14). The statement by Yin

(2003) supports the approach taken in this survey design, as it was left to the researcher to interpret the resulting data into categorical themes. Moreover, careful consideration was given in the design process to the participants‟ age regarding the wording in the survey to maximize understanding for all participants involved. The structure of the questionnaire was open-ended and the concepts, even though they varied in complexity were arranged according to grade level (e.g. grade 4 survey concepts were found in the grades 1 to 4 provincial curriculum guidelines and grade 6 and 8 survey concepts were found in the grades 5 to 6 guidelines). The participants‟ responses were not placed into predetermined categories nor were the participants offered a multiple choice selection; rather the respondents shared what they knew about each concept in a written format.

The survey in the current study does not follow a typical knowledge survey structure. In this case, the objective was to gather what students‟ have learned about ecological concepts without providing prompts to the student in the retrieval of conceptual understanding. This particular survey design was influenced by the Puk and Stibbards‟ (2010) research about preservice teacher ecological knowledge. I adopted the questionnaire design and used it as the primary instrument to collect the data. The decision to adopt the design was done to provide consistency with the Puk and Stibbards‟ (2010) study. Using a similar instrument to gather data would allow for a preliminary comparison between the various studies, while at the same time dealing with different populations.

Grounded theory. Grounded theory is “a strategy of inquiry in which the researcher derives a general, abstract theory of a process, action, or interaction grounded in the views of participants” (Strauss & Corbin, 1990). The purpose of grounded theory is not a typical quantitative methodology as “one does not begin with a theory, then prove it. Rather,

one begins with an area of study and what is relevant to that area is allowed to emerge" (Strauss & Corbin, 1990, p. 23). Creswell (2009) depicts that interaction in this form of research is grounded in participants‟ views. Haig (1995) argues that grounded theory has a tabula rasa aspect where observations are not buried under theory, rather it allows for data interpretations to speak first, and then one must prove the theory behind it or create a theory to support it. The research attempts to understand the actions behind human perspective. Goulding (1998) discusses how this research design does not follow logico-deductive methods; instead it seeks a social environment to ground its data in. Hall and Callery (2001) believe that "[t] he researcher occupies the position of the expert who decides how to accomplish the interplay between data and theory, constant comparisons, theoretical questioning, and theoretical coding" (p. 261). Strauss and Corbin (1990) suggest that the researcher must put measures in place to minimize subjective analysis. In this study, my subjective stance for the emerging themes was cross-referenced by my thesis supervisor who has expertise in this area. In a similar vein, Rennie, Phillips & Quartaro (1988) explain that "grounded theory researchers are faced with a paradox. They attempt to rid themselves of preconceptions about the phenomenon under investigation so that its "true" nature will be allowed to emerge in the analysis" (p. 141). When analyzing the data to categorize the definitions I focused solely on the meaning of the responses to capture the viewpoint of the participants as best I could, as I was fully aware that my personal experiences could influence the creation of the categories. This study utilizes the premise of grounded theory because it allows the data to speak for itself by showcasing a collection of perspectives in understanding the phenomenon under investigation. Despite the fact that the study was inspired by Puk and Stibbards‟ (2010) previous work, this study is ground breaking in its own right as it explores elementary students‟ understanding of ecological concepts, whereas the Puk and

Stibbards‟ (2010) study explored adult knowledge. Grounded theory is a research design allowing data to speak for itself. In this case, elementary students‟ understandings of ecological concepts.

Data Sources, Collection and Analysis

Data sources and data collection. Students provided written responses on an ecological concept definition survey. Follow up sessions were conducted by the researcher to provide the students with the opportunity to provide verbal clarification of the written responses when warranted. Any verbal additions or corrections by students were transcribed onto their original written responses by the researcher. The survey consisted of eight concepts, seven of which came from the K - 8 Ontario Ministry of Education Science and Technology curriculum guidelines (2007a) and was administered to each participant in their regular classrooms. Four concepts, *the environment*, *photosynthesis*, *greenhouse gas*, and *decomposition* were presented to students in grade 4 (see Figure 1). All eight concepts were given to students in grades 6 and 8 including the additional concepts of *recycling*, *biodiversity*, *sustainability* and *green* (see Figure 2). The assumption being made was that because these latter four concepts are not found in the grade 1 - 4 provincial Science curriculum, we would not expect grade 4 students to have mature definitions for these concepts. This assumption was also intended to avoid undue stress on the grade 4 students who might otherwise have no definitions for the latter four concepts. One more reason influencing the concept selection process pertains to specific concepts (*the environment*, *sustainability*, and *green*) that were also found in the Puk and Stibbards‟ (2010) study of teacher candidates teaching both elementary and secondary grades.

Name:_____

Please provide a definition for each of the concepts/words below. In other words, explain which each concept/word means.

1 .The Environment

2. Photosynthesis

3. Decomposition

4. Greenhouse gas

Figure 1. Grade 4 Concept Definition Survey

Name:_____

Please provide a definition for each of the concepts/words below. In other words, explain which each concept/word means.

1. The Environment

2. Photosynthesis

3. Decomposition

4. Greenhouse gas

Name:_____

Please provide a definition for each of the concepts/words below. In other words, explain which each concept/word means.

5. Recycling

6. Biodiversity

7. Sustainability

8. Green

Figure 2. Grade 6 & Grade 8 Concept Definition Survey

By including these concepts it will add to the knowledge base of both student and teacher understanding of a selection of ecological concepts as well as allowing the researcher the opportunity to make comparisons between a variety of studies.

The site and sample. The selected JK - 8 elementary school is located in an urban area in Northwestern Ontario. The primary reason for selecting the school was that it had the largest student population in the region. Selecting a school with a large population improved the chances of a larger sample size. The criteria involved in the sample selection were based on several factors. First, consideration was given to those grades that provide a representative sample of elementary student concept understanding. Second, the participants‟ mastery of hand writing is a significant factor because of the methods of data collection. The intent was also that by targeting this age range of 9 - 13 it would hopefully ensure that the students were capable of conceptual understanding.

This process involved obtaining concept definitions from a total sample size of 87 English-speaking elementary students in grades 4, 6, and 8. The sample is comprised of thirty-four grade 4, twenty-eight grade 6, and twenty-five grade 8 students from a large Ontario elementary school with a population of approximately 688 Junior Kindergarten to Grade 8 students. Out of 196 potential participants in the three grades, the overall number of voluntary respondents ranging from age 9 – 13 years totaled 87, resulting in a response rate of 44%.

Recruitment. Prior to the start of the survey process, the researcher, with the cooperation of the school principal, organized initial meetings with each class for several underlying reasons. First, an opportunity was provided for all students to meet the researcher, removing preexisting uneasiness, uncertainty, and unfamiliarity that may be directed at the researcher. By doing so, it created a foundation to build a rapport with potential participants.

Second, it gave the researcher a chance to explain the purpose of the study to reduce potential misinterpretations and ambiguity. Beyond answering questions, this also became a way to establish the importance of the participants‟ role in the study. This was important as it shows consideration for their young age and level of experience.

It was previously assumed that the majority of prospective participants had no prior involvement in a graduate level research study. Since this study would be their first occurrence, the above actions are not only justifiable and essential to this study‟s outcome but also critical to the well-being of the participants.

Procedure. All participants were subjected to similar routines, conditions and surroundings to ensure consistency and reliability of the data. Each survey was administered during the second term of the school year (in March) to increase the likelihood of these common concepts being taught to the students (either during that year or preceding years). The study was conducted during school hours and within a time frame that corresponded with the teachers‟ schedules to guarantee minimal classroom disruption. Depending on the grade level of the participants, the surveys included either four (Grade 4 students) or eight concepts (Grades 6 and 8 students). In grades 6 and 8, the eight concept survey was delivered in two parts (four concepts in each), separated by one 24 hour period. This was done in order to not over-stress the participants. Each segment was conducted either in class or at a private location within the school. Participants were allowed to take as much time as they wished to complete their written responses.

Follow-ups. The follow up procedure was based on researcher-defined criteria to ascertain what definitions required further questioning. The students were previously informed about engaging in a possible one-on-one discussion with the researcher to obtain and clarify

answers that would be conducted in a confidential setting. Responses were written on the survey in a different colour of ink by the researcher to identify the follow-up response. The responses that required a supplementary meeting, if any, met at least one of the following criteria: (i) a concept was undefined e.g. there was no response or stated “I don‟t know”; (ii) a definition was vague e.g. to explain what the word „something‟ meant or to ask the student what they meant by (insert word) in order to invoke further discussion; and (iii) if the concept green was defined as a colour. When necessary, follow-up questions commenced as little as one day and at most several weeks after the survey was administered. The fluctuation in time frame was a result of a combination of absenteeism and holiday disruptions.

In regard to the follow-up questions, the researcher used a non-evasive/open-ended approach. It was explained to each individual that the follow-up session was not a result of incorrect answer(s) or mistakes but rather it was merely another opportunity to share their knowledge. The terminology typically used per session was dependent upon what criteria was met that led to the supplementary meeting. The following examples showcase the researcher‟s various styles: (i) “Are you able to tell me more about this concept”? (ii) “Have you heard of this word before? If so what else do you know about it”? (iii) “Could you put this (referring to a concept) into a sentence for me”? This type of inquisitive method was used to establish understanding if the definition was limited or absent.

Overall the follow-up technique was utilized to build upon participants‟ first response(s) and in some cases gave a second opportunity to provide an explanation, especially if the first instance of the concept(s) was left with no explanation. At all times during this process the researcher was fully aware of the need to question in such a way that would not influence the

students‟ responses, which could be reflective of the researcher‟s predisposition and understanding.

Moreover, this oral approach offered students an alternative method (i.e. face-to-face oral discussion with the researcher as opposed to written responses) to express their understanding of the concept. It is important to note that during these sessions, the researcher scribed for each student, and re-read their answers to the students to ensure the responses were captured accurately.

Data reliability and validity. This section discusses the measures that were put in place to preserve the integrity of the data. Kirk and Miller (1986) suggest that "reliability is the degree to which the finding is independent of accidental circumstances of the research and validity is the degree to which the finding is interpreted in a correct way" (p. 20). Fink (2003) describes that being consistent is the component to having a reliable survey instrument, whereas being accurate is a valid survey instrument. Survey design as an instrument produces the same kind of data – student responses to questions about ecological concepts. The wording of the survey was clear and concise and was targeted for an age group ranging from 9 to 13 years of age. Reliability procedures were employed to make certain that the researcher‟s coding procedures were consistent. My thesis advisor Dr. Puk, who has expertise in this area, provided guidance by cross-checking my interpretation of the themes and how I determined the levels of maturity.

One possible area of concern involved the interaction of previous participants with prospective respondents. For example, if participants conducted the survey before their classmates and shared what concepts were on the survey, this could affect the quality of the responses. It would give an unfair advantage and enough time for potential participants to find

out the meaning of the concepts, therefore presenting an inaccurate representation of their knowledge. To reduce this possibility, I discussed the issue of retaining confidentiality between fellow classmates with all of the participants. Also, I attempted to conduct the survey with a large number of students each time and shortened the time interval in between sessions. Follow up questioning served as a way to validate the participants‟ responses to ensure that the researcher understood their definition as accurately as possible.

Data analysis techniques. The first component of the data analysis involves discourse analysis that was applied to the concept responses found in the handwritten surveys. The main component of the analysis consists of the researcher using concept analysis as it was the framework for parsing and categorizing participants‟ definitions.

Discourse analysis. The study analyzed written responses in order to deconstruct the language being used in defining concepts. Fairclough (2003) views discourse analysis as a social analysis wrapped in a qualitative approach. Discourse analysis uses language as a way to dissect and uncover a meaning that is conveyed in a certain context, usually in a written format. This study focused on the language used to describe the concepts to understanding the participants meaning of the concepts. Chambers (2008) suggests that discourse analysts should capture not only what is being said, but what is not being said or how it is being conveyed because it has equal significance. Potter and Wetherall (1987) observe that examining human communication in everyday situations provides insight into understanding individual cognitive behaviour as well as how they interact socially. Jorgensen and Phillips (2002) discuss the social constructivist element of discourse analysis as this form of analysis can shed light on the way we communicate, bringing us one step closer to understanding the human world‟s complexities.

Concept analysis. This is a variation of qualitative content analysis (Graneheim & Lundman, 2004; Krippendorff, 1980) in which concept definitions are parsed into smaller components creating categories, sub-categories, and themes to ascertain similarities, differences and misconceptions in the students‟ understanding of specific ecological concepts. The primary data analysis used in the study was concept analysis (Puk & Stibbards, 2010; 2011; in press). As Patton (1980) states, in the process of inductive analysis "the patterns, themes and categories of analysis come from the data (p. 306). According to Puk and Stibbards (in press), "[a] mature concept definition is a system of interconnected, subordinate concepts (i.e. criterial attributes) which as a whole provide embedded meaning for a higher concept" (p. 13).

The objective of qualitative content analysis is to make inferences from the data to essentially contribute new insights and knowledge by providing representations of the phenomenon (Elo & Kyngäs, 2008). It is a method that can be used to develop unique themes to highlight the range in meaning of the phenomenon in question (Zhang & Wildemuth, 2009).

> Through careful data preparation, coding, and interpretation, the results of qualitative content analysis can support the development of new theories and models, as well as validating existing theories (Zhang & Wildemuth, 2009, p. 11).

In the current study concept analysis comprised of three phases. In Phase 1, the "units of meaning" were collapsed into "categories" which eventually became themes (Puk & Stibbards, 2010). In Phase 2, each concept was examined to determine the students‟ level of maturity of understanding (Puk & Stibbards, 2011; in press). To do so, the definition itself was parsed into criterial attributes or individual "nuggets of meaning" (Puk & Stibbards, 2010). Each response was then compared with the researcher‟s composite definitions for the concepts of *photosynthesis*, *decomposition*, *greenhouse gas*, *recycling* and *biodiversity*. Lastly, Phase 3

involved determining whether or not there was any growth in understanding these concepts from grades 4-8. This process involved examining responses within each grade level to determine to what degree if any there was an increased maturity in definitions across grades 4, 6 and 8 in terms of (a) consistency in themes for each concept and (b) maturity in meaning. Finally, a growth sequence of three concepts for the elementary grades was constructed using student responses.

Phase 1 analysis of meaning. This study‟s analysis mainly followed the procedure laid out in the concept analysis strategy (Puk & Stibbards, 2010; 2011; in press) (see Figure 3) to analyze each student‟s responses to allow meaning to emerge from the data. The concept analysis consisted of the following steps: (a) definitions for each concept (which became the units of analysis) were collected; (b) the criterial attributes (which are the small units of meaning i.e. a string of words that form a conceptual meaning) found within the unit of analysis (the definition) for each concept were coded in terms of whether they were non-responses, vague responses or incorrect responses; (c) categories of meaning were then identified in the units of analysis to be able to determine their level of maturity (see Phase 2 maturity of understanding); (d) themes were constructed from the categories of similar meaning in order to determine the uniformity in the meanings of the concepts (a further explanation of this analysis is found in Chapter 4). As Guba (1978) explains, data such as this can be sorted according to two criteria i.e. “internal homogeneity” (“concerns the extent to which the data holds together”) and “external heterogeneity” (concerns the extent to which differences are clear”) (p. 53).

a/Identify Units of Analysis

b/Identify Criterial Attributes

c/ Determine Categories

d/ Provide Themes

Figure 3. Concept Analysis Strategy (Puk & Stibbards, 2010; 2011; in press)

Phase 2 maturity of understanding. To identify the level of maturity that students‟ possess for the concepts of *photosynthesis*, *decomposition*, *greenhouse gas*, *recycling* and *biodiversity*, I applied the emergent maturity scale (Puk & Stibbards, 2011; in press) (see Figure 4). “Mature is used here in the sense of the meaning that might be expected at this level of education under study” (Puk & Stibbards, 2011, p. 201). Robinson, Ross and White (1985) suggest that rather than viewing student acquisition of concept meaning as either having meaning or not having meaning, “concepts grow” (p.183). In the same vein, “Akerlind (2008) offers the phenomenographic idea of *incomplete*, as opposed to *wrong*, in terms of concept development, and *expansion* rather than *change”* (as cited in Puk & Stibbards, 2011, p.193). In the emergent maturity scale, each level represents a stage at which the maturity of understanding for a concept is expressed. The expectation is that educators would want their students to ultimately achieve a robust understanding for a particular concept. The scale ranges from levels 1 to 4, where level 1 identifies the definition as immature or underdeveloped, level 2 as minimally acceptable, level three as enriched and level 4 as a robust, mature understanding. Using the data provided in Phase 1 analysis of meaning (described above), each response will be analyzed to determine the level of maturity it represents utilizing the parameters provided by the emergent maturity scale (this process is explained again in more depth in Chapter 4). If a concept on the survey was left blank (non-response), it resulted in a follow-up discussion, only when no further defining occurred; it was then scored at level 1. With this data, I was able to determine the percentage of definitions found at each level of maturity for each grade.

Level 1 - Unacceptable: immature: these included concepts for which no definition was provided and definitions that were either vague or incorrect.

Level 2 - Minimally Acceptable: limited maturity: this level is characterized by definitions that contain one viable criteria attribute rather than a system of interconnected attributes. At this level (and the next two), the focus is not on whether the definitions are "right" or "wrong", but rather at what level of emerging maturity of meaning they are constructed.

Level 3 - Enriched: enriched maturity: this level is characterized by definitions of increased maturity, as exemplified by a partial system of viable criterial attributes.

Level 4 - Exemplary: robust maturity: this level is characterized by definitions that contain a mature, coherent system of viable, interconnected criterial attributes. Mature is used here in the sense of the meaning that might be expected at the level of education under study.

Figure 4. Emergent Maturity Scale for Concept Development (Puk & Stibbards, 2011, p. 201)

Phase 3 growth in concept development. By collecting this information in grades 4, 6, and 8, I was able to make comparisons from grade to grade and more importantly construct a growth sequence of concept maturity for the elementary grades for some of the concepts.

The overall analysis used a combination of elements from several research design approaches. Grounded theory (Strauss & Corbin, 1990) aims at letting data naturally emerge into themes without the presence of predetermined factors, thus arriving at a conceptual thematic structure. In the current study I applied a degree of interpretation to make meaning from the uncovered data relationships. In conjunction with the aforementioned approach, a form of discourse analysis (Phillips & Jorgensen, 2002) was also involved. First, text i.e. the student responses, were parsed and categorized. Second, discourse analysis was applied to determine the respondents‟ knowledge of key ecological concepts. Third, discourse analysis was utilized to capture subjective truths using language as a way to access reality (Phillips & Jorgensen, 2002). Lastly, concept analysis (Puk & Stibbards, 2010, 2011; in press) was implemented to code and interpret the definitions. I applied this procedure (see Figure 3) to every concept in the survey.

Ethics

This study adhered to the ethics guidelines and procedures involving vulnerable populations that were developed by the research ethics board at Lakehead University. This study involved minors 9 to 13 years of age, which is under the legal age of consent. For children under the legal age of consent, a consent form was sent to their legal parent(s)/guardian(s). All participants under the age of majority were also informed about the nature of the study and asked for their written consent. No data was gathered prior to the researcher obtaining the written consent from each parent, child, teacher and the Board of Education. See the Appendix for the letters of informed consent. Before the survey was administered all participants were verbally

informed of their right as participants to withdraw at any time from the study without adverse consequences. The following information was explained to participants.

1. Risks/Benefits. There are no known or anticipated psychological or physical risks that might arise from this study.
2. Anonymity and Confidentiality. Student names, the school name and the name of the school board would not used in the thesis or any publications. All data is considered to be confidential.
3. Right to Withdraw. The researcher clearly indicated to participants that they may choose not to answer any questions they were asked as part of the research and that they had the right to withdraw from the study at any time without penalty.
4. Data storage. Only the principal investigator, Dr. Tom Puk, (Professor, Faculty of Education, Lakehead University my thesis supervisor) and myself, the graduate student investigator, Amy Ritter has access to the data. All data collected remains confidential and will be securely stored in a locked area in the Faculty of Education at Lakehead University for five years. After the five-year period all data will be destroyed as per Lakehead regulations.
5. Results. A final summary of the research results will be made available to participants wishing to have a copy of the final report through mail or e-mail. Participants will be given the opportunity to indicate whether they would like a final report on the bottom of their consent form. I also anticipated reporting the study findings in professional journals and at professional conferences, where all participants‟ identities and school board information will be kept strictly confidential. A copy of the Masters thesis will be available through Lakehead University libraries.

Chapter 4: Results of the Study

Chapter Overview

This chapter is into divided into four sections. The first section provides a review of how the data analysis was organized. The second section focuses on Themes (Phase 1) that have emerged from the participants‟ definitions for each grade and is categorized according to the order that the concepts appeared on the survey. The third section discusses the Level of Maturity (Phase 2) in the participants‟ definitions by means of applying the emergent maturity scale (see Figure 4). The fourth section, Growth Concept Development (Phase 3), is comprised of three subsections: (a) variability of meaning, (b) maturity of meaning and (c) examples of growth sequences. Subsection A describes the variability found in the definitions in relation to the number of emerged themes identified for each concept. Subsection B examines the growth in the meaning of the concepts from grades 4 to 8. Lastly, a growth sequence was developed for some of the participants‟ concept definitions across the three grades as found in subsection C.

Overview of Data Analysis

The method used to collect the data consisted of surveys. There were two types of surveys (see Figure 1 and Figure 2). Grade four participants received a survey that had four concepts (*the environment*, *photosynthesis*, *decomposition*, and *greenhouse gas*) and the second survey consisted of eight concepts (*the environment*, *photosynthesis*, *decomposition*, *greenhouse gas*, *recycling*, *biodiversity*, *sustainability*, and *green*) for grades 6 and 8 participants. Students wrote their concept definitions on the surveys provided.

Following the data collection process, the first part of the analysis consisted of examining every concept definition in order to develop emerging themes for each grade. The analysis was aimed at constructing emerging conceptual themes from the empirical evidence. Using the participants‟ responses I offered my interpretations of the empirical relationships. This resulted

in classifying responses into themes for each concept at each grade level. In doing so, I was able to illustrate the variation of concept themes for each grade. The second part of the analysis consisted of extracting the meaning of the definitions into viable criterial attributes or "nuggets of meaning" (Puk & Stibbards, 2010). For this part of the analysis I applied a form of concept analysis which consisted of using the emergent maturity scale (see Figure 4). In conjunction with the concept analysis technique (see Figure 3), I utilized discourse analysis to deconstruct the language (which was in a written format) to ascertain the meaning embedded in the definitions. This resulted in establishing the level of maturity for each definition. Lastly, the third part of the analysis included determining the conceptual growth for some of the concepts across grades 4, 6, and 8. The purpose of this step was to identify if there was consistency in the themes and to discover whether or not there was maturity in the concept meanings by the time students reached grade eight.

In the following sections, the data presented for each phase of the analysis will be explained using a combination of descriptive language, tables, and figures.

Phase 1: Analysis of Themes

In this section the participants‟ responses are classified by grades. Within each respective grade, the entire collection of concepts that are applicable to the grade will be discussed. Responses that did not make any sense (e.g. photosynthesis "is a species that lives in the swamp") were not included in this analysis of themes but rather are accounted for in Phase 2. It is important to note that in qualitative research generally (and concept analysis specifically) there is always a degree of interpretation reflecting the researcher‟s analysis when categorizing definitions into suitable themes (Atkinson & Hammersley, 2007; Graneheim & Lundman, 2004; Puk & Stibbards, 2010; 2011; in press). I reviewed all my interpretations with my thesis

supervisor who has many years experience in teaching concept development and conducting ecological concept analysis.

Grade 4.

The environment - This concept had 4 respondents out of 34 (12%) who were not able to define the concept. The five themes identified are as follows: “nature”; “human community”; “nature/community”; “the earth”; and “earth/community”.

Twenty responses (59%) described *the environment* involving “nature” only. Examples of student responses include “nature, land”, “forest or river or lakes or something like that” and “nature, where animals live, where plants grow, where animals get their food”. The above definitions imply that humans are not a part of *the environment* because it co-exists separately from the human domain, highlighting a sense of ecological disconnection. The second prominent theme for this concept is “human community”. Seven participants out of 34 (20%) described *the environment* as a place for human dwelling e.g. “the city what you live in”, “our place that we live in” and “means people around you”. This theme discounts nature‟s crucial connection by viewing *the environment* as a setting only inhabited by humans. The third theme describes a combination of “nature and human community”. One respondent out of 34 (3%) simply writes, “is like the plants, the air, the grass it‟s like nature but it isn‟t … is where nature is basically where trees, buildings are, also, where we live”. Dissimilar from the last theme, where only humans were recognized, this theme suggests collaboration between humans and nature. For the “earth as a planet” theme, only one student out of 34 (3%) stated that “the environment is where we live. It is a planet. It is round, just like the other planets. It has air and gravity so we can breathe, and stay on the ground”. The last theme links earth and community together. One student out of 34 (3%) writes “the environment is like the earth or the place you live in”. This

theme is different from the last theme because this student‟s definition included another component which referred to community.

Photosynthesis - This concept had 14 out of 34 (41%) responses that provided no meaning. This concept had the second highest number of student responses that did not supply an explanation. Nineteen (56%) students produced limited or incorrect definitions. Thus only one theme was identified for this concept i.e. sunlight/food (3%). Within this theme one student writes "something that makes its own food like a plant that uses the soil to make food. The plant uses sunlight and turns it into food with the cells in their leaves".

Decomposition – For the concept of *decomposition* 11 out of 34 students (32%) could not define it. This concept had the third highest number of student responses that did not include an explanation. Additionally, the remaining 23 students out of 34 (68%) produced limited or incorrect definitions, resulting in no themes being identified for this concept.

Greenhouse gas – For the concept *greenhouse gas* 17 out of 34 (50%), could provide no meaning. The remaining 17 students (50%) produced limited or incorrect definitions, resulting in no themes for this concept being identified.

Grade 6.

The environment - This concept had only one student of 28 participants (3%) that produced a response that did not make sense. Three dominant themes were identified as follows: "nature"; "human/nature"; and "the earth".

Fifteen students out of 28 (54%) stated that *the environment* is nature e.g. "is kind of like the nature that surrounds us", "the environment is pretty much nature", and "means nature or the world things that are not handmade". Interestingly, the last response suggests that *the environment* is exclusively comprised of non-manmade substance, drawing an invisible line

between humans and nature. Two respondents also expressed a division among humans and nature by describing *the environment* as a physical location where humans can enter and exit e.g. “means outside, trees, flowers, green, and natural things”, “means outdoors, the forest, trees, flowers, grass”.

The second identified theme is a union between humans and nature. Eight students out of 28 (29%) referred to *the environment* as an accumulation of both human and non-human life forms. The following showcase a few examples from the 8 responses e.g. “is the nature and the flower and insects and trees, also the animals that live and the living”, “is where we live and what the Earth is made of”, and “means the land and the belongings in this world we have”. Unlike other responses for this concept, the above definitions recognized that a relationship exists among humans and nature. Four respondents out of 28 (14%) provided definitions that described “the earth”. An example response for this theme is “is basically our earth with all the trees, plants, and grass”.

Photosynthesis - This concept resulted in 9 respondents out of 28 (32%) who did not provide a definition for this word. In addition, 15 respondents (53.5%) gave explanations that were limited or incorrect. Consequently, the remaining respondents established two themes as follows: “a cycle”; and “making energy from the sun”.

Three students out of 28 (11%) describe *photosynthesis* as being “cyclical” e.g. “is the cycle of plants in which the plants receive energy from the sun and water from the rain” and “is the cycle of how a plant gets its food and nutrients”. For the theme of “making energy from the sun”, one student (3.5%) writes “is what plants do to get energy. A plant takes sunlight from the sun and turns it into energy”.

Decomposition - Seven participants out of 28 (25%) did not give a meaning for this concept, ranking it the second highest concept for this grade without an explanation provided. The 21 remaining students (75%) produced limited or incorrect definitions, resulting in no themes for this concept.

Greenhouse gas - This concept had only one student (4%) who did not offer a meaning. In total 27 participants (96%) created limited or incorrect explanations, resulting in no themes for this concept.

Recycling - This concept produced three themes. They are identified as "the process of breaking down materials into new products"; "turning used things into other things"; and "using reusable products to make other products". Twenty five of 28 participants (89.3%) had limited or incorrect meanings for this concept.

For the first thematic representation, one student (3.6%) said that recycling "is the process of breaking down materials and smashing them into a pulp to be made into new things". For the second theme, another student (3.6%) suggests recycling is "when you take something used and turn it into something else that you can use again". Lastly, the third theme is characterized by one student (3.6%) as they refer to recycling as a means for "when reusable products are made into other products".

Biodiversity - In examining this concept, 4 students out of 28 (14%) did not provide a meaning, whereas 22 students out of 28 (79%) produced definitions that were limited and/or incorrect. The remaining two responses formed two themes. They are as follows: "differences in nature"; "organisms living and working together".

One student (3.5%) provided a vague response implying that biodiversity "means differences in nature. Diversity means differences, and bio means earth or nature. There are

different attributes or properties for different things". Another student (3.5%) writes "all living things that live and work together to help each other".

Sustainability - The responses for the concept *sustainability* produced the largest number totaling thirteen out of 28 (46%) responses that did not provide a meaning for this word. Ten students out of 28 (36%) provided explanations that did not make any sense. The remaining responses resulted in two varying themes. They are as follows: "actions that lead to a healthy environment"; and "longevity of the environment/earth".

Two students out of 28 (7%) refer to sustainability as a way to "maintain the health status of the environment" e.g. "when you sustain an amount of something that is healthy for the environment". For the second theme, 3 students out of 28 (11%) suggest sustainability involves "whether the environment can last for a long period of time".

Green - When looking at this concept, all twenty-eight (100%) of the participants provided an explanation for this word. There are three dominant themes. They are as follows: "human actions considering the Earth (recycling)"; "describing the Natural world"; and "environmentally friendly". Three students out of 28 (10.7%) had responses that did not make any sense.

For the first theme 12 participants out of 28 (43%) describe green as another word for "recycling" e.g. "means when you go green you start recycling and reusing items". For the second theme 3 participants (10.7%) explained green by relating the concept to "elements of the Natural world". For example, "green is grass its trees it's the Earth" and "is a colour that are included in most plants". The third theme identified is that of "environmentally friendly". Ten participants (35.7%) suggested its meaning is an "alternative way of stating a

product/service/action is environmentally friendly". Examples include "another word for environmentally friendly", and "to do good things for the environment".

Grade 8.

The environment - This concept had three identifiable themes which are as follows: "nature"; "human/nature"; and "human community".

Thirteen students out of 25 (52%) stated that *the environment* represents "nature". Their responses consisted of "the living part of the world also called nature … living part refers to plants, animals and bacteria", and "a place with oxygen, plants, trees or a green place". Eleven participants out of 25 (44%) generated the second theme of "humans and the natural world". Some examples include "is essentially all the world, all the ecosystems, and the factors affecting them either natural or manmade", and "everything around us". These responses accentuate the ambiguity and open interpretation of this concept. The third theme for this concept is "human community". One individual (4%) referred to *the environment* as "the area we live in".

Most of these definitions lacked robustness, clarity, and comprehension. Many participants gave examples of what one might find in *the environment* such as trees, plants, and animals. Other responses were vague, only providing small snippets without ever really describing what the concept is e.g. "Nature, land". One possible explanation for the variance of the definitions given is perhaps that the concept of *the environment* itself is overused in a myriad of contexts, therefore conflating a common meaning for the word.

Photosynthesis - Seven of the 25 participants (28%) for this grade did not provide a definition. Eight students out of 25 (32%) produced limited or incorrect responses. There were two dominant themes for this concept. They are as follows: "sun"s energy to food"; and "plants create food from the sun".

Five respondents out of 25 (20%) suggest photosynthesis is a process where "plants receive energy from the sun". Examples include "plants get their energy from the sun", and "a plant absorbing sunlight and using a natural chemical to convert it into "food" or energy". Five other students (20%) described photosynthesis as a way plants create food from the sun e.g. "is how plants create their food. What happens is the plant retrieves water from the ground and into its stem, from then it creates its own energy by using the sun", and "the process plants use to convert CO_2 and water into food. It is powered by sunlight".

Decomposition - This concept had 3 respondents out of 25 (12%) who did not give a meaning for this word. Also, 16 respondents out of 25 (64%) created limited or incorrect explanations. There were two themes that emerged. They are identified as: "breakdown of natural material by organisms and returned to the earth"; and "breakdown of natural material and returned to the earth".

In the first theme, two students out of 25 (8%) propose "organisms are the mechanisms that aid in the breakdown of matter" e.g. "The breaking down of plants and other natural material by organisms so that eventually they become part of the Earth again". In comparison with the first theme, the second theme refers to the breakdown of matter, but without the mention of organisms. Four students out of 25 (16%) believe that decomposition "is the process of how organic material dissolves and goes back to the earth", and "is when something is put into the ground/compost it then slowly degrades into the earth and soil".

Greenhouse gas - Only one student out of 25 (4%) did not provide a meaning for this concept. This concept has one theme of "human emitted gases released in the atmosphere heat earth". The lack of themes can be attributed to the high number of limited and incorrect responses given by twenty-two of the participants (88%).

Two students out of 25 (8%) provided the one theme. Examples include “refers to emissions we release into the atmosphere. The emissions/gases create the “greenhouse” affect, by creating a sort of shield below the atmosphere, heating our environment”, and “greenhouse gases are heat trapping gases in the atmosphere. They are causing climate change by trapping heat from the sun and causing it not to leave the earth, but to bounce back and warm the earth.”

Recycling - Sixteen participants out of 25 (64%) produced incorrect or limited explanations. This concept also produced the largest variability of themes. The six themes are: “materials turned into new products”; “items reused as other product”; “the act/process of reusing products”; “destruction of objects to generate new products”; “melting down products into something new”; and “turning used things into a semi-raw state and then making them into something else”.

The first theme suggests that recycling is “materials turned into new products”. Two respondents out of 25 (8%) state that recycling is “the process in which materials such as plastic are turned into new products”, and “when something has been used for its job, and it gets remade into something else”. The second theme refers to non-specific items that can be reused to make other products. Two respondents out of 25 (8%) implied that it is “the process in which an item is reused and formed into another product”. Two students out of 25 (8%) describe the theme of “materials that can be remade into new products e.g. “is reusing plastics, glass, and paper. It all gets remade into other objects”. For the fourth theme one student out of 25 (4%) states that recycling is “when something is destroyed to be made into the same thing or something else”, and another student describes recycling as the “destruction of objects to create new objects”. For the fifth theme one student out of 25 (4%) provided a response suggestive of “melting down products into a new product”. This student explains that “we take a product, melt it down, then

put it back together as something new". For the sixth theme, one student out of 25 (4%) describes the process of recycling with a slightly different perspective by stating that recycling is "taking used things, returning them to a semi raw state, and then making them into something else".

Biodiversity - Seven participants out of 25 (28%) did not provide a meaning for this concept. Due to the high number of limited and incorrect definitions (61%), there was only one theme acknowledged i.e. "a variety of species in an area".

All six useable responses (11%) described biodiversity as a "variety of species in an area". An example of this theme is "is the vast selection of life or living organisms in the ecosystem of our planet".

Sustainability - Three of 25 students (12%) were not able to provide meaning for this concept. Eleven explanations out of 25 (44%) did not make any sense. The remaining sustainability explanations revolved around three identified themes as follows: "not running out"; "sustaining organisms"; and "durability of an object".

For the first theme of "not running out", 3 of 25 respondents (12%) imply sustainability as "a product or process which does not take more than it can produce". Four respondents" out of 25 (16%) explanations were categorized under the second theme by describing sustainability as way to "preserve organisms and ecosystems". The following are examples: "to have animals live somewhere it has to be able to sustain them", and "is the "power" to sustain many different ecosystems that mainly animals must have". All of the definitions contain some variation of sustain in their explanations, which does not provide a definition, but rather may point to the lack of experience in defining a concept. The third theme consists of 4 of 25 respondents (16%) who

suggest sustainability is the "strength of an object and/or how it can endure its surroundings" e.g. "something strong that holds stuff", and "something that is strong that can't be destroyed".

Green - For this concept, all 25 students (100%) provided responses. However, two students (8%) had responses that did not make any sense. There were four central themes identified as: "environmentally friendly"; "human actions considering the Earth (recycling)"; "carbon footprint"; "colour representing the Natural world".

The first theme that emerged from the participants was coded as "environmentally friendly". Nine of 25 students (36%) describe green as a term or an alternative word for being harmless to the environment. The following example expresses this theme: "an alternative environmentally friendly option that involves a less harmful approach to the environment". Seven students of 25 (28%) provided explanations resulting in the second theme of "human actions considering the Earth" e.g. "some people use the term "Go Green", as in to not waste water, recycle, and try hard to take care of our environment". Two participants out of 25(8%) indicate green as another term for carbon footprint e.g. "to have a small carbon footprint and not waste materials and resources". The final theme for this concept is a "colour representing the Natural world". Five student (20%) responses out of 25 described green as a shade associated with elements of the natural world e.g. "the colour that most people use to represent the environment".

Phase 2: Level of Maturity in Understanding Concepts

This segment examines participants' concept explanations as analyzed using the emergent maturity scale (see Figure 4, Puk & Stibbards, 2010, 2011; in press) for the following concepts*: photosynthesis*, *decomposition*, *greenhouse gas*, *recycling*, and *biodiversity*. The concepts of *the environment*, *sustainability* and *green* were not analyzed in terms of their level of maturity. Puk and Stibbards (2010) suggest that these concepts are so ambiguous that they have

no universal meanings and instead are often used with completely different meanings (as can also be seen in the data found in this study). Despite the fact that the participants‟ definitions were not analyzed for their meaning, it was reasonable to include the concepts as a part of the study because students are frequently exposed to the three concepts. For example, *the environment* and *sustainability* are found throughout the *Science and Technology* (2007a) curriculum guidelines and *green* is often used in environmental media messages. There is value in collecting and understanding what elementary students‟ know about the concepts because it provides a sample of students‟ conceptual understanding which would be beneficial for developing ecological education teaching strategies. Thus, for these three concepts, I simply categorized the variability of the themes found in the responses (as found in Phase 1).

The first thing that should be pointed out in this section is that the follow-up sessions did not result in any significant changes in student responses. In only one student response for one concept out of a total of 367 possible responses did the definition improve (going from a level 1 to 3). In almost all cases, the students either said they could not think of anything more to add to their previous written responses or acknowledged they did not know what the concept meant. This would seem to confirm that written responses do in fact reveal the depth of understanding that elementary students have in regard to concepts.

In this section, utilizing the Concept Analysis Strategy (see Figure 3) each definition was parsed into criterial attributes (i.e. units of meaning). Then utilizing the Emergent Maturity Scale (see Figure 4) these definitions were compared to a composite level 4 definition (see Figure 5) to assess the appropriate level of maturity for each response. Level 4 definitions represent what students should know by the end of grade 8. These definitions were created by taking the viable criterial attributes from student responses and developing a composite definition. Definitions

found in the *Science and Technology Grades 1-8* curriculum guidelines (Ontario Ministry of Education, 2007a) were also considered in determining the appropriate criterial attributes where possible. Finally these definitions were reviewed by my thesis supervisor who has expertise in this area. When a student did not provide meaning for a concept or provided an incorrect meaning, it was scored at a level 1. Incorrect is used here in the sense that the student response did not contain any viable criterial attributes found in the composite definitions. It is important to note that students did not have to match the exact words or phrasing of the composite definitions in order to be assessed at a specific level. Rather, the explanations needed to provide the meaning within each criterial attribute. The Figure 5 definitions provided a guide to determine the level of maturity of student explanations.

Level of maturity results.

Grade 4. Table 1 summarizes the percentage of concepts for which no meanings were provided.

Table 1

Percentage of Responses With No Meaning Provided

Concepts	Grade
The Environment	12%
Photosynthesis	41%
Decomposition	32%
Greenhouse gas	50%

The above table represents the percentage of participants who did not write a response on the survey, and who did not provide a response during the follow-up discussion. Out of a possible 102 definitions, 95 scored at level 1 (93%), this includes the responses where no meanings were provided. Six scored at level 2 (6%), and one scored at level 3 (1%). As indicated previously, level 1 is indicative of definitions with no meaning for the word or the meaning provided was not minimally accurate.

i/ Photosynthesis – is a process in which plants combine energy from the sun as well carbon dioxide and water and turn them into food/energy/nutrients and oxygen.

ii/ Decomposition – a natural process of breaking down materials by small living things (organisms, bacteria) into smaller elements so they can be used again and again.

iii/ Greenhouse gas – is a gas that when in the sky/atmosphere allows the sun‟s energy to pass through it but when this energy/heat is given off by the earth the gas reflects the heat back to the earth‟s surface.

iv/ Recycling – the ongoing processing of used materials/products into a semi-raw state and making new materials/products.

v/ Biodiversity – the variety of different living things found in a natural system that contributes to the health of that system.

Figure 5. Level 4 Elementary School Definitions

Photosynthesis - Twenty-seven out of 34 students (79%) scored at level 1 with immature explanations for this concept of which 14 (41%) of the responses had no meaning. The definitions were comprised of vague, incorrect or nonsensical meanings for the word photosynthesis. Examples of level 1 responses include: “is a type of plant” and “can talk to people by phone who are far away”. Six of 34 students (18%) gave a level 2 definition for this concept as it contained one viable criterial attribute, whereas only one student (3%) provided a definition scoring a level 3 on the emergent maturity scale e.g. “plant that makes its own food by the sun”. The highest possible mean score for each concept would be M = 4.00. The mean for this concept is M = 1.24.

Decomposition - All 34 participants (100%) attained a level 1 on the emergent scale for this concept. Out of the thirty-four responses there were 11 responses (32%) that did not provide any meaning. The responses that had meaning, their explanations were vague, limited, incorrect or did not make any sense. Several responses referenced composting as the meaning for decomposition. Other responses presented recycling as the main component of decomposition e.g. “a definition for decomposition is recycling”. A number of incorrect responses surfaced such as: “the black smoke that comes out of mills”, and “you help the environment and save the insects so they don‘t die”. The mean for this concept is M = 1.00.

Greenhouse gas - Similar to decomposition, for this concept every response from 34 students (100%) was assigned a level 1. Not only did every response score level 1, but 17 (50%) of the students could not supply any meaning for this word.

Table 2 summarizes the level of maturity for these concepts (percentage of students).

Table 2

Grade 4 Levels of Maturity in Ecological Concept Development (%)

	Grade 4			
Concepts	Level 1	Level 2	Level 3	Level 4
Photosynthesis	79%	18	3	0
Decomposition	100%	0	0	0
Greenhouse gas	100%	0	0	0

Grade 6. Table 3 summarizes the percentage of responses that contain no meanings for the concepts.

Table 3

Percentage of Responses With No Meaning Provided

Concepts	Grade 6
The Environment	4%
Photosynthesis	32%
Decomposition	21%
Greenhouse gas	4%
Recycling	0%
Biodiversity	14%
Sustainability	46%
Green	0%

The table above represents the percentage of grade 6 participants who did not provide an explanation of the concepts on the survey or during the follow-up discussion. Out of a possible 145 definitions, 134 scored at level 1 (92%), this includes the responses where no meanings were provided. Only 11 responses (7%) scored at a level 2 or level 3. No respondents in this grade reached a robust mature definition for any of the concepts.

Photosynthesis - Twenty-three (82%) students‟ explanations scored at a level 1, of those responses 9 (32%) had no meaning provided. Many definitions expressed incorrect information about the concept, some were vague in their meaning and others made no sense. A number of

students produced limited understanding which is evident in their responses such as: “what plants do to get energy”, “is when someone is scared of getting their photo taken” and “when plants die”. For a response to be a level 2, the response must contain one viable criterial attribute. Three respondents‟ (11%) out of 28 explanations scored at a level 2. An example of a level 2 definition is “the concept that vegetation (plants, flowers) receive nutrition from the sun”. Two students‟ (7%) answers scored at a level 3 e.g. “a plant takes sunlight from the sun and turns it into energy” and “when a plant uses the sun to create food”. The mean for this concept is M = 1.25.

Decomposition - Twenty-eight out of 28 participants‟ (100%) responses were assigned a level 1. Out of those 28 responses there were 6 (21%) responses that resulted in an explanation without meaning. Example responses include “the action of composting”, “is the process of how something disappears” and “the breakdown of an object”. The mean for this concept is M = 1.00.

Greenhouse gas - All 28 students (100%) produced meanings for this concept that according to the emergent maturity scale scored at a level 1. Only one student (4%) did not provide a meaning for this concept. Greenhouse gas typically was described as e.g. “the gas left over from trapping sunlight in a greenhouse”, “when the atmosphere is holding in heat and sun kinda like a greenhouse”, “is the pollution in the air it covers the sky and makes the clouds make the sun hotter”, and “is the pollution us humans let out into the air”. The mean for this concept is M = 1.00.

Recycling - Twenty-five of 28 participants (89.3%) scored at a level 1. All participants provided meaning for this concept.. One participant out of 28 (3.6%) scored at a level 2 and two participants out of 28 (7.1%) scored at a level 3 on the emergent maturity scale. Pertaining to level 1 explanations, the following examples illustrate what a level 1 response resembles e.g. “to

re-use something rather than throwing it away", and "object such as cans or bottles are reused". One student"s explanation contained one viable attribute by suggesting recycling is "reusable products are made into other products", therefore scoring at a level 2. Whereas, two participants (7%) provided more mature definitions which scored at a level 3. Level 3 examples are: "is the process of breaking down materials and smashing them into a pulp to be made into new things", and "is when you take something used and turn it into something else that you can use again". The mean for this concept is M = 1.19.

Biodiversity - In spite of the fact that an entire unit is dedicated to this concept in grade 6, the majority of the students, 26 out of 28 (93%) attained a level 1in their responses. Out of the 26 responses 4 (14%) responses were left without meaning. Only two students" definitions (7%) scored at a level 2. For level 1 explanations, students were vague when presenting the meaning of biodiversity such as "is the study of living things", "when plants and stuff that has something to do with the environment changes", and "it goes with science and it means plants and animals". For two students who developed definitions achieving a level 2, their responses included: "means differences in nature", and "all living things that live and work together to help each other". The mean for this concept is M = 1.08.

Table 4 summarizes the levels of maturity for these concepts (percentage of students).

Table 4

Grade 6 Levels of Maturity in Ecological Concept Development (%)

	Grade 6			
Concepts	Level 1	Level 2	Level 3	Level 4
Photosynthesis	82%	10%	7%	0%
Decomposition	100%	0%	0%	0%
Greenhouse gas	100%	0%	0%	0%
Recycling	89%	4%	7%	0%
Biodiversity	93%	7%	0%	0%

Grade 8. Table 5 summarizes the percentage of concepts for which there were no meanings provided.

Table 5

Percentage of Responses With No Meaning Provided

Concepts	Grade
The Environment	0 %
Photosynthesis	28%
Decomposition	12%
Greenhouse gas	4%
Recycling	0%
Biodiversity	28%
Sustainability	12%
Green	0%

The above table indicates the percentage of participants who did not provide a definition for the concepts, both on the survey itself and in the follow-up discussion. For this grade out of a possible 125 definitions, 94 scored at level 1 (75%), which include the above responses with no meaning. In addition, thirty-one responses (25%) attained a level 2 or 3 in their responses.

Photosynthesis - Sixteen respondents out of 25 (64%) scored a level 1 on the emergent maturity scale. However, 7 respondents (28%) of the 16 respondents did not provide a meaning

for this word. Five respondents out of 25 (20%) scored a level 2, and four students out of 25 (16%) scored a level 3. Similar to other grades in this study, the majority of the responses were limited, incorrect, or vague in their understanding of the concept. Examples of level 1 definitions include: “the reproduction of a plant cell”, and “how plants live, they harvest sunlight”. Examples of level 2 definitions consisted of: “is a process used by plants and trees to convert sunlight into usable nutrients to keep the plant healthy. It is carried out by the leaves of the plant” and “the process of plant turning sunlight into food”. Only one student gave an enriched definition resulting in a level 3 score i.e. “the process plants use to convert CO_2 and water into food. It is powered by sunlight”. The mean for this concept is M = 1.52.

Decomposition - For this concept, 5 (20%) of all 25 explanations scored at levels 2 and 3, while 20 explanations (80%) remained at level 1. There were 3 (12%) responses that did not supply meaning for the concept.

Level 1definitions demonstrated limited understanding of this concept. Examples of level 1 include “nature‟s way of taking out the trash in a sense” and “when you are throwing out or burning things”. As indicated in the above examples, students did not consider what they referred to as „waste‟, as being useful to other organisms.

Whereas, in level 2 minimal understanding is evident. Examples include “the breaking down of plants and other natural materials, so that eventually they become a part of the earth. It is the cycle of life” and “when something from nature breaks down and the nutrients stay”.

In level 3 explanations, students showed an enriched maturity of understanding for what the concept means. One example of level 3 is “is what happens when something organic dies and is eaten way by bacteria and insects, which starts the food chain all over again”. This concept resulted in a means of M = 1.24.

Greenhouse gas - Twenty-three students‟ responses (92%) achieved a level 1 on the emergent maturity scale. Only one student (4%) response did not contain meaning for this concept. Two students‟ responses (8%) scored at a level 2, whereas there were no level 3 and 4 definitions for this concept.

Examples of level 1 response are as follows: “a harmful gas to the environment”, “is a house full of flowers that attracts energy” and “is something that affects our atmosphere in a way, causing global warming”. An example of a level 2 definition is “refers to emissions we release into the atmosphere”. The mean for this concept is M = 1.08.

Recycling - This concept had three level 3 explanations (12%), making this concept the one with the most number of definitions achieved at an enriched level. All students provided a definition for this concept. Sixteen explanations out of 25 (64%) scored at a level 1, while six responses (6%) acquired a level 2 score.

Examples of level 1 responses include “is an efficient way of reusing material so that it is not wasted and be used again for other uses”, “is a practice that happens in many households”, and “it helps the earth, not to pollute the world”.

Examples illustrating level 2 definitions include: “re-using plastics, glass, and paper. It all gets remade into other objects” and “the process in which an item is reused and formed into another product”.

To achieve a level 3 score, responses had to include an incomplete set of criterial attributes which shows maturity in their understanding of the concept. The following examples exemplify what a level 3 response would consist of “when something has been used for its job and it gets remade into something else. Some things have to be burned or crushed to be able to be

made into new things" and "taking used things, returning them to a semi raw state, and then making them into something new". The mean for this concept is M = 1.48.

Biodiversity - Nineteen responses out of 25 (76%) were scored at a level 1. Seven responses (28%) did not provide meaning for this concept. Three responses (12%) attained a level 2 score and three responses (12%) scored at a level 3. The following examples illustrate level 1 responses e.g. "different ecosystems working together", "is a term for the different systems/organisms in the ecosystem" and "the different types of organisms". An example of a level 2 definition is "refers to an environment which has a blend of different animals, plants, and bugs". Whereas, level 3 explanations are as follows: "is the vast selection of life or living organisms in the ecosystems of our planet" and "is a variety of species in an environment". The mean for this concept is M = 1.37.

Table 6 summarizes the levels of maturity for these concepts (percentage of students).

Table 6

Grade 8 Levels of Maturity in Ecological Concept Development (%)

	Grade 8			
Concepts	Level 1	Level 2	Level 3	Level 4
Photosynthesis	64%	20%	16%	0%
Decomposition	76%	16%	4%	0%
Greenhouse gas	92%	8%	0%	0%
Recycling	64%	24%	12%	0%
Biodiversity	76%	12%	12%	0%

Phase 3: Growth in Concept Development

This portion of the analysis included examining growth in concept development from grades 4-8 in terms of the maturity of the participants" definitions. These concepts included

photosynthesis, *decomposition*, *greenhouse gas*, *recycling*, and *biodiversity*. The concepts of *the environment*, *green* and *sustainability* were not considered in this phase due to their perceived ambiguity and lack of uniformity in general usage (Puk & Stibbards, 2010).

(a) Variability of meaning. By the end of grade 8, there should be fewer themes, less variability in meanings for the same concepts and increased uniformity in understanding of what the concepts mean would imply growth in regard to variability of meaning. As most concepts did not achieve level 2 in terms of their maturity in all grades, there are no concepts that might be considered in this section. Between grade"s 6 and 8, two concepts might be considered. Photosynthesis had two themes in both grade 6 and 8 so there was no change in variability. In regard to recycling however, the number of different meanings for this concept increased significantly from grade 6 when there were three themes/meanings and eight themes/meanings by grade eight. It would seem that there was even more confusion and less uniformity by the end of the elementary grades. This will be discussed in the next section, however it is important to keep in mind that there were few level 2 definitions at all grades and for all concepts.

(b) Maturity of meaning. In this section, growth would be determined by the increased maturity of meaning as indicated by the emergent maturity scale. This is represented by the means for each concept which was created for every grade (see Table 7).

Table 7

Mean Scores of Student Concept Responses

Concept	Grade 4	Grade 6	Grade 8
Photosynthesis	1.24	1.25	1.52
Decomposition	1	1	1.28
Greenhouse gas	1	1	1.08
Recycling	N/A	1.19	1.48
Biodiversity	N/A	1.08	1.37

Perhaps the most important finding of the study is that there was a minimal shift in the value of the means for the five concepts. The mean values include: *photosynthesis* grade four $M = 1.24$, grade six $M = 1.25$, and grade eight $M = 1.52$; *decomposition* grade four $M = 1$, grade six $M = 1$, and grade eight $M = 1.24$; *greenhouse gas* grade four $M = 1$, grade six $M = 1$, and grade eight $M = 1.08$; *recycling* grade six $M = 1.19$, grade eight $M = 1.48$; *biodiversity* grade six $M = 1.08$, grade eight $M = 1.37$. Figure 6 clearly identifies the lack of increased maturity in the definitions from grade 4 to grade 8. However, we also need to keep in mind that out of a possible 372 definitions for these five concepts, 323 (87%) were at a level 1.

An interesting association surfaced when evaluating grade 4 responses to grade 8 responses. There was more verbiage present in the grade 8 definitions; however despite a fuller physical appearance in the grade 8 definitions, there was no substantial increase in their understanding of the concepts.

(c) Examples of growth sequences. This final section presents the most robust growth sequence from grade 4 to 8 for the concepts of *photosynthesis*, *recycling* and *biodiversity* (the other two concepts of *decomposition* and *greenhouse gas* did not have any minimally acceptable definitions (level 2) in either grade 4 or 6). These growth sequences represent a composite

picture of the most mature responses of a very few students. They also represent the understanding that is possible at the elementary grades.

In Figure 7, one can see the growth in understanding for each of these concepts. In regard to *photosynthesis*, the level 3 response adds the critical element of carbon dioxide that is converted by the plant. The level 3 *recycling* response, not only mentions that products are made into other things, but by grade 8 they are first "returned to a semi-raw state" i.e. remanufactured. The *biodiversity* level 3 response not only referred to "differences in nature", but by grade 8 the level 3 definition refers more specifically to a variety of living species in an area.

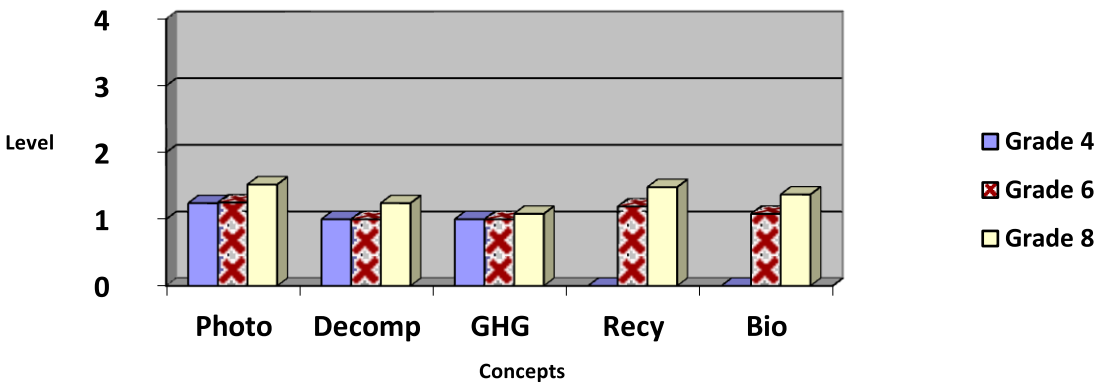

Figure 6. Mean Score of Student Concept Responses
Note: Photo = photosynthesis, Decomp = Decomposition, GHG = Greenhouse gas, Recy = Recyling, and Bio = Biodiveristy.

	Grade 4	Grade 6	Grade 8
Concept	Level 1	Level 2	Level 3
Photosynthesis	the method plants use to make energy	is the cycle of plants in which the plants receive energy from the sun and water from the rain.	the process plants use to convert co2 and water into food. It is powered by sunlight.
Recycling	N/A	is when reusable products are made into other products	taking used things, returning them to a semi raw state, and then making them into something new
Biodiversity	N/A	means differences in nature	having a variety of living things in an area

*Figure 7.*Growth Sequence for Ecological Definitions in the Elementary Grades

Summary

This chapter entailed three phases of analysis: (1) analysis of themes of understanding; (2) analysis of the maturity of understanding of concepts; and (3) analysis of growth in concept development. Each phase examined the data differently in order to determine students‟ understanding of key ecological concepts found in the Ontario elementary science curriculum. The first phase involved the identification of concept themes which emerged from my analysis of the student responses. Within this phase I found a lack of consistency in the students‟ understanding of the concepts, a pattern that existed in every grade of the study. This lack of consistency resulted in multiple understandings for the same concepts. For some concepts such as *greenhouse gas* no themes were identified at all because the responses did not include a meaning for the word.

In phase 2 of the analysis, I found that the level of maturity in the understanding of the concepts was low for all grades. As well, in phase 3, there was no overall significant growth in terms of understanding and meaning-making within the five concepts (photosynthesis, decomposition, greenhouse gas, recycling and biodiversity) from grades 4 to 8 although there was a modest increase in level 2 and level 3 responses. The vast majority of students at all grades were unable to provide level 2 responses for the five concepts.

Taken as a whole, the study provides a glimpse into the problems students have in conceptualizing ecological concepts. Possible reasons for these results are discussed in Chapter 5.

Chapter 5: Discussion

Chapter Overview

This study collected and examined elementary students‟ ecological concept knowledge. It resulted in the development of a concept maturity sequence illustrating children‟s progress from grade to grade. The chapter‟s main purpose is to discuss the data that was presented in Chapter 4, and generate possible explanations for the results as developed from the data. This is followed by recommendations including a section exploring further questions and potential research avenues. Lastly, a conclusion section reiterates the substantiated claims and relationships as a result of the study.

Discussion of Findings

This discussion is influenced by the constructs of grounded theory to derive meaning, relationships and patterns from the data. This section is divided into several areas in order to review the patterns and themes that naturally emerged from the analysis of the data. These themes include: (a) wide range in concept meanings; (b) ambiguous concepts; (c) circular referencing; (d) level of maturity of understanding for key ecological concepts; (e) curriculum and instruction and (f) growth sequences.

(a) Wide range in concept meanings. This study found that every concept in the survey at each grade level demonstrated some range in meaning as evidenced by the number of different themes found in the student definitions. The participants‟ overall understanding of the fundamental elements in the concepts lacked depth and failed to show a mature understanding of them. None of the concepts had only one dominant theme or meaning that emerged from the definitions. Having a dominant theme would demonstrate cohesion in students‟ understanding of the concepts.

What is also important to comprehend about this assortment of meaning is that it does not only exemplify how students hold varying conceptual knowledge for ecological concepts but reveals how wide the range in understanding of said concepts really is. Even responses collected from the same classroom showed variance in their definitions. This lack of fundamental understanding can be hypothetically linked to a number of possible intersecting explanations. It could be attributed to the variability of students‟ previous experience. It could be a consequence of limited understanding of the concepts by the teachers due to limited teacher training and teacher professional development. It could also be a result of students forgetting what they were taught earlier on in their schooling or it could be that they were not formally taught any one of these concepts at all. Or it could be partly related to the ambiguous nature of three of the concepts, *the environment*, *green* and *sustainability,* which will be discussed in the following section below. These explanations allude to a possible disconnection between curricular and instructional approaches and retention of information by students, affecting their level of comprehension of these ecological concepts.

(b) Ambiguous concepts. This study found that when asking students to define the three concepts of *the environment*, *sustainability*, and *green* there was a significant degree of variability, vagueness and nonsensical elements in their concept meanings, more so than in the other concepts. This seems to imply a mix of implied meaning in the use of the concepts themselves. The variability in the meaning of these three concepts made it not only unfair to assess the maturity of such definitions but difficult to provide a composite definition of each concept due to the ambiguous nature of the responses.

The following examples demonstrate the ambiguity found in the responses for *the environment*: *"*the entire world that may be getting polluted right now (the entire world means

countries and places like New York and Iran)", "is like a whole bunch of countries", and "something that deals with a job. Taking care of a huge building, something like a lawyer". The *Science and Technology* (2007a) curriculum guideline includes this term repeatedly, however there is no explanation provided to give both teacher and students an unambiguous understanding of what it might mean. Puk & Stibbards (2010) suggest that by applying the definite article "The" it creates a cognitive association that The Environment would refer to a geographical/ physical location such as "the Great Lakes" (p. 465). It would be an interesting comparison to see if dropping "The" from the concept, if participants would yield the same responses they gave on the survey or whether they would develop an entirely different set of responses.

The concept of s*ustainability* is also often found in slogans, ads, and commercials with a mix of implied meanings. Huber"s (2000) article titled *Towards Industrial Ecology: Sustainable Development as a Concept of Ecological Modernization* states that the meaning of the concept sustainability is dependent upon what perspective (economic vs. ecological) it represents and what it is being used to describe. Thus it may not be surprising that elementary students (and perhaps teachers) don"t have a firm understanding of what *sustainability* means because it does not appear to have a consistently shared meaning. In the study, the concept of *sustainability* received a number of responses that were ambiguous, making up 40% of all grades 6 and 8 student responses. Some examples of this are: "something that can sustain a long time. If something is sustainable it is green", "means how live things stay alive", "sustaining a healthy diet or a clean world", and "when something is stable or not changing". The *Science and Technology* (2007a) curriculum guidelines define *sustainability* in a very general sense as well as "a process that can be maintained without interruption, weakening, or loss of valued qualities"

(p.165). Whether and how teachers actually use this definition (or any of the definitions in the curriculum guidelines) in their instruction is unknown.

For the concept of *green,* although it is not found in the *Science and Technology* (2007a) curriculum guidelines, the Ontario Ministry of Education does use it in policy documents. One example involves a document titled *Ready Set Green! Tips, Techniques, and Resources from Ontario Educators* (on the cover an image of a pair of hands holding a green earth) (Ontario Ministry of Education, 2007c). This guide promotes environmental awareness in the schools but fails to provide a definition for the concept of *green*, leaving it open for the reader to interpret the specific meaning. In the current study, an interesting pattern emerged for this concept as it was one of only two concepts that every student provided a response. This pattern is intriguing because this is the only concept in the survey that is not found in the *Science and Technology* (2007a) curriculum guideline. So, how exactly are children forming a conceptual understanding for this word? Not only did every student in the study provide a response for this concept, it also had the most varied and dissimilar responses. The meaning of *green* was described as being "environmentally friendly", "is grass its trees it's the Earth", "having a small carbon footprint", and/or "recycling". But what exactly makes these actions "green"? The essence of the word is left undefined (if in fact it does have a shared consistent meaning). It appears to be an all-encompassing term to mean a lot of different views, actions or statements.

This case study revealed similar patterns in students' responses for *the environment, sustainability,* and *green* reinforcing to some degree that these concepts are ambiguous, and would be difficult for students and adults to understand. Perhaps there should be a reexamination of the purpose these words serve in elementary schooling if students (and perhaps teachers and the general population) are not actually sure what they mean.

(c) Circular referencing. A particularly interesting phenomenon found in the data is what I have referred to as "circular referencing". Circular referencing occurs when concept A is used to define concept B and concept B is used to define concept A when neither A or B are actually defined. Instead of providing an explanation of what concept B is, it would seem the meaning is implied by referencing another concept (A) in a kind of circular manner, except that neither is defined. The reference to another concept would become the „nugget" of meaning in the student"s explanation, instead of describing his understanding of that particular concept. For example, in the response "green is a.k.a recycling", the student went as far as to draw an arrow from the definition of green to the definition of recycling. Then upon examining the student"s meaning of recycling, e.g. "recycling an object (scrap) hazardous items", it was determined that the student did not appear to understand either concept. When circular referencing has been identified in a definition, one must compare the previous response for the referenced concept in order to understand the explanation of the concept being defined. This is to confirm if the participant(s) in fact had some comprehension of the original concept. This process can become systemic if concept B is referenced in an explanation of concept C and so on.

The results of this study suggest that concept definitions containing circular referencing can prove to be difficult when attempting to discover the respondents" concept meaning. The meaning essentially becomes diluted in the interchangeable nature of the concept definitions that participants possess for certain ecological concepts. Moreover, it can also indicate which ecological concepts students are not familiar with or do not fully comprehend. Circular referencing can become problematic because this pattern allows the student to use the terminology without revealing the student"s understanding of the concept. Instead it shows that

they can relate it to another concept, which can reference yet another concept that they might not fully grasp as well.

The nature of circular referencing also indicates a new concern. How do students know when to use the terminology (i.e. in the proper context) without fully understanding what the concepts they are using really mean? Is it because they memorized how the concept was used by others and therefore can replicate this in future applications that use the word? Or could it be that some ecological concepts are misconceived to mean the same thing as other concepts, which would explain the definitional responses such as "green equals recycling" and vice versa? Answering these questions would require further research to determine exactly how and why this phenomenon occurs. However one thing that could be done is that once a teacher understands this phenomenon of "circular referencing" and is able to recognize it in their students‟ conversation, the teacher could simply ask students to clearly explain the meaning they have for specific concepts.

(d) Level of maturity of understanding for key ecological concepts. This study demonstrated the lack of students‟ mature understanding for key ecological concepts found in the provincial curriculum guidelines. To reiterate, the concepts were carefully selected from the provincial curriculum for grades 1 to 6 in order to ensure a greater chance that all students in the survey would have been exposed to these concepts in previous grades. In addition to the reasons behind wide variability, a lack of mature understanding may in part be attributed to a lack of exposure to and practice in developing concept meaning. It would assist the learner in acquiring deep understanding of the concepts they are exposed to in school. Once again, it could also imply that participants have not been introduced to the concepts prior to study. In addition, some students stated that they remembered studying some of these concepts in school (e.g. a student in

grade 4 said he remembered studying photosynthesis in grade 3) but could not remember much about it.

The majority of participants‟ concept meanings scored at a level 1. The high number of level 1explanations does not appear to be indicative of any particular grade level, age or length of time spent in school. Students could not provide any responses for 17.6% of all possible responses (even by the end of the elementary grades, grade 8 students could not provide responses for 10% of all grade 8 responses). As well 87% of all responses for the five concepts (*photosynthesis*, *decomposition*, *greenhouse gas*, *recycling*, and *biodiversity*) assessed on the emergent maturity scale were level one responses. For these five concepts there was only a minimal increase of maturity of understanding (i.e. level 2 and level 3 responses) and this was attained mostly by grade 8 participants (see Figure 6).

Out of the entire survey only the concepts of *recycling* and *green* received a definition from every participant. It is important to point out that participants did not have to write textbook- like responses for their answers to be acceptable. It was more vital to the study to be concerned with the meaning within the words as opposed to looking for exact definitions. Individuals may have the same understanding of a concept but describe it using different words and different phrasing. It is believed that "constructing definitions may indicate a presence or lack of a presence of a deeper level of internalization and understanding of the concepts as opposed to short-term, surface level memorization and recall of exact wording" (Puk & Stibbards, in press, p. 9).

(e) Curriculum and instruction. The results of the study hint at the possibility that these concepts are perhaps too complex for elementary students to fully understand. As described previously, students may indeed use the vocabulary with little or no fundamental understanding

of the underlying meaning. Perhaps introducing some concepts to students too early is a problem. Some of these concepts may be introduced at a time when students are not cognitively ready for the internalization of the concept meaning. For example, the concept *photosynthesis*, which is first introduced in grade 3, is a complex process involving the multiple interactions between green plants, sunlight, carbon dioxide, water and oxygen. The vast number of grade 4 participants, who would be the most recently exposed participants to this concept according to the curriculum guidelines, were unable to provide a meaning or the meaning they did give did not make sense. Even by grade 8, the vast majority of students still did not possess a minimally mature level of understanding for this (and most) concept(s).

The concepts in the survey, except for *green*, are all found within the *Science and Technology* curriculum guidelines (Ontario Ministry of Education, 2007a). The applicable strands within the curriculum in every grade includes a specific expectation that students will "use appropriate science and technology vocabulary". This implies that if students demonstrate that they can use the appropriate vocabulary there is comprehension of the terms. However, the *Science and Technology* (2007a) curriculum guidelines fail to provide any information as to how to teach the meaning of concepts or that teachers should emphasize the teaching of concept meaning. Without including a fundamental emphasis on understanding the key ecological concepts that are presented during the elementary grades, students may not develop mature understanding of these concepts.

Instruction itself might also be questioned. Traditional, classroom-based instruction may not be suitable to teach complex ecological concepts that students can understand and retain for a longer period of time. One way to gauge when and how to introduce certain ecological concepts is to be cognizant of what grade level the students are in. It can be used as an indicator of their

cognitive development. Puk (in press) points out that all educators would benefit from understanding how the implications of neurobiology affect cognitive development at all stages of life in order to understand the interconnectivity between the stages. He states:

> The implication for educators is that we need to understand how each stage of life (i.e. early childhood to adult) is interdependent on preceding stages and interconnected with all stages as opposed to focussing only on individual stages of cognitive development (p. 2).

This principal reinforces the importance of teaching concepts at certain grades through embodied experience based on neurocognitive development in order to foster the internalization of ecological components before reaching adulthood (Puk, in press).

Perhaps in light of the findings of the study, the Ontario Ministry of Education may want to reassess the placement of complex concepts in the elementary curriculum and reassess how complex concepts are taught in elementary classrooms. Lisowski and Disinger (1996) had concerns of their own about teaching ecological concepts to secondary students. Their study utilized a non-traditional, field-based instructional approach. Students‟ post-test scores showed a positive correlation between the field-based approach and students‟ retention of information. Another example of a non-traditional method is Puk‟s (2010) ecological macro models (p. 131) as described previously. These models are designed to help teach students about concepts, natural systems and processes through embodied experience. Lessons usually take place in an outdoor setting with the aim of increasing the learners‟ internalization of information. Burdette (2005) states that "[w]hile playing outdoors a child is likely to encounter opportunities for decision making that stimulate problem-solving and creative thinking because outdoor spaces are often more varied and less structured than indoor spaces" (p. 48). Stibbards and Puk (2011)

demonstrated the efficacy of ecological macro models in a study involving preservice teacher candidates. There was a significant improvement in teacher candidates‟ ability to define complex ecological concepts after being exposed to this technique.

Powers (2004) reinforces the importance of preservice curriculum because it has a multiplier effect. “[O]ne teacher has the potential to impact the number of students taught throughout a career, a methods course has the potential to impact many future teachers and, ultimately, a far greater number of students” (p. 3). Thus, Powers (2004) claims that the preservice curriculum is of the utmost importance. However, the reality of the situation is that there are only a few, elective courses offered to preservice teachers in Ontario Faculties of Education that provide substantive training in ecological literacy (Puk & Stibbards, 2010). As a result teachers‟ beliefs and misconceptions could be passed on to their students. One way to offset the transfer of misconceptions is discussed in the Stibbards and Puk (2011) study. They reported a significant increase in concept maturity after the teacher-candidates completed an ecologically-based full year course. By taking an ecologically-based course, new teachers can carry this conceptual understanding into their future classrooms where they would have a foundation to build upon to effectively teach ecological concepts.

However there is little data available in regard to concept development and embodied experience during inservice, professional development for classroom teachers. Can these same principals be applied in current elementary and secondary classrooms?

(f) Growth sequences. Lastly, another significant aspect of the study is the growth sequences created to demonstrate concept development from grades 4 to 8 for a few concepts. Growth for the purpose of this study is based upon the maturity of meaning found within the participants‟ definitions across the grades and a decrease in variability of meaning from grade 4

to 8. As outlined in Figure 7, a sample of the growth sequence for three concepts (*photosynthesis*, *recycling* and *biodiversity*) illustrates the potential maturity in the definitions as children age, even though it reflects the current ability of only a few students. These three sequences, as well as the level 4 composite definitions, provide teachers with potential exemplars that they could use in their own instruction. For this study I was unable to extract a more complete set of growth sequences of concepts as two of the five concept meanings (*decomposition* and *greenhouse gas*) for grades 4 and 6 produced by the majority of participants did not attain a level 1 in their responses.

It is important to note that this study does not comment on the students‟ ability to comprehend the concepts but rather indicates what level of understanding they currently possess for key ecological concepts.

Recommendations

This case study investigated elementary students‟ ecological concept knowledge in order to bridge the existing gap in the current literature. Although this is a study of my interpretations of concept development in one elementary school, the following recommendations might be given further reflection:

1. The Ontario College of Teachers might consider providing inservice, professional development courses (i.e. additional qualifications courses) in Ecological Literacy for classroom teachers along with professional learning opportunities for team sharing among administrators, teachers, classroom assistants and other education workers. These courses should include a focus on helping teachers to implement concept development during their instruction.
2. It might be beneficial for teachers and students if the current provincial elementary curriculum included an emphasis on concept development and provided instructional

suggestions for teaching concept development within the specific expectations section of the *Science and Technology* guidelines.

The elementary version of the *Environmental Education* (Ontario Ministry of Education, 2011) document states that "most of the expectations connected with aspects of environmental education are in the science and technology curriculum and the social studies, history, and geography curriculum" (p. 4). Indeed this is recognized as a step in the right direction, but the approach may not be so effective, as studies have indicated (Biriukova, 2005; Cherif, 1992; Khasikhanov, 2008; Knapp, 2000; Puk & Behm, 2003). It would be interesting to compare the results of this current study to the results of participants who have been exposed to these key concepts in their daily elementary schooling similar to that of mathematics and language arts. Would there be a drastic change in the two sets of results? As the provincial curriculum currently stands ecological concepts are embedded in a cross-curricular approach. Gruenewald (2004) argues that environmental education will be ineffective in achieving its own goals until it can separate from the norms of general education. Perhaps Ecological Education deserves to be its own designated subject area rather than primarily being one component of Science. Puk (2010) however believes that due to the urgency in terms of ecological degradation, the whole school curriculum needs to be centered around ecological literacy and ecological consciousness. However until this occurs, he suggests that in the short-term a K-12 meta-discipline called Ecological Education should be developed at the provincial/state level that would subsume all the disciplines so that students would study the reciprocal relationships between natural systems and human systems from an interconnected, wholistic perspective rather than from an atomistic/discipline-based perspective; and that distinct, compulsory courses be developed to provide a solid foundation that would then provide a strong linkage to existing disciplines.

Regardless of which model is implemented, if the results of this study were in fact generalized to a provincial level, it would appear that ecological literacy would require more intensity in the provincial curriculum.

Further questions and potential research avenues. This study is laying the foundation for future research in regard to ecological concept development. The purpose of this empirical study was to gather preliminary evidence in regard to elementary students‟ ecological concept knowledge, in addition to building a concept growth sequence. The current study thus generates further research questions and potential research avenues.

1. As there was no observational data gathered, the study did not include a number of important factors. Further studies might attempt to discover how participants respond to learning ecological concepts by observing how concepts are taught and the interchange between student and teacher. This may also include observing how the teacher approaches this subject and how the students react to their approach. What strategies do teachers typically use to teach environmental education? What initiatives are they using from the redesigned *Environmental Education* (Ontario Ministry of Education, 2011) document? How are teachers assessing the students in their concept development? Also, one avenue to explore more fully is the differences in individual knowledge structures. Why do a few students seem to have some degree of maturity of understanding of some concepts while the majority do not?

2. Further educational research is required to ascertain a larger scope of this problem by conducting a province-wide study to gain a more complete understanding of students‟ ecological concept development. Is this only an isolated regional problem or does it have provincial impact?

3. Going one step further, to address the nature of growth in concept development, future studies might want to consider doing a longitudinal study to follow students‟ development and understanding from grade to grade as they mature.

4. Future studies might use an interview approach to gain students‟ and teachers‟ knowledge about ecological concepts, instead of using a survey to gather information. Interviews might prove to be beneficial for participants as they can partake in more dialogue, ask questions, and share their experiences.

5. The variation in students‟ response rate to the curriculum-based concepts and the non-curriculum concept, g*reen* may be an avenue for future research. How do informal educational experiences shape children, youth, and adult knowledge of ecological concepts as opposed to institutionalized methods?

Conclusion

This study provides an introduction to ecological concept development at the elementary level and is intended to serve as the groundwork in this research field by providing a small representation of elementary students‟ ecological understanding from one school. The study attempted to look at students‟ progress in this area, and to see how the growth of their understanding of concepts matures.

The analysis of the data revealed a distinct under-development in the comprehension of ecological concepts. The evidence from the study suggests that the majority of participants‟ definitions were most often vague, immature and dissimilar in meaning. The study also revealed a modest sequence of growth for conceptual understanding from grades 4 to 8. However, due to the limited results in grade 8 the study could not provide enough substantial evidence to provide conclusions about how growth in ecological understanding occurs during the elementary experience.

It is also important to point out that students‟ reactions after participating in the survey often revealed their natural curiosity about the concepts in the survey. Some students asked the researcher to help them better understand these concepts, particularly the concepts they did not provide an answer for. Students often asked follow-up questions such as where they could find out more information about the concepts. The students‟ actions suggest that they truly wanted to learn more about the concepts in the survey which further demonstrates that children possess an innate desire to learn more about their natural surroundings. What is needed now are curricular and instructional resources to respond to this curiosity.

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Appendices

Appendix A

Research Information

Dear Parent/ Guardian & Potential Participant,

Your child has been invited to participate in a research study, *Ecological Concept Development at the Elementary School Level*. The purpose of this study is to explore what students know about ecological concepts in the elementary grades. This would assist the researchers in developing a sequence of student definitions as children age and may also assist teachers in developing their lessons about the natural world.

My name is Amy Ritter and I am a second year Masters of Education student at Lakehead University and will be conducting the study. Dr. Tom Puk, a professor at the Faculty of Education, Lakehead University, will be supervising the research. Should you choose to give written consent for your child to participate in the study, your child‟s participation would be entirely voluntary. Your child may also refuse to answer any question asked as part of the research or to withdraw at any time without any adverse consequence. You may refuse to allow your child to participate in any part of the study and can withdraw your child from the study at any time without penalty or your child suffering any negative consequences.

During the study, participants will be asked to fill out a survey to define ecological concepts (either four or eight concepts depending upon the grade level of your child). These concepts are found in Ontario Ministry of Education Science curriculum guidelines. If necessary, when definitions are absent or ambiguous, the researcher might ask students to clarify their response. This will be done discreetly so no one else can hear or see the results. Only with written consent from both the parent/guardian and the child will we ask your child to participate. We expect it to take no more than 15-30 minutes of your child‟s time. This is not a test. This has in no way any consequence for your child‟s school marks. Rather this information may help us develop better opportunities for all children to learn about the natural world. While there are no anticipated negative outcomes from this study, there is a minimal risk that a student may become distressed when defining concepts. Should that occur, the classroom teacher and researcher will be there to address the situation and arrange for any follow up if required.

Your child will not be identified in any subsequent use of the data. Only myself, Amy Ritter and Dr. Tom Puk, my thesis supervisor will have access to the responses.

The information from this study will be used for a Masters of Education thesis. I may also use the information in a professional academic journal or at professional conferences, where your child‟s identity, school and school board information will not be used.

The findings and analysis of this project will be made available to you at your request upon the completion of the study. All information that your child provides will remain confidential and securely stored for five years. After the 5-year period, all raw data will be destroyed.

You can contact the Lakehead University Office of Research (807-343-8934) if you have any questions concerning the ethical nature of this study or the ethical conduct of the researchers.

Please sign and complete the attached form. If you have any questions concerning this study, please do not hesitate to contact, myself or my thesis supervisor, Dr. Tom Puk. Thank you for considering your child‟s participation in this study.

Sincerely,

Amy Ritter

Parent/Guardian Consent Form
Ecological Concept Development at the Elementary School Level

My signature on this sheet indicates that I agree to participate in a study by Amy Ritter, MEd student of Lakehead University entitled **"**Ecological Concept Development at the Elementary School Level**"** and that I have read and understand the following:

1. I have read and understood the information letter for the study.
2. I voluntarily agree to allow my child to participate.
3. While there are no anticipated negative outcomes from this study, there is a minimal risk that a student may become distressed due to a discussion regarding intolerance. Should that occur, the classroom teacher and researcher, will be there to address the situation and arrange for any follow up if required.
4. I understand that my child is expected to benefit from participation in the study also by having the opportunity to express him/or herself through the survey and by potentially contributing to curriculum initiatives in ecological education.
5. I can withdraw my child from the study at any time without any adverse academic or other consequence to my child or me.
6. My child can decline to answer any question or participate in the concept definition survey at any time without any adverse academic or other consequence.
7. The data my child provides in the survey will be securely stored at Lakehead University for five years and then destroyed.
8. I can withdraw any of the survey responses of my child from the data set without adverse consequence to my child or me.
9. I understand I can request a copy of the research findings from Amy Ritter at apritter@lakeheadu.ca at the conclusion of the study when findings have been analyzed and written-up.
10. My child and I will remain anonymous in any publication or public presentation for research findings.
11. All comments are confidential and will only be presented in aggregate or anonymous form.

_____	_____	_____
Name of Child Participant	Signature	Date
_____	_____	_____
Name of Parent/Guardian	Signature	Date

If you would like the results of this study please provide your e-mail or mailing address below:

Thank you for your participation in this study

Appendix B

Student Consent Form

Ecological Concept Development at the Elementary Level

I _____ (participant name) understand that no one other than the researchers will see the form with the definitions that I provide. I understand that my name will not be used in any reporting of the study.

I also understand that:

1. I may refuse to answer any questions asked.

2. This is not a test and will not affect my school marks in any way.

3. I am not being compared to anyone else.

4. My teacher will not see my responses.

By signing this form I give my permission to participate in the study.

_____	_____	_____
Name of Participant	Signature	Date

Appendix C

Principal Consent Letter

Dear Principal,

My name is Amy Ritter and I am a Masters of Education student at Lakehead University. I am conducting a study that will examine students‟ ecological concept understanding at the elementary level in Ontario schools. To collect this information, I would like to work with grade 4 and grade 8 students. The study involves a concept definition survey in which students will fill out to the best of their abilities. If necessary, this will be followed up by verbal questioning involving the researcher and students to clarify any ambiguity in the results. Any additional information will be recorded on the original surveys by the researcher. The survey and the follow up verbal questioning will be held at the school during regular classroom hours, at lunch or after school with the principal, teacher and parent‟s/guardian‟s written consent. While there are no anticipated negative outcomes from this study, there is a minimal risk that a student may become distressed when defining ecological concepts. Should that occur, the classroom teacher and researcher will be there to address the situation and arrange for any follow up if required.

All students, school and school board identities will be anonymous. The data collected from this study will be used to prepare a Masters of Education thesis. I may also report the results of this study in academic journals or at professional conferences.

The main purpose of this study is to determine what ecological concept knowledge children have at different ages in the elementary sector. In doing so, it would create a collection of ecological concept definitions of elementary students for grades 4 and 8. Secondly, the study would result in a concept development sequence to illustrate the maturation of concepts in terms of robustness and complexity as children progress through the elementary grades. Thirdly, it hopefully would inform teachers‟ instructional strategies with the main goal of establishing definitions and meanings for concepts essential to understanding our relationships with the Natural world.

Please note that the Lakehead University Research Ethics Board and the Lakehead Public School Board have approved this study. The students, school board and school will not be identified in any written form. Data will be securely stored at Lakehead University for five years and then destroyed as per Lakehead University regulations.

A summary of the findings will be available through the Lakehead University library. If you have any further questions about this study, please do not hesitate to contact my thesis supervisor, Dr. Tom Puk or myself.

Sincerely,

Amy Ritter

Principal Consent Form

Ecological Concept Development at the Elementary School Level

I, _____ have read the cover information letter and understand that:

1. The child participants, teachers, school and school board identities will be protected.
2. All data collected is confidential.
3. Should a participant choose not to participate, or withdraw from the study at any time there will be no adverse consequences.
4. Participants may choose not to answer any question as part of the research without adverse consequence.
5. There are no anticipated negative outcomes from this study.
6. Child participants are expected to benefit from participation in the study by having the opportunity to express themselves through the concept definition survey and by potentially contributing to curriculum initiatives in ecological education
7. The participant's parent(s)/ guardian(s) and students may receive a summary of the study upon request.
8. All raw data from the study will be held at Lakehead University in a locked cabinet for five years and then destroyed as per Lakehead University regulations.
9. The data collected will be used to prepare a Masters of Education thesis and may also be used to publish articles in academic journals or for presentation at academic conferences with all participant identities concealed.

_____
Name of Principal

_____
Signature of Principal

_____
Date

Appendix D

Teacher Consent Letter

Dear Teacher,

My name is Amy Ritter and I am a Masters of Education student at Lakehead University. I am conducting a study that will examine students‟ ecological concept understanding at the elementary level in Ontario schools. To collect this information, I would like to work with grade 4 and grade 8 students. The study involves a concept definition survey in which students will fill out to the best of their abilities. If necessary, this will be followed up by verbal questioning involving the researcher and students to clarify any ambiguity in the results. Any additional information will be recorded on the original surveys by the researcher. The survey and the follow up verbal questioning will be held at the school during regular classroom hours, at lunch or after school with the principal, teacher and parent‟s/guardian‟s written consent. While there are no anticipated negative outcomes from this study, there is a minimal risk that a student may become distressed when defining ecological concepts. Should that occur, the classroom teacher and researcher will be there to address the situation and arrange for any follow up if required.

All participants, school and school board identities will be protected. The data collected from this study will be used to prepare a Masters of Education thesis. I may also report the results of this study in academic journals or at professional conferences.

The main purpose of this study is to determine what ecological concept knowledge children have at different ages in the elementary sector. In doing so, it would create a collection of ecological concept definitions of elementary students for grades 4 and 8. Secondly, the study would result in a concept development sequence to illustrate the maturation of concepts in terms of robustness and complexity as children progress through the elementary grades. Thirdly, it hopefully would inform teachers‟ instructional strategies with the main goal of establishing definitions and meanings for concepts essential to understanding our relationships with the Natural world.

Please note that the Lakehead University Research Ethics Board and the Lakehead Public School Board have approved this study. The students, teachers, school board and school will not be identified in any written form. Data will be securely stored at Lakehead University for five years and then destroyed as per Lakehead University regulations.

A summary of the findings will be available through the Lakehead University library. If you have any further questions about this study, please do not hesitate to contact myself, or my thesis supervisor, Dr. Tom Puk.

Sincerely,

Amy Ritter

Teacher Consent Form

Ecological Concept Development at the Elementary Level

I, _____ have read the cover information letter and understand that:

1. The child participants, teacher, school and school board identities will be protected.
2. All data collected is confidential.
3. Should a participant choose not to participate, or withdraw from the study at any time there will be no adverse consequences.
4. Participants may choose not to answer any question as part of the research without adverse consequence.
5. There are no anticipated negative outcomes from this study.
6. Child participants are expected to benefit from participation in the study by having the opportunity to express themselves through the concept definition survey and by potentially contributing to curriculum initiatives in ecological education
7. The participant's parent(s)/ guardian(s) and students may receive a summary of the study upon request.
8. All raw data from the study will be held at Lakehead University in a locked cabinet for five years and then destroyed as per Lakehead University regulations.
9. The data collected will be used to prepare a Masters of Education thesis and may also be used to publish articles in academic journals or for presentation at academic conferences with all participant identities concealed.

_____
Name of Teacher

_____
Signature of Teacher

_____.
Date

Appendix E

Education Officer Cover Letter

Dear Education Officer,

My name is Amy Ritter and I am a Masters of Education student at Lakehead University. I am conducting a study that will examine students‟ ecological concept understanding at the elementary level in Ontario schools. To collect this information, I would like to work with grade 4 and grade 8 students. The study involves a concept definition survey in which students will fill out to the best of their abilities. If necessary, this will be followed up by verbal questioning involving the researcher and students to clarify any ambiguity in the results. Any additional information will be recorded on the original surveys by the researcher. The survey and the follow up verbal questioning will be held at the school during regular classroom hours, at lunch or after school with the principal, teacher and parent‟s/guardian‟s written consent. While there are no anticipated negative outcomes from this study, there is a minimal risk that a student may become distressed when defining ecological concepts. Should that occur, the classroom teacher and researcher will be there to address the situation and arrange for any follow up if required.

All students, school and school board identities will be anonymous. The data collected from this study will be used to prepare a Masters of Education thesis. I may also report the results of this study in academic journals or at professional conferences.

The main purpose of this study is to determine what ecological concept knowledge children have at different ages in the elementary sector. In doing so, it would create a collection of ecological concept definitions of elementary students for grades 4 and 8. Secondly, the study would result in a concept development sequence to illustrate the maturation of concepts in terms of robustness and complexity as children progress through the elementary grades. Thirdly, it hopefully would inform teachers‟ instructional strategies with the main goal of establishing definitions and meanings for concepts essential to understanding our relationships with the Natural world.

Please note that the Lakehead University Research Ethics Board has approved this study. The students, school board and school will not be identified in any written form. Data will be securely stored at Lakehead University for five years and then destroyed as per Lakehead University regulations.

A summary of the findings will be available through the Lakehead University library. If you have any further questions about this study, please do not hesitate to contact my thesis supervisor, Dr. Tom Puk or myself.

Sincerely,

Amy Ritter

Education Officer Consent Form

Ecological Concept Development at the Elementary School Level

I, _____ have read the cover information letter and understand that:

1. The child participants, teachers, school and school board identities will be protected.
2. All data collected is confidential.
3. Participants may choose not to answer any question as part of the research without adverse consequence.
4. Should a participant choose not to participate, or withdraw from the study there will be no negative academic or other consequences.
5. There are no anticipated negative outcomes from this study.
6. Child participants are expected to benefit from participation in the study by having the opportunity to express themselves through the concept definition survey and by potentially contributing to curriculum initiatives in ecological education.
7. The participant's parent(s)/ guardian(s) and students and classroom teachers may receive a summary of the study upon request.
8. All raw data from the study will be held at Lakehead University in a locked cabinet for five years and then destroyed as per Lakehead University regulations.
9. The data collected will be used to prepare a Masters of Education thesis and may also be used to publish articles in academic journals or for presentation at academic conferences with all participant identities concealed.

_____

Print Name (Education Officer Responsible for School Board Ethics Approval)