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A Field Study is Not Enough

by

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The undersigned certify that they have read, and recommend to the faculty of Graduate Studies for acceptance, a thesis entitled "A Field Study is Not Enough" submitted by Chenoa Marcotte in partial fulfillment of the requirements for the degree of Master of Science.

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ABSTRACT

The purpose of this case study is to explore how students use collaborative groups and discussion with technology assistance to develop an understanding of ecosystems within a middle school science unit. The findings from this study indicate that there was a positive change in understanding ecosystems; however, some student held beliefs persisted throughout the unit. One critical instructional recommendation is that more in depth discussions of the limitations of the field study results with students may lead the students to a deeper understanding of the limitations of ecological studies in general; that we can only solve small pieces of much larger more complex puzzle, and that with all those pieces together we come to a deeper and more complete understanding of a the whole. A field study that does not help students to recognize these complexities is not enough if the intention is to enhance understanding of ecosystems.

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DEDICATION

To my supportive and loving husband, Jon, and to my children, Leith and Aida, who inspire me daily with their wonderings about the world.

To my parents, who offered many extra hours of grandparent-time so that "mommy could do her work" and who also encouraged me to keep going.

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CHAPTER 1

Introduction

1.1. Overview

When we try to pick out anything by itself, we find it hitched to everything else in the universe.

(Muir, 1911, p. 110)

Ecosystems are complex and often misunderstood. Research done by Perkins and Grotzer (2001) describes how teachers often consider ecosystems (including food webs and food chains) relatively easy topics for students to learn. The research detailing students' preconceptions about ecosystems contradicts this belief.

> Students do not easily recognize interactive causal relations on their own. Most students break the patterns apart and miss the reciprocal aspects of them. (Perkins and Grotzer, 2001, p.20)

Within the fields of environmental education and ecological education, work has been done to identify key concepts that students must understand to be literate in the field of ecology (Alberta Program of Studies, 2003; Orr, 2004; Cherrett, 1989; Reading, 2005). Work has also been done in identifying common preconceptions students have about ecosystems. (Gallegos, Jerezano & Flores, 1994; Magntorn & Hellden, 2007; Munson, 1995).

Science education embraces the understanding that scientific theories change in light of new evidence that often emerges in response to collaborative efforts in scientific investigations. Contemporary science education is moving away from classrooms where the scientific method is taught as lock step procedure and in which there is an overemphasis on the memorization of facts (Carey, 1988; Driver, Newton & Osbourne, 2000). Classrooms are becoming places where teachers present science as a process in which new knowledge is supported by evidence and is often socially constructed. In classrooms, collaboration and talk are seen as essential when puzzling through problems to develop deeper meaning of concepts and big ideas (Driver, et al., 2000; Vygotsky, as referenced in National Research Council, 2000; Bloom, 1998).

In light of recent research in the cognitive sciences and into teaching and learning, effectively designed learning environments are suggested to be learner-centered, knowledge-centered, assessment-centered and community-centered (Bransford, J., Brown, A., Cocking, R., 2000). Meaningful learning occurs when learning is active, constructive, intentional, authentic (complex/contextual), and cooperative (collaborative/conversational) (Jonassen, Howland, Marra & Crismond, 2008).

The use of classroom discussion has been emphasized as a powerful way to support students' metacognition (National Research Council, 2005). Argumentation is one way to encourage students to reason scientifically, challenge their own preconceptions and create new meanings for themselves in the area of study (Driver, et al., 2000; Zeidler & Nichols, 2009). Argumentation and discussion in the science classroom is akin to what "real" scientists do with new knowledge claims in the scientific community. Argumentation and discussion are cooperative (collaborative/conversational) parts of meaningful learning (Jonassen et al., 2008).

Supporters of educational technologies in science classrooms claim that powerful learning occurs when students use technology to build knowledge using a constructivist approach (Shane & Wojnowski, 2005). Technology can be used as more than just a tool to learn; it can also be used to create an environment where students can work together (Burniske, 2005).

Computers enable communities of students that can collaborate, establish relationships with each other and ultimately build understanding together in a social context. With informational technologies, students can connect to experts while inquiring about real-world and authentic problems related to the environment (Breuleux, 2001; Burniske, 2005; Jonassen et al., 2008). Learning becomes authentic and meaningful when students can use technology to solve problems with the same instruments that real scientists would use (Jonassen et al., 2008). Furthermore, students can use various technologies to help them develop a deeper understanding of the investigating problems (Houle & Barnett, 2008; Bodzin, 2008).

1.2. Potential Significance

Within the reviewed literature, no specific research related to students' developing and elaborate understanding of ecosystems at the Grade 7 level can be found. I also did not find studies that specifically addressed using discussion and collaboration to develop a deeper understanding of ecosystems. Additionally, very little has been written on the use of communication technologies in science classrooms to encourage students' collaboration and discussion about ecosystems and human impacts on ecosystems. Given the importance of developing such an understanding of ecosystems, a study that closely examines the impact of using collaborative learning environments with technology would be important for teachers designing and assessing the impact of conducting field study units in their science classrooms. Also, understanding how collaborative environments and technology influence students understanding of ecosystems is beneficial for society in general, as a population with a solid understanding of human impacts on ecosystems will make better environmental decisions in the future.

1.3. Purpose Statement

The purpose of this case study is to explore how students use collaborative groups and discussion to develop an elaborate understanding of ecosystems and ecological literacy within a middle school science unit.

1.4. Definition of Terms

Collaborative Groups are described as students working in groups to perform a task. Discussion can take place in many forms: "At times, the students discuss in small groups and at times as a whole class; at times the teacher leads the discussion; and at times the students take responsibility for the questioning" (National Research Council, 2005, p. 577).

Ecological Literacy in this study is defined as "the capacity to perceive and interpret the relative health of environmental systems and to take appropriate action to maintain, restore or improve the relative health of those systems" (Reading, 2005, p. 7). *Understanding Ecosystems* is defined as students hold a developing or elaborate conception of ecosystems. The conception has been broken down into five categories of understanding. The five categories were selected as core understandings of ecosystems central to the discipline and developmentally appropriate for students at the Grade Seven level. The categories are: i) biodiversity, ii) population dynamics, iii) abiotic and biotic interactions, iv) ecological integrity, and v) transfer across contexts. These categories were developed by the researcher in consultation with the following: (a) Alberta Program of Studies, (b) guest speaker (Sarah Nevill) to the studied class, who is a field research scientist, (c) a research ecologist, (d) a former junior high science teacher, and (e) a science teacher educator.

1.5. General Research Question

How do students develop ecological literacy throughout a unit of study in a technologically enriched learning environment that encourages collaboration and discussion?

1.5.1. Sub questions

1. What are students' understandings of ecosystems before beginning the unit? During the course of study, how do these understandings change (or not) into an

elaborate understanding of ecosystems and an understanding of the human impacts on ecosystems?

2. How (if at all) do collaboration and discussion affect knowledge building in a unit about ecosystems and human impacts on ecosystems?
3. How can technology aid in collaboration and discussion? How can this lead to more elaborate understanding in individual students?
4. What themes emerge from gathering the information about the change (or lack of change) in conceptual understanding of ecosystems during the course of this study, and how do these themes inform further acquisition of ecological literacy?

1.6. Limitations

1. For in-depth exploration and to minimize the numerous possible interventions that could lead to students' growth in understanding, only students from one class with one teacher will be observed for the study, and all artifacts will be collected from this class.
2. Due to the in-depth nature of case study research, only selected students from the observed class will be followed for: (i) in-depth pre- and post-interviews; (ii) close observations while collaborating in groups throughout the semester; and (iii) thorough analysis of student work.
3. The students in this study might be familiar with the researcher, as there is a strong possibility that the researcher may have taught the students in a previous grade. For this reason, the researcher's new role will be made clear to the students and parents.

CHAPTER 2

Literature Review

2.1. Introduction

Different keyword combinations were used in ERIC and in Internet searches to locate articles related to this study. The keywords used included combinations of: children's and students' understanding of ecology; ecosystem understanding; misconceptions and preconceptions; environmental education; science classrooms; discussion; argumentation; discourse; technology; and communication technologies. A few key articles emerged where researchers studied students learning with technology and demonstrated a growth in understanding in a specific environmental topic. These articles were studied in greater depth.

The articles were divided into three broad categories to organize the literature review: (i) students' understanding of ecosystems; (ii) classroom communities that encourage scientific reasoning and discussion; and (iii) using technology to encourage discussion and create real-world opportunities for investigation. Many times there was overlap in the literature between the categories. In these cases, the articles were situated in the most applicable category. Each category was then subdivided into more specific areas of focus.

2.2. Students' Understanding of Ecosystems

Before we can study how the students' understanding of ecosystems change during the course of the unit, it is important to know what prior knowledge they have about ecosystems. This information will be gathered from students in the case-study group (see Section 3.3).

As background work to this endeavor, I reviewed literature that documented common misconceptions students have about ecosystems. Much of this work focused on food chains and student understanding of predator-prey relations. (Munson, 1995; Gallegos, Jerezano & Flores, 1994). Munson (1995) also addresses related to carrying capacity and more holistic beliefs about ecosystems. I did not find research that broke down the core understandings students need for an elaborate understanding of ecosystems *with* an accompanying piece that broke down those core understandings into specific criteria that students may have difficulty grasping or about which they have misunderstandings.

Ecosystems are complex and not easily understood. One way to look at what constitutes understanding in ecosystems is to consider what concepts experts think are key for ecological literacy.

2.2.1. What should students know to be ecologically literate?

An elaborate understanding of ecosystems sits within a greater context of ecological literacy. Though these go beyond the Grade 7 Science unit under investigation, it is important to examine what basic concepts are essential to comprehend the complexity of ecosystems and to examine how humans impact ecosystems. Orr (2004) provided a list of concepts without which he claimed "no student should graduate from any educational setting" (p. 14). Cherrett (1989) surveyed members of the British Ecological Society and identified the 20 most important ecological concepts. Cherrett's list was also referenced in other pieces of literature that will be mentioned in other sections of this review (Munson, 1995; Magntorn & Hellden, 2007). Finally, in a document prepared for the Calgary Board of Education, Reading (2005) distinguished between environmental awareness and environmental literacy:

> Environmental awareness is typically characterized by knowledge and awareness activities, that are process based, which lead to some understanding about the natural world…Environmental literacy is defined as the capacity to perceive and interpret the relative health of environmental systems and to take appropriate action to maintain, restore or improve the health of those systems. (p. 7)

While reviewing the literature, a comparison was made between what the literature considers important for students to know about ecology with the curricular guidelines for Grade 7 as outlined in the Alberta Program of Studies (2003). When designing units for instruction, a teacher's primary concern is to address the curriculum as reflected in the Programs of Study. However, the interpretation of the curriculum can take place in many different forms. Reading's (2005) list of abilities provides an interesting interpretation of how ecological literacy moves us beyond basic ecological concepts (as Cherrett's list demonstrates) to one of ecological literacy, where we behave in ways that impact the natural world in a positive way (also emphasized in the Program of Studies). The Program of Study takes a very localized view of ecosystems, with an emphasis on monitoring, performing and recording as skills gained during the unit, where as Reading's list seems to take the abilities one step further by suggesting long term commitments, transferring skills to new contexts and thinking in terms of systems and how we are connected to natural systems. The methods by which teachers structure learning tasks will determine whether the unit is taught by simply learning concepts *about* ecosystems and learning *about* human impacts on ecosystems or whether skills, attitudes, behaviors and abilities, are also developed.

2.2.2. What are common preconceptions students have about ecosystems?

Munson (1995) wrote that although much work has been done to document students' prior understandings in the physical sciences, little attention has been paid to their understanding of ecology. A summary of his findings and one other are highlighted in Table 1:

Table 1

Common student preconceptions about ecosystems

Key Concepts of Ecosystems	Common Pre-Understanding
Food Webs / Food Chains	An animal's choice in food is determined by whether they are ferocious or passive (not carnivorous or herbivorous) (Gallegos, Jerezano & Flores, 1994)
	Size determines predator-prey interactions. For example, a plant is at the bottom of a food chain because it is small and defenseless (Gallegos, Jerezano & Flores, 1994).
	Animals at the top of the food chain can feed on all the animals below them (Munson, 1995).
Ecological Adaptation	Development of traits is part of a predetermined grand plan (Munson, 1995).
Carrying Capacity	Ecosystems have limitless resources (Munson, 1995).
Ecosystem	Some organisms are important to an ecosystem and others are not (Munson, 1995).

Table 1 provides key pieces of information that teachers at many levels can use to leverage the understanding developed in their classroom. Teaching that addresses specific alternate conceptions, or teaching for conceptual change, encourages students to look at phenomena in new ways that are contrary to their previously formed frameworks. As a result, this deepens student understanding (Bransford et al., 2000).

2.3. Classroom Communities That Encourage Scientific Thinking

Ideally, students should expect to engage in learning tasks where they behave as scientists in the classroom; in other words, they will not just memorize what science has already discovered, but participate in learning environments that are authentic scientific investigations. The Alberta Program of Studies for Science 7-8-9 states that:

> Science-based ideas are continually being tested, modified and improved as new knowledge and explanations supersede existing knowledge and explanations. (Alberta Program of Studies, 2003, p. 4)

In effectively designed learning environments, students come to know this firsthand. Essential to the development of ideas in science is the availability of peers with whom to discuss findings and to offer new insight. Classrooms in which communities of students work together to socially construct knowledge have been shown to change students' knowledge and reasoning abilities (Bransford, et al., 2000). Working in collaborative groups instead of in isolation in the classroom also mimics what is occurring in contemporary science today. "Much creativity occurs in groups rather than individuals alone" (Dunbar, 1997, p. 463). Dunbar's research accounts for how new ideas and concepts are often generated during lab meetings when peer colleagues can challenge hypotheses and encourage scientists to re-conceptualize their ideas. This can also occur in a classroom setting. As Carey et al. (1988) says:

> [I]f students are to gain a better understanding of the nature of scientific inquiry and knowledge, they must be actively involved in constructing and evaluating explanations for natural phenomena, and they must be engaged in metaconceptual reflection on that process. (p.5)

Discussion supports metacognition (National Research Council, 2005, p. 577). When working in groups and engaging in discussions around a particular scientific problem or inquiry, students are forced to make their ideas public. In making their ideas public, they are questioned by their peers and/or teachers and then forced to reflect on the validity of their ideas: "A primary goal of classroom discussion is that by observing and engaging in questioning, students become better at monitoring and questioning their own thinking" (National Research Council, 2005, p. 577). Discussions can take place in a variety of settings, from small peer groups to large class discussions facilitated by the teacher:

> In addition to relationships with trusted adults, peer groups can exert a major influence in shaping social and academic relationships in classrooms. Intellectually engaging work taps into learning as a highly social activity – expert learners are able to explain their thinking, elaborate on their ideas, and consider multiple (and sometimes dissonant) viewpoints as they negotiate individual and shared meanings. When

> students have opportunities to work with their peers as intellectual partners, they develop deeper conceptual knowledge, as well as important social and cultural skills. But effective collaboration requires roles and relationships most students are unfamiliar with. Learning to engage in thoughtful conversations, understanding the legitimacy of differences, and collaborating to achieve group outcomes are skills and habits that need to be integral to students' work together and key elements of all designs for learning. (Dunleavy & Milton, 2009, p.15)

2.4. Using Technology to Encourage Discussion

2.4.1. Computers in ecology classrooms

McLaughlin (1994) described ways in which technology and environment often have an antagonistic relationship. He cited Disinger (1986), who claimed that environmental education in the past has had a negative perspective of technology, and has often focused on what is wrong with technology and environment interactions (p. 32). A common perception is that children spend too much time indoors, using technology as their pastime instead of engaging in active outdoor play. There is also a belief that because children spend more time indoors and less time exploring the natural world, they do not have an appreciation for the outdoors or an intuitive sense about natural areas; therefore, they do not have an inherent need to protect natural spaces. Both Hagemenn (1997) and Burniske (2005) warn that technology runs the risk of enabling students to study nature at a distance at the expense of studying local environments in their own backyards. Studies of the rainforest can take place on a computer while a local park is left unseen – and, as Berry (2000) notes, unloved:

> We know enough of our own history by now to be aware that people exploit what they have merely concluded to be of value, but they defend what they love. To defend what we love we need a particularizing language, for we love what we particularly know. The abstract, "objective," impersonal, dispassionate language of science can, in fact, help us to know certain things, and to know some things with certainty. It can help us, for instance, to know the value of species and of species diversity. But it cannot replace, and it cannot become, the language of familiarity, reverence, and affection by which things of value ultimately are protected (Berry, 2000, p. 41).

Hagemann (in Traina & Darley-Hill, 1997) questions whether we should own computers in the first place because of their impact on the environment in their construction alone. He also reminds the reader that multinational and business corporations who may have ulterior motives produce many of the educational software programs available.

The challenge of this study is to use technology to help develop a deeper understanding of a local natural area that the students know well. The technology is not being used to access places at a distance from the students but to leverage the technology to enable students to collaborate and understand more deeply the places closest to them. McLaughlin (1994) says that technology education can enable students to see that technology can cause environmental problems but can also be a part of the solution to environmental problems. In essence, the digital natives of today will be solving the environmental problems of tomorrow.

2.4.2. Can technology be used to develop an understanding and connectedness to ecosystems?

Burniske and Monke's book *Breaking Down the Digital Walls* (2001) begins with a reminder that supporters of computer use in classrooms claim that they encourage an appreciation for efficiency, measurability, objectivity, rationality, progress and the accumulation and manipulation of data. What is not inherently encouraged is the pursuit of truth, comprehension of complex ideas, use of good judgment, and understanding others:

> With the welfare of our students at stake it is not enough for educators to merely ride contentedly along on the technological bandwagon. That course will inevitably turn us into technicians and education into mere training. If we want to truly enrich and ennoble the lives of our students, then we each have to grab the reins and force these new dynamos to work for us in ways that once again elevate the human purposes in education (p. 29).

Azevedo, Winters and Moos (2004) have also contributed interesting research regarding the use of computers in classrooms. They looked at self-regulated learning, in which they consider whether students are cognitively, motivationally and behaviorally active in their learning process. The research concluded that students have difficulties learning in web-based hypermedia environments because they cannot self-regulate their own learning.

However, technology can be used in many ways to increase student understanding. Data-logging, data-handling, simulating, modeling, reporting and presenting, using integrated-learning systems, researching, and effectively using the Internet are all used to support new ways of learning in classrooms (Kelleher, 2000). Probes, global positioning systems, hand-held devices, Internet sites such as Google Earth and Project GLOBE, video-conferencing with experts, podcasting (the list goes on) have all been shown to increase student motivation and understanding of various scientific concepts (Bodzin, 2008; Bransford, et al., 2000; Jonassen et al., 2008).

Most pertinent to this study is research that looks into community-building with technologies (Burniske & Monke, 2001; Evagorou & Avraamidou, 2008; Jonassen et al., 2008; ; Kelleher, 2000;). Computer-Supported Intentional Learning Environments (CSILEs) and Knowledge Forum are two online environments described by the above authors that support this aim:

> Knowledge Forum 4, based on the philosophy that shared knowledge leads to innovations and growth, is based on over 15 years of research at the University of Toronto's Department of Cognitive Science. It is a knowledge-building environment that supports collaboration as users create and continue to improve ideas rather than simply complete tasks (Jonassen, et al., 2008, p. 102).

The above-mentioned authors also describe co-constructing knowledge with %Wikis and through blogging and other online collaborative tools that support the building of collective understandings with students. Effective use of technology is more than a way for students to work together, it can be used as a way for students to build deeper meaning:

> Educational telecollaboration is, for us, not just a matter of how to get the machines and students communicating with each other. It is not just a technical activity. It is, rather, an enterprise governed by the search for opportunities for student growth. At times we have been surprised at the depth of human understanding that the computer has facilitated. (Burniske & Monke, 2001, p. 28)

CHAPTER 3

Design and Methodology

3.1. Overall Approach and Rationale

The focus of this inquiry will take the form of a case study. Creswell (2007) defines a case study as:

> …a qualitative approach in which the investigator explores a bounded system or multiple bounded systems over time through detailed, in-depth data collection involving multiple sources of information and reports a case description and case-based themes. (p. 73)

The intent of this study is to gather a clear picture of how students reason collectively, in discussion and in group work, to develop an understanding of ecosystems. This study sits within the social constructivist worldview where the goal of the research is to rely as much as possible on the participant's views with the understanding that meaning is often negotiated socially and historically (Creswell, 2007). As such, it is essential to gather as much evidence as possible from the participants as they work and learn with others about ecosystems.

3.2. Population and Site Selection

The school selected for this study is a charter school with a focus on inquiry-based learning. Professional development opportunities within the school have focused on inquiry-based learning and integrating technology into the curriculum. The principal stated in his interview, "I think there is a general recognition that learning, whether it is with students or professionally on staff, learning is a collaborative venture." (Principal Interview, June 2010, p.7 of transcript)

The school has ample technology available to teachers and students. Currently, there is a one-to-one laptop program in place whereby each student is assigned their own Macbook for use at school and at home. Teachers are encouraged to use technology in all aspects of their program. Outdoor education is also a strong emphasis at the school. Students participate in two overnight field trips a year and numerous day field trips. The school is situated within walking distance of a local natural area which provides ample opportunity for outdoor field studies.

In the context of this school, many opportunities are available to incorporate digital technologies into ecological studies (probes, digital cameras, GPS, etc.). Computers are readily available to analyze and communicate findings (spreadsheets, blogs, podcasts, etc.). For these reasons, this school is seen to be a prime location to study possibilities for engaging and meaningful learning experiences about ecology.

The study will take place in the context of a Grade 7 Science class. The composition of students is approximately one-third female and two-thirds male. A grade-level proficiency test is administered before students are admitted to the school. Some students do attend the school with a performance below grade level in reading and mathematics, but the majority of students admitted show average to above-average performance on grade-level proficiency tests. The school draws from all four quadrants of the city. The majority of students are bused to school. Students fall in a wide range of economic brackets. They also have had varying degrees of outdoor experience.

The majority of students remain in the school from Grade 4 to 9. By Grade 7, they would have had many camping and outdoor field study experiences in previous grades. Many (if not all) of the students in the class have visited the natural area where this study is based on numerous occasions for sports days or as part of their science curriculum. For example, students may have participated in a forest investigation at the natural area in Grade 6, or a picnic in Grade 5, or a biking trip in an outdoor education class. Outdoor education is also offered as an elective class which many of students in this study chose to take.

The science teacher in charge has experience working with students in outdoor settings. At the time of this study, the teacher has been at the school for just over 1 year. She has developed an understanding of inquiry-based learning through professional development opportunities offered at the school and remains active in her own professional development in this area.

3.3. Data Collection

Subjects. Case-study research enables the researcher to examine multiple sources of information in greater depth. I worked closely with the teacher involved to design the unit of study and help plan the lessons that would be used during the course of the unit. The students were comfortable seeing me in the room and became accustomed to my presence during periods where students had time to work on their inquiry, study at the natural area, and present their work. I interacted with many of the students during the course of their unit of study. For my research, I chose to focus on two small groups of students and follow them from the beginning to the end of the unit of study. Seven students were selected for a more in-depth study of how their understanding of ecosystems developed. Specifically, I hoped that the selected students would help demonstrate different notions of what ecological literacy means to students in this age group. I selected the students from those with permission to participate after the pre-unit interview questions. As there was a small pool of students to select from and as I was mostly interested in how the students changed over the course of the unit, the initial selection process was mostly random in nature.

In order to maintain the anonymity of the students involved in the study, I had permission from the teacher to place the students in small groups. I placed the seven students selected for the study in two small groups. The other students in the class were also placed in small groups. Efforts were made to ensure that the teacher was unaware of which groups of students had submitted the forms with approval to participate in the study. All students in the class participated in the same lessons and activities during the course of the unit regardless of their participation in the study, the exception being that the seven students selected to be involved in the study also participated in the student interviews. In an effort to maintain anonymity, these interviews occurred during times when the teacher involved was unaware of which students were participating in the interview process. Efforts were also taken to ensure that the teacher was unaware of which groups of students were being video taped at various times during the study. These efforts were aided by the fact that much of the work occurred outdoors in a natural area, and also by having groups of students meet in various locations throughout the school.

Data. For the sample group the following was closely analyzed: (i) observations of students during class discussions, (ii) pre- and post-unit interviews, (iii) collaboration using technology, and (iv) student work (both rough work and completed projects). Classroom artifacts (rubrics, assignment details, other) involved in the unit of the study were also collected. Teacher interviews and reflections were gathered, and the school's principal participated in an interview. What follows are more detailed descriptions on each of the data collection procedures in various phases of the study.

3.3.1. Overview of Unit Lesson Design

The unit was designed as a collaborative effort between the teacher and myself. We specifically aimed to address the curricular outcomes expressed in the Alberta Programs of Study (2003) Grade 7 Unit on Interactions and Ecosystems in the unit lesson design. In general, it was intended that this unit would accomplish the following: "To foster an understanding of ecosystems, this unit develops student awareness of ecosystem components and interactions, as well as natural cycles and processes of change. Building on this knowledge, students investigate human impacts and engage in studies that involve environmental monitoring and research." (Alberta Learning, 2003, p.11) We were also interested in developing the students' awareness of human impacts on local urban parks, specifically urban parks that have a lot of people using the area for recreational purposes.

Before the unit began, we asked the students to think about whether or not the natural area was a healthy or an unhealthy ecosystem, and to list their reasons why in either (or both) cases. We used a presentation from a research biologist who worked in the natural area as the first engaging activity to get the students hooked on the topic. The speaker was asked to specifically address some of the key impacts humans had on the natural area and how a conservation biologist would study them during the presentation. Following the presentation, student groups were invited to select one human impact on the natural area that they would design and conduct a comparison field study around. The focusing question suggested by the guest speaker for the students to investigate was, "How has the [natural area] been affected by changes? Is the [natural area] changed?"

The two student groups that I followed chose different topics to investigate. Group 1 chose to investigate how caragana, an invasive plant, impacts the native vegetation that grows near it. In their entry to the Google Doc, the group stated their focus as follows: "We are studying the impact of the invasive caragana shrub the plant life around it versus the impact of the native saskatoon serviceberry on plant life around it." The second group that I followed chose to explore how the bird feeders placed in the natural area by visitors impacted the native squirrel populations. Although it was discouraged by the preservation society, some visitors insisted on maintaining and placing feed for the birds in feeders placed in trees in the park. Subsequently, the native squirrel population also used the feeders. Although the preservation society had attempted to remove the feeders, determined visitors always put them back up. The feeders remained despite the preservation group's disapproval. This student group stated their focus as:

> We are seeing if small mammals prefer to eat their natural food such as cones, or if they prefer to eat the food that is put in the feeders. To find the answer we will go to the [natural area], and find a bird feeder, and we will find a tree with pine cone, and we will count how many small mammals go to the bird feeder, compared to the tree with the cones.

The students worked through a planning template in their small groups to develop the field test they would use for their specific focusing question in the natural area. The student groups would have opportunities to collaborate together on Google Docs (an online collaborative tool) to plan the field study, and also be able to see other groups' studies to provide feedback on their work. Peer feedback groups were specifically established so that each student group would deliver and receive feedback at various points during the planning and conducting their field study, to specifically address the student's methods and analysis. A scientific panel discussion was done before the groups went out into the field to provide feedback around whether or not the group's methods would generate accurate and reliable results. The teacher also provided specific feedback to the groups during the planning process.

The students went to the natural area twice to conduct their comparison tests. After gathering their results, they were expected to prepare a presentation to report back to the natural area as to the significance of their human impact on the ecosystem, and recommendations the students' had to mitigate (or not) the human impact or invasive species.

3.3.2. Phase 1: Pre-Unit Interviews

I conducted semi-structured interviews with the teacher. They were audio taped to access information on (i) what the teacher's instructional intentions and plan of the unit were, (ii) what the foreseeable learning was intended to be, (iii) the areas where the teacher might predict some learning difficulties and how she hoped to deal with those obstacles to learning. I collaborated with the teacher to create the learning opportunities for the students. I gave the teacher the option to select someone other than myself to conduct the interview to allow for more honest reflection than may otherwise be apparent with the close collaboration between myself and teacher. She was comfortable to allow myself to administer the interview and felt she could be honest in her reflections.

I interviewed the principal of the school to gather information on the vision and goals of the school, and how the school worked to help teachers and students in the areas of environmental literacy and technology. Obstacles and successes in learning were targeted in the semi-structured interview. The interview was audio taped.

3.3.2.1. Pre-Unit Student Interviews

During each student interview, the participant was shown a series of images of scenes in the outdoors. The images were scenes from: (i) a manicured garden, (ii) a forest ecosystem, (iii) a clear-cut logged forest, and (iv) a grassland ecosystem. After the participant had time to review the images, they were asked to reflect on what a healthy and unhealthy ecosystem is and how humans impact ecosystems.

The student interviews were audio-taped and adhered to a casual conversation format based on the following questions:

1. Can you tell me how you would define an ecosystem?
2. How would you tell if an ecosystem is healthy?
3. How would you tell if an ecosystem is unhealthy?
4. How would you study an ecosystem to determine if it was healthy or unhealthy?
5. How do you think humans have positive (good) impact on ecosystems?
6. How do you think humans have negative (bad) impact on ecosystems?
7. Why do you think humans impact ecosystems in the way they do?

3.3.3. Phase 2: Observation of Students During Classroom and Field Work

Observations were made during lessons, fieldwork and classroom work. The researcher focused on the following when conducting observations:

1. How do students question their understanding of ecosystems? What questions do they ask of their teacher and each other?
2. As the students expand their notions of an ecosystem, how do they use collaboration and discussion?
3. Are there noteworthy instances when the students seem to take steps that deepen understanding? What motivates them to do so?
4. How does technology enhance and enrich learning about ecosystems? When is it a hindrance to understanding?

5. What unforeseeable events occurred during the learning that needed to be addressed by the teacher? How does the teacher attempt to resolve them?

The select group of students was videotaped while at work and, when possible, during small-group discussion.

3.3.4. Phase 3: Collection of Student Work

Copies of written assignments and rubrics were collected and analyzed following the completion of the unit. This included copies of the collaborative work done by each selected group using Google Doc software. Student work from the selected seven students was collected and copied periodically during the unit and at the end of the unit.

3.3.5. Phase 4: Teacher Reflection

During the course of the unit, the teacher in the classroom was asked to reflect on the student's learning. She was asked to consider the following while she worked with her students:

1. How does she use discussion to build collective understanding?
2. How do students troubleshoot in the lessons?
3. How do students deepen their understanding in the lesson? What evidence does she have if she experiences instances of students deepening their understanding?
4. If there are blocks in student's understanding in a given lesson, what does she do to attempt to remove those blocks?

5. How does technology enhance or enrich students' learning in her lessons? What examples or techniques does she use to build collective understanding among students?
6. When is technology a hindrance to learning in her lessons if she experiences this?
7. Does she have other thoughts and reflections regarding the lessons she taught?

3.3.6. Phase 5: Post-Unit Student Interview

An interview will be conducted once the unit is complete with the select group of students. In addition to repeating the questions that were asked in the pre-unit interviews, the following questions were also asked:

1. Are there moments that you remember during this unit where you thought you learned something new? Please tell me more about the moments.
2. Do you think technology (Google Docs, digital cameras, presentation software) helped you learn about ecosystems? If yes, please tell me more. How did it help?
3. Do you think that your classmates helped you to learn in this unit? Could you give me an example?
4. Was there something that one of your classmates said or wrote that caused you to think about things differently? Could you tell me more?

Similar types of reflective questions were asked of the teacher in a post-unit interview:

1. Do you think that the students have developed a deeper understanding of ecosystems during this unit? If so, what are the instances you can use to describe and support this observation?
2. Was there evidence that you saw of students building collective understandings? How did discourse help in this process of building collective understanding?
3. What overall role did technology play in your students' learning of ecosystems?

3.4. Data Analysis Procedures

Once all the data had been gathered, it was examined in detail to find themes (within-case analysis), followed by a thematic analysis across all data sets (cross-case analysis). Once the thematic analysis was complete, assertions or interpretations of the meanings of the identified themes was further documented.

In general, the student cases were analyzed based on the following questions:

1. How has students' understanding of ecosystem components changed over the course of the unit?
2. What evidence is there that discussion and group collaboration has helped students create new meaning about ecosystems?
3. What is the evidence that technology has helped to enhance or enrich students' learning about ecosystems?
4. Are there other noteworthy observations relevant to students' learning about ecosystems?

From the analysis of each student case, general themes were created to summarize the results. These themes were then compared.

To specifically analyze the student's development of understanding ecosystems, individual student comments are clustered around the following interview questions:

1. Basic understanding of ecosystems
    - How would you describe the word "ecosystem" to a Grade 4 student?
2. How to study ecosystem health
    - How would you tell if an ecosystem is healthy?
    - How would you tell if an ecosystem is unhealthy?
    - How would you study an ecosystem to determine if it were healthy or unhealthy?
3. Human impacts on ecosystems
    - How do you think humans have a positive (good) impact on ecosystems?
    - How do you think humans have a negative (bad) impact on ecosystems?
    - Why do you think humans impact ecosystems the way that they do?
4. Analysis of images: Students were shown four different images, asked if they thought the image shows a healthy or unhealthy ecosystem, and asked to explain their reasoning.

3.4.1. Analysis of Student Understanding of Ecosystems in Interview Data and Concept Maps

To analyze the data from the student pre- and post-interviews and concept maps, a coding rubric was developed. Five categories were highlighted as core understandings of ecosystems. The categories selected for the core understandings were: i) biodiversity, ii) population dynamics, iii) abiotic and biotic interaction, iv) ecological integrity and v) transfer across contexts. The specific criteria for the rubric was developed in part from the curriculum students would have studied in Grades One through Six that were related to the core understandings of ecosystems. This included how to study ecosystems and human impacts on ecosystems. Roseberry, Warren, and Conant's (1992) study of scientific discourse also provided ideas for the criteria included in the final category, where students' consideration of hypothesis and experimentation when solving problems is described as evidence of more developed scientific reasoning. The coding rubric is shown in Figures 1 and 2:

	Biodiversity	Population Dynamics	Abiotic / Biotic Interaction	Ecological Integrity	Transfer Across Contexts
Elaborate Understanding	• Demonstrate knowledge of bio-diversity being an important indicator of healthy ecosystems (DE1) • Demonstrate knowledge of how all species (not just large ones, both animals and plants) are important components of a healthy ecosystem (DE2) • Discuss/communicate differences between native and non-native species, or wild and domestic animals (DE3) • Students recognize the importance of balance in an ecosystem (e.g. lack of balance creates things such as an algal bloom) (DE4)	• Students can demonstrate knowledge that different animals and plants have different needs. Both animals and plants fulfill their needs from the ecosystem. (NE1) • Students recognize diverse types of ecosystems such as forest, grassland, ocean, etc. (NE2) • Students recognize that an ecosystem is composed of population of individuals. (NE3)	• Discuss/communicate how both living and non-living things are important components of healthy ecosystems. (AE1) • Demonstrate knowledge of various types of interactions occur between living and non-living things in an ecosystem. (AE2) • Demonstrate knowledge of recycling occurs in a healthy ecosystem (e.g. dead leaf is broken down, nutrients returned to the soil). (AE3)	• Distinguish and demonstrate knowledge of scale of impacts occur in ecosystems. (RE1) • Demonstrate knowledge of how ecosystems change and mechanisms involve in the change. (RE2) • Communicate/discuss how humans can have dramatic impacts on ecosystems that can cause too much change- this can threaten the animals and plants that depend on the ecosystem and/or students discuss how human's can work to counteract change that has occurred. (RE3)	• Students are able to transfer key understandings from one context to another. (TE1) • Students consider a variety of variables assessing ecosystem health. (TE2) • Students engage in the same types of studying approach that a conservation biologist would when approached with a problem related to ecosystem health: they hypothesize and then consider experimentation. (TE3)

Figure 1. Coding rubric used for student elaborate understanding about ecosystems.

	Biodiversity	Population Dynamics	Abiotic / Biotic Interaction	Ecological Integrity	Transfer Across Contexts
Developing Understanding	• Students may not see bio-diversity as a part of healthy ecosystem, they might focus only on the healthy individual species (DD1) • Students may only consider large animals as important in an ecosystem. (DD2a) • Students may not recognize that there is a great diversity of plant species. Plants might be seen as one entity. (DD2b) • Students might not consider whether a plant or animal is a common or a non-native specie to the area (DD3) • Students may not recognize the dominance of one species as a possible indication of an ecosystem in peril (e.g. algal bloom) (DD4)	• Students might focus only on what animals need from the ecosystem, not what plants or "lesser known" species might need. (ND1) • Students may have a reduced view of what an ecosystem is, such as viewing forest as an ecosystem but a grassland is not. (ND2) • Students may focus on how one individual's needs get met ignoring the whole population. (ND3)	• Students may not recognize that things such as soil, nutrients, moisture as important components of an ecosystem. (AD1) • Students may not understand the interactions between living and non-living things in an ecosystem. (AD2) • Students may not see death as a normal part of the cycling in ecosystems. (AD3)	• Students may not have an understanding of the scale of impacts (e.g. one pop can will not destroy an ecosystem). (RD1) • Students may not understand succession of ecosystems and think they should remain the same all the time. (RD2) • Students understanding of human impacts on ecosystems may appear to be incomplete. (RD3)	• Students are only able to use knowledge in one context and have difficulty drawing on understandings in new contexts. (TD1) • Students use single parameter (such as appearance alone) to assess ecosystem health. (TD2) • Students jump to conclusions and do not consider ways of accessing evidence to inform their conclusions. (TD3)

Figure 2. Coding rubric used for student developing understanding about ecosystems.

3.4.1.1. Justification for coding rubric

The categories used to analyze the content of students' work and instructional material emerged from various sources: (i) Alberta Program of Studies, (ii) guest speaker to the studied class, who is a field scientist, (iii) a research ecologist, (iv) a former junior high science teacher, and (v) a science teacher educator. The categories have been developed through various iterations. They were applied to code selective students' work, and needs for modifications emerged during the trial coding. The final form was validated with a research ecologist.

3.4.1.2. Protocol for coding data

The coding rubric was designed to include criteria describing elaborate and developing understanding for each descriptor under each category. When analyzing transcripts, work was considered elaborate when the student demonstrated this level of understanding consistently throughout the interview. If there were moments of discrepancy (i.e. the student demonstrated both elaborate and developing at different times during the interview), then the work was considered developing, At times, differences in ranking were determined to be evidence of another criterion. For example, it was determined that sometimes the difference between elaborate and developing understanding was due to student difficulty with transfer skills that impacted their ability to reach the elaborate level. In these cases, the student understood the concept in one context but had difficulty transferring it to a new context. Anecdotal records were kept of each student's coding to refer back to and reflect on the accuracy of the codes assigned in each case. Samples of transcripts and concept maps were compared with one other person to ensure consistent interpretation of the coding rubric.

Pre and Post Interviews and Concept Map coding protocol:

During the interviews, students' were asked a variety of questions related to ecosystems and asked how they would determine if an ecosystem was healthy or unhealthy. The coding rubric was used to describe the characteristics of the student's understanding at that particular point in the unit. For the concept maps, each statement written by the student was coded. If the students drew an image with no accompanying written words to describe their thinking, then the image was coded. Once each statement and image was coded, the codes were summarized to determine the characteristics of the student's understanding at that particular moment in the unit.

On final analysis, student individual pre- and post-interview data were compared to individual student pre- and post- concept map data to ensure that possible trends were consistent with both data sets. The interview data was seen as primary data source, as students were probed for understanding by the interviewer more than on the concept map, where students were not asked for clarification of ideas nor asked to elaborate when their ideas were not clear.

3.4.2. Student-Articulated Pre-Understandings During Pre- and Post-Unit Work

A second round of coding was done to specifically track the common beliefs or pre-understandings that students articulated during the interviews and student work. I considered a statement common for this study group of students if three or more students articulated the same belief or pre-understanding. I wanted to track common specific alternate conceptions from pre to post work to see if there was a change from beginning to the end of the unit.

Four student beliefs were identified following the analysis of the students' work and interviews. The first common notion was that students felt that for an ecosystem to be healthy it needed to appear "green" and not "brown." Students often mentioned things like dead grass, dead leaves, dead trees or brown foliage as indicators than an ecosystem was unhealthy. A second common statement made by students was that litter in a natural area was an indication that the natural area was unhealthy. A third common theme expressed by the students was general mention of the impact of pollution and deforestation on ecosystems without considering the particular impacts they might have. For example, there seemed to be agreement that pollution was unhealthy for an ecosystem, but students did not articulate exactly how the pollution was unhealthy and appeared to have difficulty explaining where the pollution came from (aside from air pollution from cars). Finally, students made telling assumptions about the way a natural area *should* look if it were healthy. Following the trend of the "if it looks green" comments, students commented that if water looked "dark" it might be unhealthy, then they indicated they would conclude that it might be unhealthy.

To track student alternate conceptions, I highlighted evidence of these conceptions in pre- and post-unit interviews and concept maps and then compared the number of students who articulated them during pre- and post-unit work.

3.4.3. Student Knowledge of Human Impacts on Urban Parks

Another round of coding was also done to highlight students' knowledge of specific human impacts on urban parks. Urban parks, such as the one the students studied, face unique challenges due to their proximity to a large population of people who have easy access to the natural area. Common threats to urban natural areas include: 1) the impact of many dogs defecating in the area, 2) invasive weeds, 3) the impact of trails and benches, 4) illegal pathways, 5) human disturbances, 6) noise pollution, 7) water pollution from sources upstream of the park, 8) impacts from the immediate surrounding community, and 9) bird feeders and bird seed placed in the park by visitors. This list summarized the issues brought forward to the students by the guest speaker (also a research scientist) from the local natural area and was verified by a conservation biologist working in the field.

Student transcripts were coded for evidence of awareness of these urban park issues. I looked for how many students listed each of the above-mentioned human impacts on urban parks when questioned about this topic. In essence, I wondered how in-tune the students were with the natural area close to the school that they had often visited. How knowledgeable were they of potential human impacts in urban natural areas?

3.4.4. Teaching Effectiveness and Unit Task Design

To understand the impact of collaboration and technology on students' developing ecological understanding, it is important to consider the effectiveness of the unit design and the teaching strategies employed throughout. To do so, I used the Canadian Education Association's *Teaching Effectiveness Framework* (Friesen, 2009). Although the teacher was the primary instructor, the design of the unit was a collaborative effort between the teacher and I. Therefore, the teaching effectiveness is a combination of all of the elements of instruction that went into the design and delivery of this unit.

I used the *Inquiry Task Rubric* developed by the Galileo Educational Network (2000-2008) to assess the degree to which the unit meets the criteria for a strong inquiry work, including appropriate use of technology and effective collaboration. For each category of the rubric, the unit was assessed at the beginning, developing and accomplished level in each of the following categories: i) authenticity, ii) academic rigour, iii) assessment, iv) beyond the school, v) appropriate use of technology, vi) active exploration, vii) connecting with expertise, and viii) elaborated communication. Within each of these categories, there were three or four sub-sections used to describe the particular category. As a result, the task design might have received different rankings for a particular category. To come to an overall ranking of beginning, developing or accomplished within a particular category. I selected the rank that appeared most often.

3.4.5. Effectiveness of Student Collaboration

The field study was set up so that group work and collaborative efforts were central to the study. Students made decisions through consultation with their group members. To analyze student collaboration, I used the section of The Galileo Educational Network's rubric for assessing field studies that is particularly dedicated to collaboration (2007-08). The coding rubric is detailed in Figure 3. In doing so, I looked for anecdotal instances where a collaborative environment seemed to have changed the understanding of the students. I considered the suggestions made by the teacher during scientific panel discussions and small-group discussions as part of the collaborative process. The Google Docs and video from the scientific panel was analyzed based on the collaborative content. Students were also asked to comment on their collaborative work during the post-unit interviews. I also analyzed comments made by the teacher on the students' collaborative work during her reflective interview post-unit.

	Level 1	Level 2	Level 3	Level 4
Collaboration with Others	Requires teacher intervention or frequent supervision to remain on task and engaged (1.1) Interferes with the learning of others (1.2) Does not build on, extend or challenge other's ideas (1.3) Is frequently unprepared for team meetings or working sessions (1.4) Cannot clearly identify his or her contribution to the group effort (1.5)	Inconsistent use of available collaborative environments May contribute by doing his or her own work, but seldom offers assistance to others in problem- solving situations. (2.1) Does most of his or her work when the deadline is near, or when teacher supervision is required. (2.2)	Uses a variety of collaborative environments to keep in touch with group members and to build knowledge. (3.1) Remains engaged with others through the developing work rather than through teacher supervision. (3.2) Is consistently helpful to others. (3.3)	Depends on collaborative environments to push thinking and work forward. (4.1) Offers leadership that builds group cohesion and effectiveness. (4.2) Makes connections that build on and extend ideas. (4.3)

Figure 3. Coding rubric used to analyze collaboration in small groups.

(Galileo Educational Network, 2007-2008)

I had difficulty at times distinguishing between criteria 4.1 and 4.3. I took "pushing thinking and work forward" to mean incidences where the student's field study work was improved by simple suggestions made by their peers, such as ways to improve the accuracy of their testing or ways to control variables. "Making connections that build on and extend ideas" was taken to mean incidences when it could be seen that the collaborative environment led to deeper understanding of ecosystems or evidence of the critical thinking that is involved behind fieldwork, like the analysis of data and coming to conclusions. This could include evidence of deeper questioning or deeper thinking.

To code the data, each comment made by a student during the post-unit interviews was coded for the specific collaborative characteristic. The Google Docs were coded as a collective piece with the identifying criteria that characterized the whole document. The teacher post-unit interview was coded based on the criteria that characterized each comment that she made mentioning collaborative student work. The scientific panels were assigned a code based on the criteria that summarized the whole video clip.

After analyzing the interviews, I realized that my line of questioning was biased in asking the students, "How did your classmates help you learn?" but I did not question how the group work might have been detrimental to their learning. Therefore, the data may be skewed in a positive direction towards effective collaboration. Because I could not be present in the classroom at all times during the course of the unit, I relied on the observations of the teacher during the post-unit interview to gather information on the possible detrimental impacts of the collaborative environment.

3.4.6. Student Use of Technology During the Study

As described in Section 3.4.4, the task design was analyzed to highlight how use of technology in the classroom and during the field study enabled or hindered the students' understanding of ecosystems. This analysis overlapped with the previous section on collaboration, as it was the Google docs that enabled some of the collaboration that occurred during the unit.

3.5. Ethical Considerations

1. Consent was obtained from the participating students, teacher, and the school principal.
2. Anonymity was maintained at all time during the research.
3. Students were made aware that their involvement in the research at any level would have no impact on their assessment of grades. The researcher did not have access to or have influence on the assessment of the students' work or on the determination of their grades during the unit.
4. Students had the option to withdraw from the study at any time.
5. The teacher and principal's words were transcribed verbatim. They were asked if they wished to check the researcher's reflections or interpretations for accuracy.

CHAPTER 4

Findings

4.1. Ecological curricular outcomes in Grades One Through Six

I undertook a content analysis of the Alberta Science Program of Studies to determine what ecological understandings students should have been exposed to before Grade 7. In particular, the focus of the analysis was on what overall experience the program may provide to students as they complete their first six years of formal education in Alberta. The analysis foci thus led to the three areas of understanding relevant to this case study: i) ecological concepts, ii) field study processes and iii) understanding of human impacts on the environment.

According to the examination of the curriculum, I found that students in Alberta are exposed to many foundational concepts that help them to build their understanding of ecosystems. The ecological concepts expected of students prior to entering Grade 7 seem to have an overall focus on understanding animals and plants and how various living things interact. Students are expected to understand the relationship/interaction between living and non-living things in Grade 2 and then Grade 5 science curriculum.

The process skills relevant to field study expected of students prior to Grade 7 also represents a whole range of skills from observation, describing and classifying, to comparing, contrasting and posing inquiry questions. The expectation for students in Alberta to learn about human impacts on their environment is consistently expressed in Grades 1 through 6.

4.2. Student Interviews and Concept Map Analysis Results

The coding rubric outlined in Figures 1 and 2 was used to analyze the pre- and post- unit interviews and concept maps to note changes in understanding from the start to the end of the unit. The results of the coding are summarized in this chapter, and additional supporting anecdotal evidence with accompanying data description for each student is described in Appendix F. In the majority of cases, students demonstrated growth in understanding ecological concepts. However, many of the students had one criterion that persisted from beginning to end. In particular, many students failed to develop the idea that death is natural part of the cycling of ecosystems (AD3). It must be noted that this data indicates that students did not demonstrate this information within the data gathered. As this coding rubric (Figures 1 and 2) was developed after the data gathering was complete, some criteria on the rubric might not have been completely addressed in the questioning and therefore not articulated by the students.

4.2.1. Finding 1: Analysis of pre- and post-interview data and concept map data shows that 6 out of 7 students (86% of students) demonstrated growth in their understanding from the beginning to the end of the unit.

The majority of students demonstrated a growth from developing to elaborate understanding within one or more categories. One student demonstrated only one change in one criterion, and this change was demonstrated only on their final concept map. It was therefore determined that this student showed limited growth in learning about the concepts in the unit. Another student began the unit with an already established elaborate understanding in some categories. This student demonstrated growth from beginning to the end of the unit in one category.

Further synthesis of the results from the coding was done to demonstrate exactly how much growth and how many persistent understandings were attained for each student:

Student A: Overall, student A demonstrated development from developing to elaborate understanding in 4 categories. Student A showed little change in moving towards the elaborate understanding that recycling occurs in a natural system (code AD3 persisted and did not progress to AE3).

Student B: Student B demonstrated growth from pre- and post-work in terms of: i) biodiversity, ii) interactions of biotic and abiotic matter and iii) applications and transfer of concepts. Student B persisted in thinking that death was an indication of an unhealthy ecosystem (Code AD3) and was still at the developing level with the scale of impacts on ecosystems and their understanding of human impacts on ecosystems.

Student C: Student C demonstrated an elaborate understanding in pre-unit interviews. He/she showed some growth in understanding of biodiversity in the post-unit work but this was not visible in the codes used.

Student D: Student D was the only student who did not demonstrate much change from a developing understanding from the beginning of the unit to the end of the unit. In this case, the student persisted with the idea that: i) green was an indication of a healthy ecosystem and that death was unhealthy (Code AD3), ii) was still developing their understanding of human impacts on ecosystems (Code RD3), and iii) was still considering only single parameters to assess ecosystem health (Code TD2).

Student E: Similar to Student C, Student E seemed to have an already developed understanding of ecosystems in the pre-unit analysis. A strong understanding related to biodiversity persisted throughout the unit. Student E developed a more elaborate understanding of the application and transfer of knowledge about ecosystems across contexts, and more elaborate understanding of ecological integrity and human impacts. The idea that death is a sign of an unhealthy ecosystem (AD3) also persisted throughout the unit.

Student F: Student F showed growth in almost all categories. Their understanding of the scale of impacts (RD1) persisted at a developing understanding from pre to post unit analysis.

Student G: Student G showed an increase in understanding of application and transfer of knowledge of ecosystems across contexts and that ecosystems meet the needs of plants and animals. The scale of human impacts (Code RD1) and developing an understanding of death in an ecosystem (Code AD3) persisted from pre to post unit work.

4.2.2. Finding 2: Students developed a more elaborate understanding of biodiversity but still struggled with concepts related to population dynamics, ecological integrity and the transfer/application of knowledge to new contexts.

The coding indicated that the concept of biodiversity has been well-understood by students by the end of the study, as has the students' ability to assess some of the variables related to ecosystem health and their understanding of the biotic and abiotic components of ecosystems. However, students still struggled with some aspects of population dynamics, ecological integrity and their ability to transfer and apply their understanding to new contexts.

More specifically, the coding criteria highlighted in the following list were selected if three or more students (out of seven students) demonstrated an elaborate understanding by the end of the unit:

- Demonstrate knowledge of biodiversity being an important indicator of healthy ecosystems (DE1)
- Demonstrate knowledge of how all species (not just large ones, both animals and plants) are important components of a healthy ecosystem (DE2)
- Discuss/communicate differences between native and non-native species, or wild and domestic animals (DE3)
- Recognize the importance of balance in an ecosystem (e.g. lack of balance creates things such as an algal bloom) (DE4)
- Discuss/communicate how both living and non-living things are important components of healthy ecosystems. (AE1)
- Transfer key understandings from one context to another. (TE1)
- Consider a variety of variables assessing ecosystem health. (TE2)

In contrast, the following list is of the criteria where only one or no students (out of seven students) demonstrated an elaborate understanding by the end of the unit:

- Demonstrate knowledge that different animals and plants have different needs. Both animals and plants fulfill their needs from the ecosystem. (NE1)

- Recognize diverse types of ecosystems such as forest, grassland, ocean, etc. (NE2)
- Recognize that an ecosystem is composed of population of individuals. (NE3)
- Demonstrate knowledge of various types of interactions occur between living and non-living things in an ecosystem. (AE2)
- Demonstrate knowledge of recycling occurs in a healthy ecosystem (e.g. dead leaf is broken down, nutrients returned to the soil). (AE3)
- Distinguish and demonstrate knowledge of scale of impacts occur in ecosystems. (RE1)
- Demonstrate knowledge of how ecosystems change and mechanisms involve in the change. (RE2)
- Engage in the same types of studying approach that a conservation biologist would when approached with a problem related to ecosystem health: they hypothesize and then consider experimentation. (TE3)

4.2.3. Finding 3: Students had already begun to grasp specific criteria related to biodiversity before the unit began and continued to develop more elaborate understandings throughout the unit.

Many students had already developed elaborate understanding of some criteria within the concept of biodiversity before the unit began and continued to deepen their understanding of more criteria related to the concept of biodiversity throughout the unit. Many students also moved to develop a deeper understanding in two of the criteria related to transferring and applying knowledge to new contexts.

4.2.4. Finding 4: Students do not consider death as a normal part of the cycling of ecosystems (Code AD3)

The results indicate that code AD3 persisted for almost all students. Synthesizing the information attained from the previous table, Table 2 shows the number of students demonstrating growth in understanding within a particular category, the number of students that demonstrated elaborate understanding within a category at the beginning of the unit, and the number of students who had a persistent developing understanding that did not change by the end of the unit. Here we can see the persistence of code AD3, as well as the elaborate understanding of some of the criteria related to biodiversity at the beginning of the unit and at the end.

Table 2

Student growth (out of 7 students) within specific categories

Category (Concepts)	Number of students demonstrating growth within one or more criteria of a concept.	Number of students demonstrating an elaborate understanding at the beginning of the unit.	Number of students who still demonstrated a developing understanding at the end of the unit.
Biodiversity	4	5	0
Population Dynamics	2	1	0
Abiotic/ Biotic Interaction	4	3	5 (AD3)
Ecological Integrity	3	0	3 (RD1) 2 (RD3)
Transfer Across Contexts	5	1	1 (TD2)

From Table 2, we can see the persistence of a few key developing understandings in the final column, particularly in AD3 (as mentioned above) but also in two of the criteria within the concepts related to "ecological integrity." We can also see that despite there being five students who moved to an elaborate from developing understanding in the final concept ("Transfer Across Contexts"), we know that this is within two criteria of this concept, and the remaining criteria stayed at the developing level.

4.3. Common Alternate Ecological Conceptions Articulated By Students in Pre- and Post- Unit Work

Four key alternate conceptions articulated by students emerged from the pre-unit and post-unit data. The belief or statement was considered common if three or more students articulated the conceptions. Table 3 shows results of tracking conceptions articulated by students during pre and post unit interviews and concept map analysis:

Table 3

Number of students (out of 7) who articulated common ideas at beginning and at the end of the unit

Common Student Idea	Pre- Unit	Post- Unit
Green vegetation is healthy, brown vegetation is unhealthy	6	5
Litter is a threat to ecosystem health	7	5
Mention of pollution and/or deforestation	7	3
Water bodies are a "normal" (not dark) colour if they are healthy	3	0

4.3.1. Finding 1: Students think that litter is an indication that an ecosystem is unhealthy (7 out of 7 or 100% of students expressed this notion in pre-unit analysis, 5 out of 7 or 71% at the end of the study).

During the pre-unit interviews, when asked how they would be able to determine if a local natural area is healthy or unhealthy, all of the students replied that seeing litter on the ground was an indication that an ecosystem is unhealthy. Student C offered a typical response: "The [natural area] is not healthy because of lots of litter and trash on the ground." The naturalist brought into the classroom as an expert on the natural area they were studying did not mention this as one of the human impacts on the area, nor was it a focus area for any of the student groups in their in-depth study of the area.

Despite this, during post-unit interviews and concept map analysis, students still mentioned litter as one of the indicators that an ecosystem is unhealthy.

4.3.2. Finding 2: Students stated that pollution and deforestation are threats to ecosystems (7 out of 7 or 100% of students expressed this notion during pre-unit analysis, 3 out of 7 or 43% during post-unit analysis).

The students are expressing a common understanding about the environment; i.e. that pollution and deforestation are incredible threats to ecosystems. However, students often mentioned the word "pollution" when talking about threats to ecosystems, but did not define specifically how pollution might impact ecosystems. When pressed, students would often indicate air pollution from cars as the threat. Statements such as the following comment from a pre-unit interview demonstrate this finding: "Cars near the [natural area] ruins the animals' environment too. Pollution and sightings with humans." Deforestation or cutting down trees was also mentioned, often tied together with statements about pollution. Students are aware that these are major environmental issues, but their specific understanding of the issue seems limited.

4.3.3. Finding 3: Students think that in order to be healthy an ecosystem needs to be "green" (6 out of 7 or 86% of students expressed this notion during pre-unit analysis, 5 out of 7 or 71% during post-unit analysis).

When asked the question, "How would you be able to tell if an ecosystem is healthy?" students often replied that the health of the ecosystem can be determined if the ecosystem looks "green" or "brown" (dead). It was apparent that the students felt that evidence of decay or brown colors other than green colours would indicate that the ecosystem was unhealthy. Statements such as the following show how students expressed this notion: "The [ever]-green trees look healthy because they're green and it looks really healthy." "Because everything is alive and not dead" (Student D). "The grass isn't completely green and is yellow at times" (Student A).

4.3.4. Finding 4: A few students used assumptions about the way they think water should look and would use this as an indicator of ecosystem health (3 out of 7 or 43% of students expressed this notion during pre-unit analysis, no students mentioned this in post-unit analysis).

Some students expressed how they thought things should look, particularly when discussing the water in the natural area. If the environment did not look the way they thought it should look, then this to the students would indicate that it was unhealthy. For example one student said the following in her pre-unit interview: "The color of the water seems like a normal color.... If the water's not a blue color or a normal color you would see." No students mentioned notions such as these in post-unit analysis.

4.4. Students' Understanding of Human Impacts on the Urban Natural Areas in "Their Own Backyard"

Table 4 summarizes how students' awareness of human impacts on urban natural areas changed from the beginning to the end of the unit.

Table 4

Number of students (out of 7) demonstrating evidence of an understanding of human impacts on urban natural areas

Human Impact	Pre-Unit	Post- Unit
Impact of dogs in area	2	2
Invasive Weeds	3	6
Impact of Paved trails and benches	4	7
Impact of walking off trail	1	7
Noise pollution or human disturbance	6	6
Water contamination upstream	1	0
Impact of surrounding community (pesticides)	4	5
Impact of Bird Feeders	0	5
Other ideas expressed by students	6	1

4.4.1. Finding 6: Students showed an increase in their ability to identify potential human impacts on urban natural areas.

During the pre-unit analysis, one student could list four accurate human impacts on urban parks, three students could list three accurate human impacts, one student could list two impacts, and one student could list one accurate human impact on urban parks. The most common human impacts mentioned were noise pollution and human disturbance (six students mentioned this). Only one student mentioned water contamination from upstream sources. No students mentioned bird feeders placed in the area. Students also had other ideas about how humans impact natural areas that they listed during the interview and on concept maps. These were noted (see Appendix H and I), but as the focus of their subsequent work would be on urban natural areas, I highlighted only the human impacts that affect these protected spaces.

By the end of the study, the students showed an increase in understanding potential human impacts on urban natural areas. Specifically, more students mentioned invasive weeds, paved trails and benches, the impact of walking off the paved trails, and bird feeders as human impacts on the ecosystem.

4.5 Teaching Effectiveness

The teacher and I worked together to design the unit. During the pre-unit interview with the teacher, the teacher was asked what she felt her students understandings would be of ecosystems before their study began. She indicated that the students had already spent some time studying the unit "Plants for Food and Fiber" (part of the Grade 7 curriculum) but that they had not touched on any of the objectives related to ecosystems that school year. The year before (in Grade 6) the students had completed a unit on "Trees and Forests," and she felt some of the concepts from this unit would be carried over to this year (the same teacher had taught these students in Grade 6). When asked where she thought the students would be with their understanding of ecosystems, she stated the following:

> I would say.. that's a hard question.. where they're at...I think they probably have a basic understanding of ecosystems. I think this school

> does a good job if getting kids out into ecosystems so they've at least experienced that and I think basic requirements of ecosystems they should understand and I think when you get into food chains that are kind of higher order… I would anticipate that there would be a lot of growth in understanding ...but the basic food water shelter space…sort of "what is an ecosystem" they should know.

Table 5 displays the results of the analysis of the teaching effectiveness. In general, the effectiveness of the instruction was assessed at the accomplished level. However, assessment and fostering deep understanding were assessed at a lower level than the other areas of teaching effectiveness.

Table 5

Analysis of teaching effectiveness

Category	Level Teaching Effectiveness
Design is focused on building understanding	4
Design is informed by disciplinary knowledge	4
Work is authentic	4
Work fosters deep understanding	3
Assessment is comprehensive	3
Clear criteria are established	3
Students are self-directed	3
Students' relationship to the work	4
Teachers' relationship with the students	4
Students' relationships with each other	4
Teaching is a scholarship	4

(Friesen, 2009)

4.5.1. Finding 1: The teaching effectiveness in this unit was assessed in many criteria of the *Teaching Effectiveness Framework* (Friesen, 2009) at a high level.

The design of this unit was intentionally connected to strong disciplinary understanding with a connection beyond the school. The students were asked to engage in the same types of thinking that a conservation biologist would. The study was of real concern to the community and world outside the classroom. The students often came in at recess and worked on the weekend to complete the tasks and were excited to communicate their findings to the experts involved in the study. The teacher engaged in serious challenging dialogue with the students when providing feedback, and the student groups challenged and provided feedback to each other in a serious, intellectually engaging manner. The preparation for the study involved a deep investment on the part of the teacher, which included a growth in understanding of the topic for the teacher:

> INTERVIEWER: Do you think that your own thinking has changed in any way?
>
> TEACHER: Well I know more about the [natural area] than I knew before I started this. I didn't know about all those illegal trails. I had no idea that they were there and that we weren't supposed to be on them. So perhaps going down there now will change the way I present how we interact in that space, as a class. Just knowing that now.
>
> I just really loved seeing them down there and really engaged in their work. There were small groups that were super-focused for the hour and a half that they were there, on what they needed to accomplish. And there wasn't any goofing around. There was [*sic*] no behavior issues to deal with. They were respectful of the area they were in, and worked really well together. So I think it just reinforced in me the need to do that. To work with my students.
>
> INTERVIEWER: And do you think the, having the purpose and the intention behind why they were there, and the…
>
> TEACHER: Oh absolutely. It was a serious endeavor.
>
> INTERVIEWER: If you had just taken them on a hike down there you may have seen different things.
>
> TEACHER: Oh yeah. Totally.
>
> INTERVIEWER: But because they had, they were accountable to themselves and the [natural area] society, and to you, and they were making that understanding public. And they each were responsible for a specific study that was different. That kind of helped focus them and not be…

TEACHER: Yeah absolutely.

4.5.2. Finding 2: Areas of growth for the teaching effectiveness were in "fostering deep understanding" and in "assessment."

Students were asked to come to conclusions based on quantitative evidence and to consider the implications of their conclusions. However the students were not asked to carefully consider ambiguities, analyze assumptions, formulate working theories or discuss how things might have been otherwise (supposition). This was seen particularly in the final presentations, where at times despite a lack of sufficient data students still came to conclusions that they reasoned to be true. Had they partaken in deeper levels of questioning they may have determined that their data was insufficient and proposed further study instead of forming a definitive conclusion. For example, in the case of the group who were studying squirrels at a birdfeeder, their study consisted only of one feeder and one tree as test sites, and observations occurred two times for around 20 minutes. Despite their lack of data, the group still determined that the feeders were impacting the natural behavior of squirrels and should be taken out of the park. Perhaps with an increased depth of analysis the students might have concluded that further study was required to make an accurate assessment of their question.

The teacher used a predetermined rubric for field studies that the students referenced a few times during the course of the study. However, peer feedback was based around a series of questions without the guiding criteria of the rubric. The students did not see exemplars of what a high-level study would look like. Oral feedback from the teacher, although intellectually engaging, was not used in combination with the criteria from the rubric and was more suggestive in nature. This is noteworthy, as in some cases, intellectually engaging questions through peer and teacher feedback were not taken up seriously by the groups. This will be further explored in the analysis and conclusions section.

4.6. Analysis of the effectiveness of the field study unit design.

In general, the task design was assessed at the accomplished level. However, assessment, appropriate use of technology and connecting with expertise was assessed at the developing level. Table 6 summarizes these findings.

Table 6

Analysis of unit design according to the Inquiry Task Rubric

Category	Evaluation of task (Beginning, Developing, Accomplished)
Authenticity	Accomplished
Academic Rigor	Accomplished
Assessment	Developing
Beyond the School	Accomplished
Appropriate Use of Technology	Developing
Active Exploration	Accomplished
Connecting with Expertise	Developing
Elaborated Communication	Accomplished

(Galileo Educational Network, 2000-2008)

4.6.1. Finding 1: The task ranked accomplished for "Authenticity".

Students had choice in determining the topic of their specific field study based around the overarching question, "How has the natural area been affected by changes? Is the [natural area] changed?" This overarching question is central to ecological studies, and the students had choice underneath this umbrella. Conservation biologists are currently studying human impacts in urban parks. The topics chosen by the students were relevant to the issues explored by real scientists today. Some of the students' specific topics for investigation field had not been done in this natural area and were therefore contributing to the knowledge of the community. The results of their findings were communicated back to the park so their study lived beyond mere "school work" that would be handed in to their teacher. Students were asked to provide feedback to each other in the form of a scientific panel and as peer editors. They were asked to incorporate the feedback into their study design. There was an expectation that the results were to be based on specific evidence, just as would be expected in the science field.

4.6.2. Finding 2: The task ranked accomplished for "Academic Rigor".

On the whole, the task ranked highly in this category. However, although the task presented a relevant and real-world topic, the specialized focus area of each specific student study did not necessarily lead to an understanding of the bigger picture. More intentional teaching into this space might have leveraged the work to a space of generality for the students. This will be discussed in the conclusions/recommendations section of the thesis. Students used methods to solve their specific question that were central to the discipline. A comparison study (impacted versus non-impacted site) is the same as what a conservation biologist would do. The task did require students to develop habits of mind associated with academic rigour: They were to use evidence to inform their conclusions, consider the accuracy and reliability of their data, and offer recommendations to the park to minimize their impact.

4.6.3. Finding 3: The task ranked developing for "Assessment."

Students gave ongoing feedback to each other in peer reviews and as part of scientific panels. Specific questions were given to guide feedback. Although an assessment rubric was highlighted at the beginning of the study, more intentional use of the rubric to guide feedback and next steps throughout the unit may have been helpful. The rubric was also set by the teacher and not negotiated with the students. Conservation biologists from the community provided summative feedback to the students at the end of their work, but had they used a negotiated rubric that the students were familiar with the assessment may have been more relevant.

4.6.4. Finding 4: The task ranked accomplished for "Beyond the School".

The study was based on the curriculum but required the students to address a problem that lived beyond the school. Students were provided with general questions to help guide their planning and given specific due dates for various tasks, and they had to manage their time within these contraints. Students worked in their groups to determine their topics, experimental methods, data-recording methods and presentation methods. The students selected topics based on a menu of choices generated by the class with advice from the expert (conservation biologist?). Teamwork and problem solving were involved in setting up the studies, dividing labour to access necessary background information, assigning roles and responsibilities during the investigation and reporting of results, and collaborating to develop more accurate and reliable tests.

4.6.5. Finding 5: The task ranked developing for "Appropriate Use of Technology."

Technology used in the study was effective in allowing collaboration around a single document, peer review through file sharing, and data-keeping with digital photos. But the technology was not essential to the task. The technology made the teamwork more efficient, but the field study could have occurred if the technology had not been present. The teacher decided which technologies would be used. Students had some choice in determining presentation software to communicate findings. They did not request use of technologies other than the ones provided. Probes and other digital data-recording devices could have been used in the field had the students been more familiar with their use. For the most part, students conducted research, shared information, made decisions, solved problems, created meaning and communicated with each other within the classroom context. Outside expertise was involved at the beginning and the end of the unit but was not accessed during the unit. Students had ongoing online access to their work, and this allowed them to continue working collaborating on the same document outside of regular class hours. In order for the work to be available to the larger online community, others could have been invited into the project, but this possibility was not used to its fullest potential. Students had access to Google docs, the internet, digital cameras and presentation software (iMovie and PowerPoint).

4.6.6. Finding 6: The task ranked accomplished for "Active Exploration".

The task required the students to spend a considerable amount of time planning for and doing field work. The study required students to engage in an authentic investigation. The students presented their findings to their peers and to two biologists from the natural area in a classroom presentation.

4.6.7. Finding 7: The task ranked developing for "Connecting with Expertise"

The students connected with expert guest speakers at the beginning and at the end of the study. They did not connect with outside expertise during their investigation. The experts were only available in a limited way to work with the students. While the teacher designed the study in connection with expertise, the students were not involved in the study design.

4.6.8. Finding 8: The task ranked accomplished for "Elaborated Communication"

Students had opportunities to support and challenge each other's ideas. They had choice in choosing a method to present their findings, and they communicated their findings with peers and with the experts involved in the study.

To push the lesson plan to a higher level of authenticity, the biologists could have been present during students' deliberation of evidence and could have provided feedback at various points in the process rather than just at the beginning and the end of the study. This may have helped students better determine whether or not their results were reliable and accurate. The field study was intended to foster deep understanding, but more intentional work might have been necessary to ensure that students considered whether they had enough evidence to draw reasonable conclusions. More intentional work to develop a holistic perspective to contextualize all of the information gathered about the health of the natural area may also have been helpful. Although intended, more consideration might have been given to analyzing assumptions, discussing how things might have been otherwise (supposition), examining implications, and consider ambiguities. Although spontaneously addressed during class discussion and while mentoring small groups, more intentional teaching into these spaces might have pushed some of the students to more deeply consider the implications of and connections between their own and each other's studies.

Intentionally stepping back and considering "what does this all mean?" in the larger context of human impacts on natural areas might have been an interesting question to consider as a large group. Although students were asked to form conclusions, being able to step back from their field work and consider whether or not their comparison test should be used as a indicator of ecosystem health or as sufficient evidence to change park regulations would have been an interesting undertaking. Some of the groups pushed their thinking in this direction, but more careful consideration could have been done in this area.

The teacher recollected that groups of students came in at recess and worked on their study at home and over the weekend. She also indicated that they were self-monitored, that there was not the line-ups at her desk, and that students felt responsible for reporting their study back to the biologists involved in the study. It is evident from the final presentations that each group member contributed to the work and was engaged in the final results. Their work was meaningful to them and to the local biologists.

4.7. Collaborative Work in the Small Groups: Findings

The students were asked to contribute to the working online document using different font colours so it was possible to track the work and comments made by each student over the course of the unit. Peer editors also critiqued each group's work on the same online document using a different set of font colours. It was then possible to track how peer feedback influenced a change in the group's process and thinking. Students were asked not to delete anything on their document but to edit by reworking underneath the previous work if they felt a change was needed.

Student groups also received feedback from the whole class in the form of a scientific panel. Each group presented their experimental plan in front of the class. Guiding questions were given to help students provide feedback to their peers during the scientific panel presentations.

The data was coded and summarized for the number of times a specific characteristic of collaboration was used to code a piece of work within a document or video. In general, it was observed from the data that many times the characteristic assigned indicated a high level of collaboration. It appears from the data that the scientific panel had less incidences of high scores. It must be noted that during the interviews, the students and teacher were specifically asked to reflect on student collaboration. Their reflections are the data that was coded. In the Google Docs and Scientific Panel data, the coding is reflecting what specifically happened when the students were in groups collaborating.

Anecdotal evidence was also gathered to describe collaboration within the small-group discussions and collaborative documents. There are many instances of Level 4 documentation and less of the lower-level categories. The following is a list of findings for student collaboration at each level:

LEVEL 4 (HIGHEST LEVEL):

- Peer feedback was used to develop strong experimental methods (4.1)
- Peer feedback was used to develop more accurate testing methods and check reliability of results (4.1)
- The importance of quantitative measurements was emphasized in scientific panel discussions. (4.1)
- Other students took up and elaborated on ideas presented by one student after student discussions. (4.3)
- Groups were self-managed to accomplish tasks. (4.2)
- Some students were highlighted as leaders in certain areas. (4.2)
- Some groups demonstrated how peer feedback caused them to analyze their results more critically and consider how their experimental methods might impact their results. (4.1)

Level 3:

- Peer feedback led to more complete and thorough background research. (3.1)
- Accuracy was emphasized when watching other group's feedback during the scientific panels. This led to slight adjustments in their own study design. (3.1)

- Student groups managed their own time to meet deadlines. The teacher did not feel that she needed to monitor the groups to meet deadlines. (3.2)

Level 2:

- The teacher felt that sometimes the group work might lead the students to jump to conclusions, or misconceptions might be perpetuated or go unchecked. (2.1)

Level 1 (Lowest Level):

- At times, the teacher observed off-task behavior. (1.1)
- The teacher felt that at times, some students contributed more to the group work than others. (1.5)

4.7.1. Finding 1: There were many instances where students worked at a high level of collaboration.

Within the high-level instances of collaboration, "makes connections that build on and extend ideas" occurred the least number of times. There were more instances of students depending on collaborative environments to push thinking and work forward, especially when students used peer feedback to ensure that their field test designs were accurate, reliable and based on fair testing. There were also some instances where students worked at a lower level of collaboration.

4.8. A Closer Look at the Impact of a Technology- Enriched Learning Environment on Deepening Understanding

This section will explore how the technology used in the classroom and during the field study enabled or hindered students' understanding of ecosystems. Recall that when the unit was assessed using the *Inquiry Task Rubric* (Galileo Educational Network, 2000-2008), the unit scored at the beginning and especially at the developing levels for appropriate use of technology. I suggested that had the technology been used to its fullest potential and had student work been made available to a wider audience on a more ongoing basis, use of technology in the study may have scored at the accomplished level.

The task received a rank of "developing" because the technology used in the study was effective to allow for collaboration around a single document, for peer review through file sharing, and to allow data storage with digital photos. However, the technology was not essential to the task. The technology made the teamwork more efficient, but the field study could have occurred if the technology had not been present. Students conducted research, shared information, made decisions, solved problems, created meaning and communicated with each other, mainly in the classroom. Expertise was involved only at the beginning and the end of the unit. Students had ongoing online access to their work. In order to make their work available to a larger community, outsiders could have been invited into the project. This possibility was not used to its fullest potential. Students had access to Google Docs, the internet, digital cameras and presentation software (iMovie and PowerPoint) however they did not use probes or other data-collecting devices.

The task received a rank of "beginning" because the teacher decided which technology would be used for student collaboration. Students had some choice in determining presentation software to communicate findings. The students did not request use of other technologies than the ones provided. Probes and other digital data-taking devices could have been used in the field had the students been exposed to more elaborate data collection.

4.8.1. Finding 1: Technology, although widely used during the study, was still assessed at the beginning level.

It was apparent that the access to online collaborative tools (the Google Docs) enabled the students to work together during times when they would not normally be able to do so. The teacher and students commented that they were able to continue thinking and working on their project as a group after school hours despite being in different locations because of their access to technology: “That helps when you’re working with a group and you can’t all be together at the same time” (Student E, Post-Unit Interview). The teacher also commented that the online collaborative tools enabled students to critique each other’s work in ways that normally would not have been possible:

> TEACHER: I think it is a useful tool to deepen understanding. Anything that is especially relevant when they had to go into each others peer groups, into their partner group, and critique the information that was there. Because that was background information that that group wouldn’t have been exposed to had they not done that. And doing that using paper and pencil is just not effective, it is not efficient. Those kids that were doing this over the weekend at home on the same document that that group is working on, at home on the weekend.
>
> INTERVIEWER: So it just offered more opportunities for them to make their understanding public, and then have someone to provide feedback on that understanding. Whereas otherwise you’d have had to set up more moments where they could comfortably verbalize that and negotiate. But that has enabled them to negotiate understanding.

> TEACHER: Well they could work together and if one group wasn't finished yet they could say, "Look we're going to work on this tonight and by…" - maybe it is a Friday - "…and then by tomorrow you can come in and look at our document." And they could arrange that on e-mail, or verbally, or however. But there were groups that were doing that. They were saying, "Look, we need one more night to work on this." But it was due Monday. So they could go in on the weekend and do it. And then it is not putting everything behind schedule, because if they had to wait until Monday morning to look at the hard copy, to then write in there… they won't do it. (Teacher Post-Unit Interview)

Students also commented how it was easier to keep track of things, that there weren't sheets to be lost in a month-long investigation, and that everyone could have access to the group's information.

Another student commented how having access to online collaborative tools enabled "everyone to have a say" (Student G, Post-Unit Interview). The teacher also commented on this shift in classroom dynamic between a more verbally oriented collaboration and one that was more digital:

> And what was interesting with having them work in Google Doc was that the room was mostly quiet most of the time. Even if they were sitting at a time, with three or four of them working together, they were communicating through the Google Doc. They weren't speaking to each other. So in order for me to see what was happening I would have to go into the Google Doc and then follow their conversation. So it was less verbal exchange and more digital. (Teacher Post-Unit Interview)

In some cases, this less verbal and more written form of exchange between students was beneficial for the teacher in tracking students' thinking and pushing them deeper into their work:

> TEACHER: Because you can't be listening to all the conversations at the same time. But you can go in and capture what they've done that day on the Google Doc. And then some kids, they get pretty chatty or conversational. Like I found some of the things they were doing were slightly off task at times. They would start talking to each other over it, instead of actually working. But for the most part they were pretty focused on what they need to do. And it was a great way for them to organize their information and to make sure they've covered off the things that they need to. And they'd paste in documents that we'd sent them and worked directly in their Google Doc.
>
> INTERVIEWER: And did you feel that with them using the Google Doc, that you could have insights into them that you wouldn't normally have?
>
> TEACHER: Well yeah, if you miss those conversations and if they are happening there. I guess every project is different in terms of how they present their information or their knowledge. But this was a good way for a group to collaborate on a project. (Teacher Post-Unit Interview)

The students used digital cameras during their study trials to record their information and to use later to communicate their findings: "The digital cameras helped because you could take pictures and look back on them" (Student B, Post-Unit Interview).

One student commented on the ease with which they had information available to them while researching for their field study topics because they had access to technology (the Internet). "I think it helped a lot, because when we have access to all this stuff we can just pull out information really easily instead of going to the library and looking through a book and it is not there. And then we have to go and go search for it" (Student E, Post-Unit Interview).

One student insightfully commented that actually being in the natural area was where the real learning took place, but that being able to see via photographs what the other students were doing in their presentations also helped their learning:

> INTERVIEWER: And do you think that technology like the Google Docs and the digital cameras and the PowerPoints - do you think that that helped you learn about ecosystems? And yes, can you tell me more about how it helped you?
>
> STUDENT: Kind of. I don't know. I think going to the actual ecosystem and looking at it helped quite a bit so that you could actually see what was happening. And then the Google Docs and PowerPoints and cameras helped for other people that were telling you about their in-depth research. They could actually show you stuff with pictures and digitally show you things to help you understand better. So that they are not just telling you, but you can actually see it, and it helps you understand more and realize what is happening. (Student C, Post-Unit Interview)

The teacher commented how making the study and findings public by doing digitally-based presentations was another step in the learning process for the students. The teacher said that when the students prepare and deliver digital presentations in front of their peers "...they have to know what they are talking about" (Teacher Post-Unit Interview).

4.9. Summary of Key Findings

The findings from this unit indicate that there was a positive change in understanding ecosystems and human impacts on ecosystems. Students showed an increase in their ability to identify specific potential human impacts on urban natural areas that are heavily used for recreational purposes. Almost all students demonstrated a growth in understanding in one or more key concept areas outlined by the rubric we developed to assess student understanding of ecosystems and human impacts on ecosystems, particularly in the area of understanding biodiversity.

But is this enough? More specifically, did the study help them develop a more complete understanding of how to study ecosystems and make informed, evidence-based conclusions?

A closer look at some of the areas that did not improve or change over the course of the unit gave me some insight into where this unit of inquiry fell short. Also, the analysis of the unit based on the *Teaching Effectiveness Framework* and *Inquiry Task Rubric* indicated possibilities where more intentional unit design in particular areas might result in deeper student understanding. These key findings will be used in the concluding chapters of this thesis.

CHAPTER 5

Discussions and Conclusions

5.1 The importance of identifying learned and non-learned aspects of ecological understanding

5.1.1. Student learning of biodiversity and ecological integrity

According to the data analysis results presented in Chapter Four, students demonstrated growth from developing to elaborate understanding in many areas. The concept of biodiversity was well articulated by many students by the end of the unit. Students could (i) demonstrate knowledge of biodiversity being an important indicator of healthy ecosystems, (ii) articulate that plants and animals were important components of ecosystems; (iii) demonstrate understanding of the difference between native and non-native species and the potential impact of non-native species; and (iv) recognize the importance of balance in an ecosystem. Students also showed growth in their knowledge of potential human impacts on urban natural areas. These results were promising, as biodiversity and human impacts on ecosystems are the key concepts we emphasized in the unit and they seem to be understood by the students.

However, it was evident from the results of the analysis that students' understanding of ecological integrity, or the ability of an ecosystem to recover from change, was incomplete. Although students would use the words "disturbed", "changed" and "impacted by humans", some students seemed to treat any threat or disturbance to the environment equally; i.e. they did not distinguish the scale of a given threat's potential impact. At the end of their study, five students still mentioned that litter was a threat to ecosystems, despite the fact that litter was not discussed as an impact at any time during the study. The following conversation shows how students flip between small- and large-scale impacts as if they were of equal significance:

> RESPONDENT: Well I think that humans can help with ecosystems because if the ecosystem is naturally crashing or going down, the humans can do things to help it to stay up and running well. But the ecosystem couldn't do it on its own.
>
> INTERVIEWER: And how do you think humans have a negative or a bad impact on ecosystems?
>
> RESPONDENT: They can disrupt them and make major changes into them. And they can harm the earth with it. So with cement and stuff, putting it down. And noise and going through, it could change a lot of behavior of animals, and how they go to the plants and find food and everything about them, it could completely change a lot of that.
>
> INTERVIEWER: And why do you think humans impact ecosystems in the way that they do?
>
> RESPONDENT: I think sometimes because of the growing population they impact them, because they just want to keep growing out and out, because there is more people. And some people like to be in the trees and stuff, but they don't realize that they are impacting it. They just like being in that type of environment. (Student C, Post-Interview)

Student C seems to be at the developing stages of understanding that if an impact is sufficiently altering, the ecosystem will not recover, but flips back and forth between suggesting that urban sprawl *and* walking through the trees will impact an ecosystem with an implied equal magnitude. Although both actions *could* have an impact on ecosystems, the magnitude of each impact is vastly different. One person walking off trail is significantly different than thousands of people walking off trail.

Students also missed extrapolating out to see that at times, implementing a lesser impact might mitigate a larger impact. For instance, putting paved trails through a park can mitigate people walking off trail. There seems to be confusion as to what to do with the pieces of learned information and how to place the pieces within a broader conceptual framework of human impacts on ecosystems.

It was promising to see that students were using biodiversity as an indicator of ecosystem health and transferring this understanding to new contexts. However, despite having learned about the importance of diversity and using it as one possible indicator of ecosystem health, students had difficulty letting go of their notions of "green" and "death" as other possible indicators of ecosystem health. Many students lumped diversity with the student preconception of "green" as their indicators. Coding results often indicated that students considered more than one variable when assessing ecosystem health but sometimes one of the variables they used was not necessarily based on elaborate ecological reasoning, like considering "green" as an indication that the ecosystem was healthy. Biodiversity, invasive weeds, "green" and "death" (preconceptions of students), were the main lenses students used to assess the health of the new ecosystem images.

In a study conducted about students' understanding of stream ecology (Syslak, 2001), Grade Ten students listed "recycling of nutrients" and "how decomposers recycle nutrients in a stream ecosystem" (p. 82) as concepts they found hard to understand. It is interesting that in this Grade Seven classroom we see evidence of this same concept beginning to surface as one that students struggle with and interfering with their more complex understanding of ecosystems.

Students often described a lack of biodiversity as: "everything is the same". Although they seemed to understand that biodiversity was an important indicator of health, their understanding of biodiversity seemed to remain limited to looking for the amount of "sameness". I was uncertain how deeply the students understood why "sameness" could be a threat to an ecosystem. If I were to undertake a study like this again, I might articulate more specific levels of student understanding. These are the levels that more clearly articulate the progress from developing to more elaborate understanding: Level 1) considering "green" as the indication of ecosystem health, Level 2) still using "green" to determine health, but also seeing a lack of diversity ("everything is the same") as problematic with un-articulated reasons why it is problematic, Level 3) understanding that a lack of diversity in age and species means that the ecosystem is more vulnerable to disturbance and would have difficulty recovering from a threat, Level 4) understanding that biodiversity can appear different and is specific to the ecosystem (a rainforest is more diverse than a grassland) and understanding that an ecosystem's health is dependent on the ecosystem's specific diversity characteristics. These levels might be used to more clearly determine to what extent students understand biodiversity.

5.1.2. Student transfer of learning

Transfer of learning is extremely important in learning. In this study, I was curious to what extent students could take learned concepts (like biodiversity) and apply them to new real or hypothetical contexts. In the last category of "Transfer Across Contexts," two criterion progressed to an elaborate understanding and one of the criteria was left unchanged at the developing level for all students. Many students moved to an elaborate understanding the need to consider a variety of variables when assessing ecosystem health (TE2), and many students were able to transfer one key understanding (biodiversity) from one context to another (TE1), but students did not engage in the same types of studying approach that a conservation biologist would when approached with a problem related to ecosystem health; i.e. hypothesizing and considering experimentation (TE3). When shown an image of a different ecosystem, students did not ask questions or propose experimentation but immediately tried to come to a conclusion. This was most likely due to the way I asked the questions (having the coding rubric ahead of time might have changed the way I asked questions during the interviews), but I do find it curious that despite having just engaged in a lengthy field study to uncover whether or not a local area had been impacted, the students did not consider "I would design a field study" as a possible response to the questions asked of them.

Roseberry, Warren and Conant (1992) discovered that at first, students will not use scientific reasoning when asked to solve problems, but after a year immersed in a collaborative inquiry classroom where discourse is encouraged, students began to consider experimentation and hypothesis in their responses to tasks.

> Nevertheless, what is clear is that, whereas in September, the students had viewed their problem-based or personal-knowledge-based explanations as sufficient evidence to explain phenomena, in June they seemed to be developing some sense, if still incomplete, of the way in which conjecture and experimentation function in scientific inquiry. (p.90)

It seems that in this case, the students added biodiversity into their list of sufficient answers, but rarely did they push past this factual list to consider more deeply the ways in which a scientist might solve the problems posed to them. It must be emphasized again that the types of questions that students were asked during the interviews and on the concept maps may not have provided enough reason for these concepts to surface in the students' responses. Had we developed the coding rubric before the study began, we may have designed a more intentional series of questions specific to the rubric. I also wonder how the coding rubric would have influenced our task designs in the first place.

Additionally, the instructional design did not adequately consider how to assist students in making shifts in their deeply held beliefs regarding ecosystems and the study of ecosystems. For example, in the following conversation between the interviewer and a student, the student is asked how they would know if an ecosystem is healthy or not. The student-held idea that "a healthy ecosystem is green and an unhealthy ecosystem is dead" persists, even when reflecting back on their study. I wondered if the students see ecosystem health in two extremes, either "green and lush" (like a rainforest) that is healthy, or completely destroyed (like a recently clear cut forest) that is unhealthy. How do they determine health in ecosystems that are in the middle of these two extremes? In this case, the student begins to articulate that a healthy ecosystem is diverse, but when asked how he/she would study the health of an ecosystem, the student reverts back to the old belief:

RESPONDENT: I'd tell them that a healthy ecosystem would be diverse. So there'd be lots of plants. There would be a lot of living things. And there wouldn't be any pathways or … just, it wouldn't be disturbed.

INTERVIEWER: And how can you tell if an ecosystem is healthy? You've kind of answered that a little bit already, but what would you do to determine, or how could you tell if you came across a natural area, if it was a healthy ecosystem?

RESPONDENT: Well it probably wouldn't be dead. There wouldn't be a little people there. There wouldn't be benches or pathways, or garbage. So probably everything would be natural.

INTERVIEWER: And what do you mean when you say, 'Natural'?

RESPONDENT: Nothing has been disturbed. Everything is healthy, and there's no benches and stuff.

INTERVIEWER: Okay good. And how would you be able to tell – and you've kind of answered this – how would you be able to tell if the ecosystem is unhealthy?

RESPONDENT: If it is dead and been disturbed?
(Student D, Post-Unit Interview)

Continuing with the post-unit interview with Student D (quoted below), I had to probe more deeply to get the student to see beyond death as the only way to study the health of an ecosystem. This post-interview experience reflects the powerful utility of assisting students to make connections between what they learned:

INTERVIEWER: And let's say that you wanted to study an ecosystem to determine if it was healthier and healthy. What would you do?

RESPONDENT: Probably some of the tests that we did, that our class did.

INTERVIEWER: Can you describe some of the kind of testing that you did?

RESPONDENT: Uhh…. This is hard. I don't know.

INTERVIEWER: I think - so you kind of came across that ecosystem that made you zone in to test…

> RESPONDENT: Maybe like which plants – like how many plants that are dead. Yeah.
>
> INTERVIEWER: And what was the study that you guys did, your group again?
>
> RESPONDENT: Our test was how many, like how many, the number of plants around native species and invasive species.
>
> INTERVIEWER: And so what did you find out in your results?
>
> RESPONDENT: We found out that there are more plants around native species than invasive species.
>
> INTERVIEWER: Okay. So there is more diversity.
>
> RESPONDENT: Yeah.
>
> INTERVIEWER: And did you find around the invasive species that there were a lot of dead plants? Or did you find that there just wasn't as many diversity of plants?
>
> RESPONDENT: There were more. It depends. There were a couple of plants around it, but it just depends on the radius. If it's near the plant, then it is just grass and just dandelions.
>
> INTERVIEWER: And that was it.
>
> RESPONDENT: Yeah.
>
> INTERVIEWER: Whereas around the native species, what did you find?
>
> RESPONDENT: We found around trees and there were more plants around it. (Student D, Post-Unit Interview)

The results of the case study open three critical questions for future researchers to consider: (i) What are the Grade 7 instructional elements necessary to assist students in moving beyond a surface level understanding of diversity to a deeper understanding regarding how diversity is a critical component to determining the health of ecosystems? (ii) What instructional strategies might encourage students to consider experimentation as way to approach uncertainty in ecology? (iii) What critical instructional considerations of educational technology should be planned so that effective post-activity discussions (between students and between teacher and students) enable students to make stronger connections among things learned?

5.2. The importance of identifying specific criteria for assessment

This unit was designed so that all student work was conducted in collaborative groups and monopolized peer groups as one source of feedback. But was the structure of the collaborative groups used to the fullest potential to deepen student understanding? More specifically, was there enough structure placed within the collaborative groups so that the feedback was specific and intentional? Figure 1 shows one instance where groups were asked to provide feedback to each other. The photo shows a list of questions that were placed on the board for groups to provide feedback to one another.

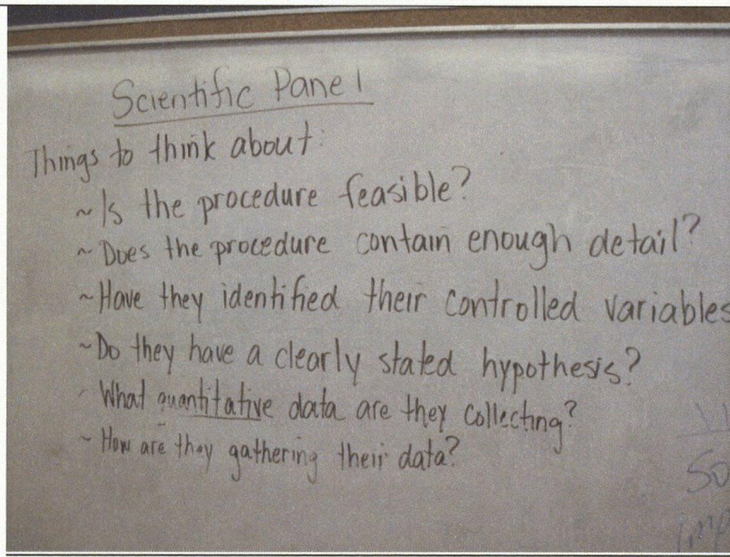

Figure 4. Guiding questions for peer feedback on field study planning.

Although this list of questions is engaging and gets to the heart of effective field study design, there are no assessment criteria accompanying each question. Therefore, the feedback that students would have given each other would not have been as specific as it could have been had the students used specific criteria to gauge the characteristics of the work and offer specific suggestions to guide the improvement of the work. The ineffectiveness of broad questions or ill-defined goals on student learning has been documented in the assessment literature:

> These levels of attainment we have termed "success criteria," and goals without clarity as to when and how a student (and teacher) would know they were successful are often too vague to serve the purpose of enhancing learning. (Hattie & Timperley, 2007, p. 88)

A field study rubric was used with the students, but it was only explored and utilized a few times during the study. Also, the rubric that the students used did not tackle the *design* and the *thinking* behind the development of an effective field study to monitor the health of an ecosystem, it only dealt with the execution and analysis of results from a field study. Had the students co-constructed a rubric that could have been used to assess their field study *design*, would their work have been more elaborate and would their habits of mind have developed more to more closely resemble those of a biologist working in the field? Had specific criteria for feedback (rather than just guiding questions) been used more frequently, and had the students become more familiar with the specific characteristics of the thinking involved in setting up effective ecosystem studies, would their resulting understandings have been more elaborate? I realize now that deepening student understanding of such a complex topic needs more than specific criteria from which to assess their progress; the importance of *time* for ideas to percolate within the group and intentional effective feedback that targets specific alternate conceptions and group assumptions is also essential. These ideas are summarized more completely in the next section.

5.3. The importance of providing enough time for ideas to percolate within group discussions.

I was interested to see if I could track how particular ideas or concepts progressed from developing to elaborate understanding through the group conversations and collaborative work. This proved to be harder than I first thought, as I was not able to record every single interaction, lesson, conversation and monitor the individual thinking of each student throughout the whole unit. The task was too monumental. I was able to collect the online collaborative document for each team, and this enabled me to observe a few instances of how ideas were taken up and how students developed deeper insights within the collaborative group structure.

Specifically, I noticed how the collaborative group structure enabled instances where repetitive questioning led to a shift in the group's thinking. In these instances one student first posed a reflective question. At first, the significance of the question might be ignored, and group discussion continued on another topic. During the discussion, the question seemed to float around for a bit as if suspended over the group, until its significance was noted and reinforced by another student (perhaps after they had time process the question more?). This led to a modification in the group's thinking or work. I was intrigued by one example from the Google Doc where the repetition of an idea by a few students eventually led to a shift in thinking by the group. I also observed the same thing occurring in small group discussions. When the same idea kept reappearing in their conversations or collaborative document, eventually the group took notice and began to internalize the idea more completely. Had that same idea surfaced only once in discussion, would the students have abandoned the idea and not paid as much attention to it? This highlighted for me the importance of providing extensive *time* for the groups to discuss: Because the group had sufficient time, the question resurfaced with more clarity. For example, the following collaboration from the Google Doc shows an idea that is repeatedly questioned by the peer feedback group. The online conversation began with one student editor asking:

> The changes seem like they will help out the testing a lot. It seems like you will still have [troubles] finding a good site without a bird feeder, though. What will you do if you can't find any? (Google Doc, Group 2)

Later, another student editor builds on this thinking by asking:

> What will your group do if no squirrels come? Do you think your test is accurate if only a couple of squirrels come? (Google Doc, Group 2)

Further on, yet another student editor asks:

> What if the same squirrel comes a lot? (Google Doc, Group 2)

The feedback group seemed to be digging deeply into the importance of the site selection for the study. The group paid attention to the repeated questioning, and in their analysis of the results made reference to the issues brought forward by the peer reviewers.

In another instance, a very interesting question was brought up by a peer reviewer but was not taken up by other students. In this instance, the student asked the group to consider their hypothesis more deeply:

> You have good ideas for your quantitative measurements. Your hypothesis makes sense, but you may want to say why you think that there will be more plants around Saskatoon bush. An example could be: I think that there will be more plants around a Saskatoon bush because…. You say that the caragana can grow in poor soil, and that I [*sic*] messes up

> the eco system, so you clearly state that caragana is a bad plant for this eco system. (Google Doc, Group 1)

During the scientific panel discussion the teacher asked a similar question. The group did not take up the question as deeply in this particular case. The group did address it superficially, but not as intentionally as the line of questioning suggested by Student C. Would the group have taken up the question more deeply had they been asked on more occasions? If more intentional criteria had been set to guide the formulation of concise and specific hypotheses, would the group have spent more time doing so? Did the group ignore this line of questioning as too challenging? If so, how can collaborative groups be encouraged to take on increasingly challenging work? Were they held accountable to the feedback they received? Did the group think that they had sufficiently addressed the question?

This event has implications for classroom assessment procedures and group tracking. How do teachers monitor groups to ensure that deeper levels of questioning are addressed and not overlooked by group members? How do we effectively use feedback loops to ensure that deeper questions are not lost? The teacher made a reflective comment on the nature of teaching and the amount of legwork that needs to be done to stay on top of the groups in this investigation:

> I think it depends on who is providing that feedback. Because there are kids that will just perpetuate misconceptions to each other. You need to be careful. And it takes a high degree of monitoring. I probably wasn't monitoring as closely as I should have been to catch all of those. But I

> think that they could kind of self-perpetuate misconceptions potentially, if someone doesn't interject and say, "Actually why don't you think about this." And I think that happened orally when they were doing their practice presentations. And even after the presentations, there were kids who were asking questions that were looking at some of those misconceptions. (Teacher, Post-Unit Interview)

Despite the fact that in some cases questions that might have pushed the group to a deeper level of understanding were not taken up, the level of thinking involved in asking the question shows that peer-feedback loops work in the other direction as well. A group might not have monopolized on an idea suggested through peer review, but the process of peer review is both beneficial for the team receiving the feedback and the people delivering the feedback. The peer reviewers analyzing another team's work also achieved new insights. It is difficult to track how the insights may then be internalized in their own work, but it does represent a deepening of understanding as a whole. From this perspective, the collective understanding of the whole class likely grows despite the group not adequately addressing one question.

5.4. Online collaborative environments are one possible way that teachers can be "everywhere at once."

Having analyzed the unit design through the different frameworks described in this study, it became clear that the unit lacked authentic use of technology in the field and that the technology could have been leveraged to include collaboration with others beyond the school. The more intentional involvement of outside expertise in the work of the students as it progressed might have also deepened student understanding. One powerful element of the online work was students' and teacher's ability to access work at any time in any place. One teacher cannot be a part of every group discussion to monitor how assumptions may or may not be addressed by the group, but the online space enables the teacher to have an inside look at the group's current thinking. This can be leveraged later on to take up pre-understandings either as whole class discussions or by questioning specific groups to help move them to the new levels of understanding.

However more reflection could have taken in the unit design as to whether or not the online environment we chose for the students to collaborate within was the optimal environment for the improvement of their ideas. Scardamalia and Bereiter (2003) described very specifically the types of spaces that encourage knowledge building. They state that a knowledge-building environment (KBE) is: "Any environment (virtual or otherwise) that enhances collaborative efforts to create and continually improve ideas." (p.2) But they go on to describe this as being a minimum requirement for an effective knowledge building environment, and that:

> Among the characteristics of an effective KBE are supports for the formulation of knowledge problems, for preserving ideas and making them accessible as objects of inquiry, for dialogue that is democratic and favorable to idea diversity, for constructive criticism and analysis, for organizing ideas into larger wholes, and for dealing with recognized gaps and shortcomings of ideas. (p.2)

I wonder if we had more carefully and intentionally chosen the environment that students would collaborate within would a different online environment, more in line with what Scardamalia and Bereiter described above, have led to deeper insights and more complex learning from the students?

5.5. A field study is not enough

At the end of this study, I felt that just doing a field study to develop students' understanding of ecosystems was not enough; that it was also important to understand students' alternate conceptions and specifically and intentionally open up spaces that enable students to develop more complex understandings. This was reinforced when the teacher commented how this study did not push students as deeply as it might have into the space of elaborate ecological understanding:

> I have a feeling some of the kids were coming away thinking that the [natural area] is not healthy because of their localized study. So as, I think they can make generalizations very easily and say, because there were birdfeeders, it is not a healthy ecosystem. When in reality that is a very small component of the ecosystem. That probably isn't having as negative a consequence as they think, based on their study.
>
> So there were like, "These are the pathways, yes. They are contributing to erosion and invasive species, but in the grand picture of that entire ecosystem, it is not really affecting wildlife movement." It is not.... Like

> I think they were really quick to jump to… because we said it is something that was negative, that this is an unhealthy ecosystem. (Teacher Post-Unit Interview)

The teacher's comments remind me of Orr's (1994) worry that we teach students to think in boxes:

> The great ecological issues of our time have to do in one way or another with our failure to see things in their entirety. That failure occurs when minds are taught to think in boxes and not taught to transcend those boxes or to question overly much how they fit with other boxes. We educate lots of in-the-box thinkers who perform within their various specialties rather like a dog kept in the yard by an electronic barrier. And there is a connection between knowledge organized in boxes, minds that stay in those boxes, and degraded ecologies and global imbalances. The situation is tragic in that many suspect where all if this is leading but believe themselves powerless to alter it. (p. 95)

I worry that in falling short of pushing students to more elaborate ecological understanding, this study does contribute to the problem of in-the-box thinkers. I think there was more need for intentional teaching that pulled the students out of their isolated study and into the space of carefully considering how each localized study was linked to the other. Leach, Konicek and Shapiro (1992) also found that isolated focus on one topic does not enable students to link the focused study to larger concepts. In their study of student understanding of decay, they said:

> In addition, no pupils linked their specific knowledge about photosynthesis, feeding, respiration and decay into a concept of a matter cycle. Observation of teaching suggested that this was to some extent due to teaching of each process in isolation with very little mention of the role of the decay process. (p.16)

The rubric that we developed to analyze student understanding of ecosystems (Table 3) was established only after the study was complete. How would our unit design have changed if we had used this rubric to help design the tasks? Would our study have more intentionally addressed key ecological concepts? How might we have more seriously considered students' prior understandings in our unit design?

I realize now how quickly I jumped into the design space without stopping to carefully and seriously assess where the students were at so that we could specifically target their prior understandings within the unit. I also realize that this particular group of students had different prior understandings than what had been documented as typical in the research literature. Therefore, careful assessment of students' prior understandings needs to be done on a class-to-class before designing a unit of inquiry. With that said, this and other studies that identify common alternate conceptions may contribute to other teachers' understanding of possible pre-understandings students may have about ecosystems.

I also considered how previous curricula might have influenced students' understanding as they first approached this study. Although the majority of students had heard the word "ecosystem" before they started the unit, their understanding of the concept was rather limited. I was particularly interested in students' repeated use of the idea that *green* was an indication of ecosystem health. In this case, the student begins to use biodiversity as a lens to interpret the image, but this is intertwined with the student conception of *green* used to interpret a picture of a lush forest:

> INTERVIEWER: What about Number 3?
>
> RESPONDENT: It looks healthy, I guess it is green. But it doesn't seem like there are a lot of different species, it is just the same tree. I don't know. But it looks pretty alive and healthy.
> (Student E, Post-Unit Interview transcript, p. 10)

Also, many students emphasized litter as an indication of an unhealthy ecosystem. Here's a typical example:

> As you can see in my drawing the [natural area] is mostly healthy. There is some garbage and illegal trails but there is a lot of different animals and plants.
>
> (Student F, Post-Unit Concept Map)

Although this student seems to be considering more of a holistic perspective to determine the health of the ecosystem, they still feel compelled to mention litter in their analysis.

Although students did often mention biodiversity in the post-unit data, the notions of "greenness" and litter were prevalent during both the pre- and post-unit interviews and in the concept maps. The guest speaker and the classroom teacher discussed neither of these concepts, so they must be ones that students have carried forth despite their experiences in this unit. The persistence of student ideas despite teaching otherwise has been well documented in the research literature (Bransford et al., 2000; Perkins & Grotzer, 2000). After all, both of these ideas make sense. In Grade 4, students study and grow plants as a major science unit. In a house or seasonal garden, a green plant is usually healthier than the same type of plant that is not green. If a plant is not getting what it needs to survive in an ecosystem, it will wither and die. They also study waste in Grade Four. After studying this unit, perhaps it can be expected that students think of waste in terms of excessive amounts of garbage or as toxic waste, both of which can have devastating impacts on ecosystems. In Grade Six, students study forest ecosystems. In this unit, students learn about large-scale impacts like deforestation and clear cutting and that these can lead to a loss of ecological integrity (i.e. the ability for the ecosystem to recover). But how do students bring forward these understandings and apply them to new situations to determine the health of an ecosystem? What is missing from the students' ecological conceptual framework that might enable them to see them more in their entirety? Magntorn and Hellden (2007) said that: "Decomposition seems to be a linchpin concept helping the students to recognize the cyclical processes in ecosystems." (p.91). Was the student's lack of deep understanding of the cycling of matter in ecosystems interfering with their ability to interpret the ecosystems?

When looking more broadly at ecosystems, plants in ecosystems that are brown or "dead-looking" are not necessarily an indicator of an *entire* unhealthy ecosystem.

Seasonal changes in ecosystems, particularly northern ecosystems such as the ones these students live in (most students grew up in the prairies or foothills), have periods of plant dormancy in the winter with rejuvenation in the spring. Lack of green is not always an indication of poor health. A dead tree is not necessarily an indication that the whole ecosystem is in peril. Similarly, a gum wrapper or pop can in a natural area is not necessarily an indication that the *entire* ecosystem is in peril. Again, the students seemed to lack an understanding of scale when considering the larger system.

Taking my analysis of green as an indication of ecosystem health a few steps further, images of destroyed ecosystems (e.g. a clear-cut) do show a lack of green. But a very green, manicured lawn is also unhealthy in that it requires fertilizer, remains susceptible to invasive weeds and pests, and is dependent on watering and re-seeding to survive from season to season. The emphasis of biodiversity as the indicator of health was the main focus of this unit, so why was the idea of green also so persistent?

What remains puzzling to me within the data is that most of the students assessed the image of the manicured lawn as "healthy" during the pre-unit interview. In the post-unit interview, most students assessed the lawn as "unhealthy", but no students used a lack of diversity as their reasoning for it being unhealthy. The students said things like, "it looks fake" and "it doesn't look natural" but their reasoning behind the lawn being unhealthy did not include biodiversity. In contrast to this, when students assessed images of a forest and grassland system, they did use words like "it doesn't look to be very diverse" and "all the same species" in their reasoning, but often times their reasoning was also justified with reference to the appearance of things being dead or alive. Within the same sentence, students would indicate that the plants "looked healthy" even though they also indicated that "they're all the same". They also used diversity and an indicator, with the preconceived notion of death as an indicator as well. For example, Student B says when looking at a picture of a grassland:

> I think it is unhealthy. It looks like it is all the same plant. They kind of look like they're half dead.
>
> (Post-Unit Interview, p.13 of transcript)

The students seem to flip back and forth from considering the individual plant as the indication of ecosystem health, and then considering the whole system when reasoning with biodiversity. I took the student preconceptions of "death" and "green" a bit further in my own analysis: Is a forest healthy in the winter, when it appears "dead"? Is a forest less likely to survive threats in the winter versus the summer? Are periods of dormancy during the winter a more vulnerable time for ecosystems? Are students using lush rainforests as their unconscious indicators of healthy ecosystems? If so, why would Albertan students be influenced in this way? How much intuitive understanding do students have of their local areas? Do they understand how local plant species grow and change throughout the year? Are they aware of how these plants fit into the larger ecosystems? How much have they internalized death and decay as a natural and healthy part of ecosystems, essential to nutrient cycling within that system? These questions might lead to interesting investigations, but was not the intention of the field study under investigation. However, I wonder had we introduced these hypothetical questions at various points during the field study if students may have gained a deeper understanding of human impacts on ecosystems? Just by asking these probing questions, without necessarily expecting a firm solution to the question, would students have deepened their own thinking in relation to the ecosystems they were studying?

Magthorn and Hellden (2007) suggested that is a combination of developing students intuitive and personal connection to local natural ecosystems and intentional teaching of the processes and core concepts of ecology that lead to a deeper student understanding:

> Could the naturalists read nature or are the "molecular spectacles" a prerequisite for this ability? We believe it is a combination of the two. [Realising] the importance of plants for producing sugar and oxygen is important for reading nature, but without the [behavioural] aspects on molecular level the distinction between linear flow of energy through the ecosystem and the cycling of particulate matter is very difficult to make. An alternative is to build a foundation for understanding by focusing on concepts for which students have intuitive ideas that are more compatible with expert proposition, which can anchor the learning of material that is more difficult. (p.95)

In this field study, had we used the experiences students had at the natural area with more intentional and specific teaching of the processes that occur in ecosystems when reflecting on their personal experiences, would the students have come to deeper understandings?

Somehow in the student's exposure to nature-based instruction in previous years, it seems the isolated plant overshadows the entire ecosystem. Could this be because the students' lived experience is so connected to their lawn and garden, where individual plant health is the main focus? When students go to natural areas for recreation, do they consider the health of the area? How deeply do they (and we) differentiate between "natural" and "non-natural" landscapes? I understand the rationale behind students' thinking, but the results of this study indicate that there is a need for more intentional teaching about *entire* ecosystems and a need for students to engage more deeply in considering the complexity of ecosystems and the interrelationships within them. In essence, a field study that does not recognize these complexities is not enough.

5.7. Possible Entry Points

A quick glance back over the Alberta Program of Studies (1996) shows many entry points for students to uncover key pieces of information that could give them deeper insights into assessing ecosystem health. Interactions, habitats, pond studies, forest studies, food chains, impact of waste, and human responsibility for caring for the environment are just some of the objectives mentioned in previous grade's science curricula that would serve as building blocks for the Grade 7 year. I wonder if intentionally taking up more of the big ideas related to ecology would help students transfer more of the understandings to new contexts. I wonder, too, how deep were the students understanding of the previous curriculum objectives, even within the specified contexts? How compartmentalized were the units that they explored in previous years? Are students capable of taking these understandings and transferring the concepts when approached with new problems related to the environment? Can students pull big ideas from one natural context (like a wetland study) and apply them to the next context they are faced with?

5.8. The importance of leaving space in our task designs for spontaneous but deep learning to occur.

Reflecting on my own experiences as a parent when I could see my children making deeper connections to the natural world around them than I would have initially predicted, I am intrigued by son's ponderings over a winter snowstorm that was happening outside. He started articulating his beliefs about why the storm was hitting the city and where it was coming from, and he just *had* to express his idea. He went into quite an elaborate and animated explanation of how he felt the earth was spinning and the storm clouds (in space) were waiting for the earth to spin into them. Then, according to his theory, it would start to snow over the city. His theory about weather patterns was interesting in itself, but I was also captured by his *need* to express this idea that so excited him. He had to get the idea out in the open and share it. His passion for his idea was contagious, and despite trying to prepare supper for the family, I felt compelled to stop and listen. My son's investment in his discovery reminded me of the term "Intellectual Engagement" used to describe similar situations that occur in classroom settings. Intellectual engagement has been defined as:

> A serious emotional and cognitive investment in learning, using higher-order thinking skills (such as analysis and evaluation) to increase understanding, solve complex problems, or construct new knowledge. (Willms, Friesen & Milton, 2009, p. 7)

My son was deeply invested, emotionally and cognitively, in his weather theory. He did not spontaneously come up with ways to test his theory or to otherwise move forward from his initial idea, but had we had the time to invest more into this cognitive space, we could have begun an interesting exploration that I'm sure would have further immersed him in his ideas.

In the classroom that I observed and investigated, I believe we asked the students to engage in worthwhile tasks. They engaged in authentic work in conservation biology. They spoke and conversed with experts in the field and collaborated with each other to develop their studies, to synthesize and analyze their data and to come to evidence-based conclusions. They reported their work back to the biologists who worked in the natural area under investigation. It seemed that the tasks assigned to the students had all the makings of a good inquiry project. So why did their work, at times, not feel *deep enough*?

When confronted with a new situation within the designed task, there should be enough flexibility within the task design for students to explore new possibilities that surface within the structure presented. In other words, the task needs *liberating constraints*:

> Well crafted learning activities are one that maintain a balance between enough organization to orient students' actions and sufficient openness to allow for the varieties of experience, ability, and interest that are represented in any classroom. That is, learning activities must simultaneously limit and enable possibilities. (Davis, Sumara & Luce-Kapler, 2000, p. 87)

The ways student's ideas about ecology and human impacts on the environment are taken up by the teacher in the classroom could have a dramatic impact on how the students internalize their understandings. To be ecologically literate, a person should be able to consider how their actions impact the environment. According to Reading (2005):

> Simply being aware of an issue does not necessarily lead to any positive action that assists in solving concerns. Environmentally literate people demonstrate an ability to convert awareness into issues resolution and life-long positive action that in turn leads to greater knowledge and understanding. (p. 14)

Encouraging students to enter into spaces of deep exploration of fundamental concepts is easier said than done. When I started looking more closely at the data collected for this study, I noticed trends in the types of conversations the students were having with each other and in their groups. The conversations were mostly procedurally based, with a few moments of deeper insight. Student C's post-unit interview echoed the inkling that I had that the investigation wasn't pushing the students as deeply as I thought it might:

> It was just kind of advice about maybe make your study longer, or pick a better area. Nothing really had a huge impact on our study, but it just helped it be a bit more accurate.

Why was there so little impact? What could we have done to create a classroom environment where the cognitive investment occurred more often and there were more instances of profound discussions amongst the students?

Reflecting in this way, I have often needed to remind myself of the intent of the field study. The major emphasis of the unit was to engage the students in developing a test where they could compare an impacted to a non-impacted site in the natural area. After their test, they would pose recommendations to reduce the effects of the human impact. They would be using these studies to assess, in the bigger picture, the health of the natural area. Much of their work had to do with the effective design of their field study, which resulted in more procedural-based discussions. Was this unit design the best one to accomplish our goals of an elaborate understanding of ecosystems? Once again, I felt that the field study was not enough to probe the students understanding to deep enough levels.

The fact that the students spent the majority of their collaborative time discussing the their experimental procedures and designing fair tests makes sense. That is what the task design forced them to accomplish. The intention to drive the students deeper into seeing the ecosystem and its processes as a whole needed to be teased out more in the learning design. This was lacking from the inquiry design, and it did not emerge naturally from the discussions and collaborative work.

Magnthorn and Hellden (2007) specifically addressed students' ability to generalize understandings of ecosystems from one ecosystem to another. They described this as a student's ability to "read nature":

> This literacy has to do with an ability to recognize organisms and relate them to material cycling and energy flow in the specific habitat that is to be read. It has to do with authenticity where the natural world that we face outside is the book to be read and the tools we have are our experiences from previous learning experiences both indoors and outdoors. (p. 69)

Reading (2005) described 11 abilities of an environmentally literate person. I was immediately drawn to how this study addressed the first item on his list: "distinguish the planetary health from any projected view" (p.11). More specifically:

> Through personal connections with natural environments that feature hands-on direct interaction, environmentally literate people are able to distinguish between projected images of a beautiful and seemingly healthy planet from the reality of the relative health of the earth. (p. 11)

Reading's comment is poignant in emphasizing the ability to think critically about the images we see of the planet and seek deeper understanding of how human actions could be negatively impacting ecosystems and natural spaces. On the flip side, it seems that students have no real intuitive understanding of healthy versus unhealthy landscapes. Their personal connections have not left them with a lens from which to assess the health of an ecosystem, and so despite adding biodiversity to some of their assessments, they still sometimes fall back on what their previous lenses have given them: litter and green leaves. Deeper understanding, like an understanding of the importance of biodiversity, was foreign to them at the start of the unit. Students mentioned ideas that demonstrated a growing awareness of its significance but their understanding was not necessarily intuitive.

Could Orr (1994) be correct in his assumption that our traditionally activity-based, compartmentalized methods of education have led students to miss out on developing deeper understandings of ecosystems, so much so that despite a curriculum rich with key concepts leading to a deeper understanding of ecosystems, students still have no intuitive sense of the health of the natural spaces in their own backyards? Why did five of seven prairie students still use green as an indicator of the health of an ecosystem? I believe that many of us have a deep disconnection from the natural world that surrounds us, so much so that unraveling the layers of misunderstandings and lack of awareness that we have of ecosystems is very complex. It is hard to know where even to begin with my own understanding of ecosystems, let alone find ways to deepen students' understanding. But somehow, we have to push deeper:

> Well we could probably plant some more trees and stuff. We may like, if the weather is not raining or anything, we'd probably just water the plants. (Student D, Post-Unit interview)

5.9. Does forcing students to come to a conclusion in an ecosystem study create more confusion?

> I cannot help but wondering if an educational system that promotes black or white and yes or no answers might be affecting how reward systems develop in our youth. If the fundamental thrust of education is "being correct" rather than acquiring a thoughtful awareness of ambiguities, inconsistencies, and underlying paradoxes, it is easy to see how the brain reward systems might be molded to prefer certainty over open-mindedness. To the extend that doubt is less emphasized, there will be far more risk in asking tough questions. Conversely, we, like rats rewarded for pressing the bar will stick with the tried and true responses. (Burton, 2008, p. 99)

Part of the difficulty I had in forming conclusions for this study was dealing with the complexity of the topic I had chosen. I tried to synthesize the data into more manageable pieces, but everything was connected, and it was hard to put a box around sections of the data. This was frustrating for me, as I felt that all the data needed to be seen as a whole. I wondered if the field study also did the same thing for the students. They were each given a small study to focus on within a larger ecosystem. From their small study, they were expected to form a conclusion based on their data. But in forcing the students to come to conclusions, were we stifling their potential to see the larger picture? In our push to encourage students to use evidence to come up with “the” answer instead of requiring them to articulate a series of uncertainties, wonderings, new questions and next studies, have we forced them to see the natural world being less complex than it actually is? What is the impact of questions that require students to "come up with an answer" instead of “sitting with uncertainty”? Sobel (1998) said that when we force students to take on problems they are not ready for, they develop oversimplified solutions:

> This kind of balanced understanding is somewhat the ken of normal third graders, so instead we settle for easy dichotomies. Ocelots are good and bulldozers are bad. This doesn't mean that we should stonewall children when they inquire about rainforests. Rather, we can answer their questions reassuringly and make our curriculum decisions based on accessible content and realizable goals. (p.29)

Human impacts on ecosystems are complex concepts for all of us to understand. Unfortunately, our actions are almost always portrayed in black and white rules that I believe become difficult for children to navigate, especially when space is not opened up for children to start exploring the places where the “rules” become ill-defined and less polarized. For example, we are all taught from a very early age not to litter. What about apple cores? Won’t they decompose? If every city dweller threw their apple core on the ground, would it create a problem? Would they eventually decompose, or are the conditions in a city not ideal for decomposition? Is composting better? What if a compost bin is not available? If we were in an urban park, should we throw our apple cores in the garbage or into the trees? Would that introduce seeds into the area that are non-native? But aren't we contributing to the landfill if we place our cores in the garbage? It seems that the rules we place around appropriate environmental behaviors are not as "right" and "wrong" as we make them out to be when we tell children.

As well as receiving conflicting messages about appropriate environmental behaviors, students' (and our) lack of deep understanding of the natural processes of ecosystems makes it difficult for all of us to discern the "grey" areas of human impacts on the natural world. We see images of large-scale damage in the media when massive ecological disasters happen. But our ability to know when an ecosystem is unhealthy and when it is healthy is limited by our lack of deeper understanding of the ecosystem and the processes that sustain it.

When I think back to the original focusing question we gave the students, "Is this ecosystem changed?" it now seems so complex for their small isolated study. Not that this question was a poorly designed; in fact, I think it was a great focusing question. But I question more our handling of its complexity with the students. We should have clearly and intentionally discussed with them that their study could only answer a small question within a larger more complex system. That the limitations of their field study could not give them a certain answer to the larger and more complex question. Perhaps after a more in depth discussion of the limitations of the results of their study the students would have gained a deeper understanding of the limitations of ecological studies in general: that we can only solve small pieces of much larger more complex puzzle, and that with all those pieces together we come to a deeper and more complete understanding of a complex whole. This would be a great beginning to developing their ecological literacy.

CHAPTER 6

Recommendations

6.1. Identifying student alternate conceptions and making room for complex insights.

The importance of understanding students' alternate conceptions and specifically opening up spaces that allow room to develop complex insights and pose new questions is essential for students' ongoing pursuit of understanding human impacts on the natural world.

Identifying student alternate conceptions and beliefs that persisted throughout this unit was very time consuming. Classroom teachers do not have the time to conduct student interviews, closely analyze data and look for trends. However, for students to develop more complex understandings of ecosystems, the importance of identifying student alternate conceptions cannot be underemphasized. Despite a rich and engaging field study, the students in this study held on to alternate conceptions about healthy ecosystems despite intentional teaching regarding the larger concepts of the unit (like biodiversity). Effectively designed units need to begin with an assessment that is specifically designed to identify the beliefs and alternate conceptions students are bringing forward into the classroom. Finding questions that adequately tease out underlying beliefs is at times difficult, but with careful consideration and a few short open-ended questions, classroom teachers can at least begin to identify key alternate conceptions around which they can then design their unit.

It is important to see classroom teaching as a *research* endeavour. More intentional work needs to be done to unite the two fields. Effective classroom teaching is inseparable from research and reflection, and especially with more complex topics like ecosystems, the importance of the teacher as reflective practitioner and as a researcher into student understanding is essential to helping students develop deeper understanding. Effective unit designs need to consider students' prior understandings in order to be effective. Otherwise, even authentic and challenging tasks designed for students might "miss the mark" when it comes to overcoming prior beliefs. Leach, Konicek and Shapiro (1992) took this idea one step further and made the link between classroom talk and teachers as researchers:

> In addition to important implications for research, in the interviewing of students, this suggests that teacher approaches which enhance students' opportunities to express their ideas freely on an ongoing basis will allow them to demonstrate their thinking and patterns in thinking to teachers who can become researchers of student thought in their own classrooms. Ultimately, students become clearer about their own thoughts and thought processes. (p.20)

6.2. Effective collaborative environments need sufficient time for ideas to form.

Effective student collaborative environments that deepen student understanding need sufficient time for ideas to form, specific criteria to guide the group, and collaborative tasks that are intentionally designed with deep student understanding in mind.

In order to monopolize on the great potential that collaborative groups provide for deepening student understanding, three elements need to carefully considered by the teacher to ensure that the collaborative groupings are successful: 1) clear criteria need to be established to ensure that the group can monitor its progress (Hattie & Timperley, 2007), 2) sufficient amount of time needs to be given to the group to collaborate so that new ideas have time to develop, and 3) collaborative tasks must be designed to specifically target relevant pre-understandings and move the group forward in developing more complex understandings. During the collaborative process, the teacher needs to be able to oversee student understanding as it develops and offer specific feedback (including challenging specific group misconceptions) to help move the group forward. Online collaborative tools are particularly helpful for the teacher to be able to monitor group dialogue and progress, especially when working with large groups of students. Online collaborative tools are essential for teachers to be able to effectively track, research and develop more intentional lessons that target student understandings. Teachers must continually shift back and forth from providing intentional and specific feedback to small groups, to intentionally bringing forward specific questions and challenging ideas to the larger class for analysis and discussion. The more times the teacher can bring forward ideas and questions that challenge students' ideas, the deeper their understanding will become. The above-mentioned points are summarized in Figure 2:

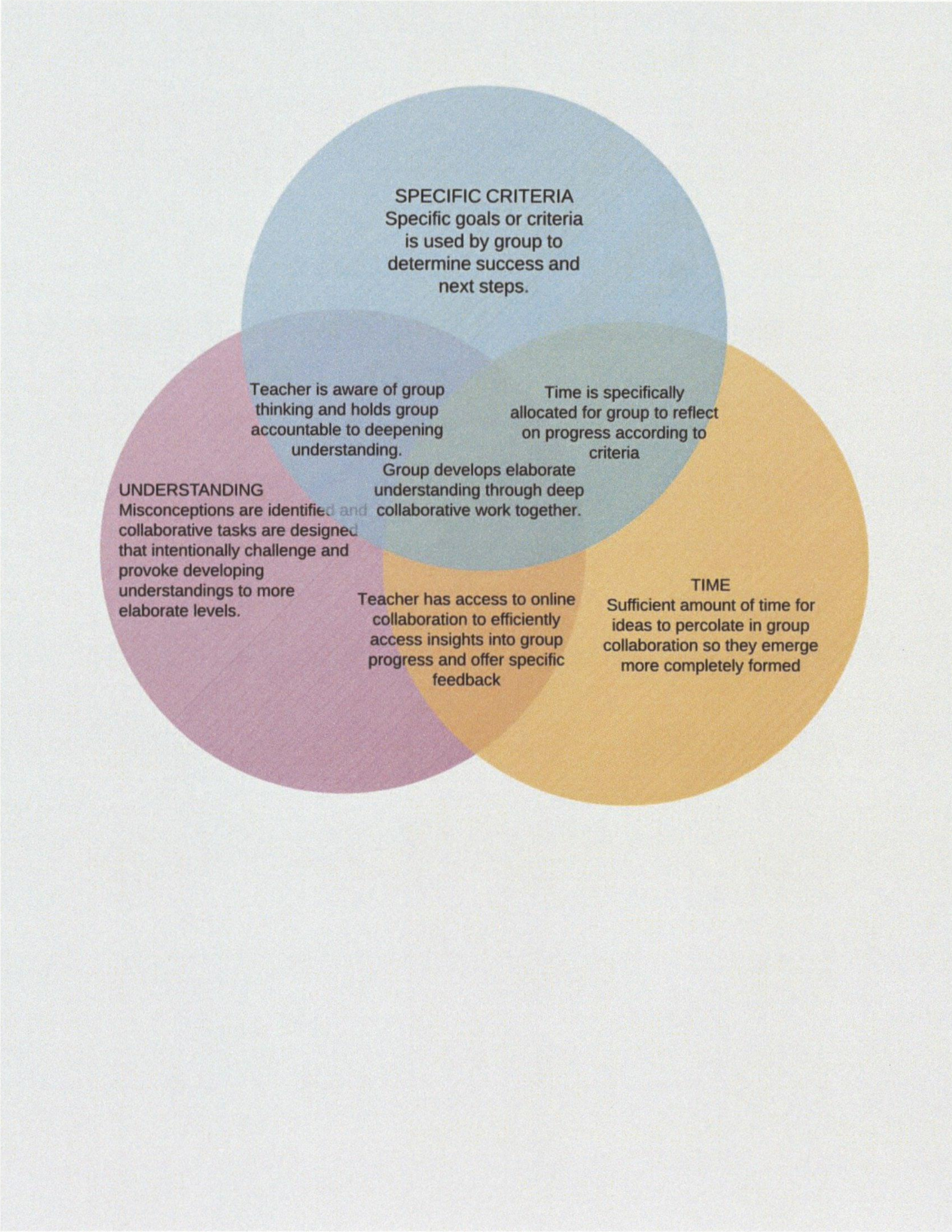

Figure 5. Effective collaborative environments that encourage deep understanding.

6.3. The importance of developing a more intuitive understandings of ecosystems in the early years through nature-based experiences and deep discussion.

The responsibility for developing a deeper understanding of ecosystems is not limited to Grade 7. Every elementary grade from the Alberta Program of Studies has a unit that focuses on ecology. Each of these units need to be addressed with the intention of deepening student understanding of ecosystems.

For example, when exploring the topic of seasons in Grade 1, students might be asked: "Does a forest die in the winter?", "Are trees still alive in the winter?" and "Why do they grow back in the spring?" From these bigger questions, students might begin to develop the deeper understanding that ecosystems change over time and from season to season, and develop a more intuitive understanding of a whole system. Students could also spend time in local natural areas observing the area at various times of the year. These observations should occur frequently and with much discussion about what the students are noticing and the significance of their observations to understanding the seasons and how ecosystems change.

Careful attention needs to be paid to provide opportunities for young children to develop an understanding of various images of what ecosystems can look like. They need to discuss the key concepts that are developed within various local environments. In addition, careful attention needs to be taken to address students' ability to transfer their understandings to new environments. Focusing on the big ideas in relation to ecosystems in early years and designing units with these big ideas might further students understanding of ecosystems from the earlier years and lead to more complex understandings in later grades.

REFERENCES

Alberta Learning, (2003- Updated 2009). *Science 7-8-9.* Retrieved June 2, 2011 from http://education.alberta.ca/media/654829/sci7to9.pdf.

Azevedo, R., Winters, F., & Moos, D. (2004). Can Students Collaboratively Use Hypermedia to Learn Science? The Dynamics of Self-And Other-Regulatory Processes in an Ecology Classroom. In *Journal of Educational Computing Research, 31*(3), 215-245.

Berry, W. (2000b). *Life is a miracle: An essay against modern superstition.* New York: Counterpoint.

Bloom, J. (1998). *Creating a Classroom Community of Young Scientstis: A Desktop Companion.* Toronto, ON: Irwin Publishing.

Bodzin, A. (2008). Integrating Instructional Technologies in a Local Watershed Investigation with Urban Elementary Learners. In *Journal of Environmental Education,* 39(2), 47-58.

Bransford, J., Brown, A., Cocking, R., & National Academy of Sciences - National Research Council, W. (2000). *How People Learn: Brain, Mind, Experience, and School. Expanded Edition.* Washington, DC: National Academy Press.

Breuleux, A. (2001). Imagining the Present, Interpreting the Possible, Cultivating the Future: Technology and the Renewal of Teaching and Learning. In *Education Canada, 41*(3), 12-15.

Burniske, R. (2005). Sharing the Sacred Fire: Integrating Educational Technology without Annihilating Nature. In *TechTrends: Linking Research & Practice to Improve Learning, 49*(6), 50-52.

Burniske, R. & Monke, L. (2001). *Breaking Down the Digital Walls: Learning to Teach in a Post-Modem World.* Albany, NY: State University of New York. pp.18-29.

Burton, R. A. (2008). *On being certain: Believing you are right even when you're not.* New York: St. Martin's Griffin.

Carey, S., Educational Technology Center, C., & Others, A. (1988). An Experiment Is When You Try It and See if It Works: A Study of Junior High School Students' Understanding of the Construction of Scientific Knowledge.

Cherrett, J.M. (1989). Key Concepts: The results of a survey of our member's opinions. In J.M. Cherrett (Ed.), Ecological Concepts. (pp.1-16). Oxford: Blackwell Scientific Publications.

Creswell, J.W. (2007). *Qualitative Inquiry & Research Design: Choosing Among Five Approaches.* Thousand Oaks, CA: Sage Publications.

Driver, R., & Others, A. (1994). Constructing Scientific Knowledge in the Classroom. In *Educational Researcher*, 23(7), 5-12.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the Norms of Scientific Argumentation in Classrooms. In *Science Education, 84(3)*, 287-312.

Dunbar, K. (1997). How scientists think: Online creativity and conceptual change in science. In T.B. Ward, S.M. Smith, & S.Vaid (Eds.) *Conceptual structures and processes: Emergence, discovery and Change*. Washington DC: APA Press.

Dunleavy, J., & Milton, P. (2009). *What Did You Do In School Today?: Exploring the Concept of Student Engagement and its Implications for Teaching and Learning in Canda.* Retrieved February 18, 2011 from http://www.cea-ace.ca/sites/default/files/cea-2009-wdydist-concept.pdf

Evagorou, M., & Avraamidou, L. (2008). Technology in Support of Argument Construction in School Science. In *Educational Media International*, 45(1), 33-45.

Friesen, S. (2009). *Teaching Effectiveness Framework.* Retrieved January 25, 2010 from http://www.cea-ace.ca/sites/default/files/cea-2009-wdydist-teaching.pdf.

Galileo Education Network. (2008). *Assessing Critical Thinking.* Retrieved November 1, 2010 from http://www.galileo.org/tips/rubrics/ct_rubric.pdf.

Galileo Education Network. (2007- 2008). *Field Study.* Retrieved November 1, 2010 from http://www.galileo.org/tips/rubrics/fs_rubric.pdf.

Hattie, J. & Timperley, H. (2007). The power of feedback. Review of Educational Research. 77(1), 81 – 112.

Hogan, K., & Fisherkeller, J. (1996). Representing Students' Thinking about Nutrient Cycling in Ecosystems: Bidimensional Coding of a Complex Topic. In *Journal of Research in Science Teaching*, 33(9), 941-70.

Houle, M., & Barnett, G. (2008). Students' Conceptions of Sound Waves Resulting from the Enactment of a New Technology-Enhanced Inquiry-Based

Curriculum on Urban Bird Communication. In *Journal of Science Education and Technology, 17(3)*, 242-251.

Jonassen, D., Howland, J., Marra, R. & Crismond, D. (2008). *Meaningful Learning with Technology: Third Edition.* Columbus, OH: Pearson Prentice Hall.

Kelleher, R. (2000, March). A review of recent developments in the use of information communication technologies (ICT) in science classrooms. In *Australian Science Teachers Journal*, 46(1), 33.

Leach, J.T., Konicek, R.D. & Shapiro, B.L. (1992). *The ideas used by British and North American school children to interpret the phenomenon of decay: a cross-cultural study.* Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco: CA.

Magntorn, O., & Hellden, G. (2007). Reading New Environments: Students' Ability to Generalise Their Understanding between Different Ecosystems. *International Journal of Science Education*, 29(1), 67-100.

McLaughlin, C. (1994, January 1). Developing Environmental Literacy through Technology Education. *Technology Teacher*, 54(3), 30-34.

Muir, J. (1911). *My First Summer in the Sierra.* Retrieved May 17, 2011 from http://www.sierraclub.org/john%5Fmuir%5Fexhibit/writings/my%5Ffirst%5Fsummer%5Fin%5Fthe%5Fsierra/.

National Research Council. (2005). *How Students Learn: Science in the Classroom.* Committee on *How People Learn,* A Targeted Report for Teachers, M.S. Donavan and J.D. Bransford, Editors. Division of Behavorial and Social Sciences and Education. Washington, DC: The National Academies Press.

Orr, D. (2004). Earth in Mind: On Education, Environment and the Human Prospect. Washington, DC: Island Press.

Perkins, G. & Grotzer, T. (2001). *Models and Moves: The Role of Causal and Epistemic Complexity in Students' Understanding of Science.* Retrieved May 28, 2011 from http://pzweb.harvard.edu/research/UCPpapers/CausalityAERA.pdf

Reading, J. (2005, February). Integrating Environmental Ethics Across the Curriculum Using an Environmental Literacy Approach to Foster Ecological Stewardship. *Calgary Board of Education,* 1-22.

Roseberry, A.S., Warren, B., & Conant, F.R. (1992). *Appropriating Scientific Discourse.* Retrieved May 28, 2011 from http://www.eric.ed.gov:80/PDFS/ED326058.pdf

Scardamalia, M., & Bereiter, C. (2003). Knowledge building environments: Extending the limits of the possible in education and knowledge work. In A. DiStefano, K.E. Rudestam, & R. Silverman (Eds.), *Encyclopedia of distributed learning.* Thousand Oaks, CA: Sage Publications.

Shane, P., & Wojnowski, B. (2005, March 1). Technology Integration Enhancing Science: Things Take Time. *Science Educator*, 14(1), 49-55.

Syslak, A.M. (2001). *Valuing Learner Ideas on Stream Ecology: Exemplar Vignettes of Thoughts and Feelings During a Unit of Study.* (Master's thesis). University of Calgary, Calgary: AB.

Traina, F. & Darley-Hill, S. (1997). *Perspectives in Bioregional Education.* Washington, DC: North American Association for Environmental Education. pp.77-83.

Willms, J.D., Friesen, S. & Milton, P. (2009). *What Did You Do In School Today?: Transforming Classrooms Through Social, Academic and Intellectual Engagement.* Retrieved February 18, 2011 from http://www.cea-ace.ca/sites/default/files/cea-2009-wdydist.pdf

Zhang, J., Scardamalia, M., Reeve, R., and Messina, R. (2009). Designs for Collective Cognitive Responsibility in Knowledge-Building Communities. *Journal of the Learning Sciences*, 18(1), 7—44.

Zeidler, Dana L.; Nichols, Bryan H. (2009, March 22). Socioscientific issues: theory and practice *The Free Library.* (2009). Retrieved August 01, 2009 from http://www.thefreelibrary.com/Socioscientific issues: theory and practice.-a0201035579

APPENDIX A

Conceptual Framework

A.1. Conceptual Framework

Pre-Unit Understanding of Ecosystems and Human Impacts on Ecosystems

- Understanding of ecosystems and how to study ecosystems
  - Biodiversity
  - Population Dynamics; Meeting Needs
  - Accumulation and Interaction of Abiotic and Biotic Matter
  - All Natural Processes Are Occurring (ecological integrity or ability to recover)
  - Application/Transfer of Knowledge of Ecosystem Across Contexts
- Awareness of potential human impacts on urban parks
  - Impact of dogs in the area (HI0)
  - Invasive species (weeds) (HI1)
  - Impact of paved trails and benches (HI2)
  - Impact of people walking off designated trails (HI3)
  - Noise pollution or human disturbance (HI4)
  - Water contamination upstream (HI5)
  - Impact of surrounding community (pesticides, herbicides, cars) (HI6)
  - Impact of bird feeders (HI7)
  - Other (HI8)
- Common themes or articulated beliefs from student pre-unit work
  - "Green" vegetation is better than "brown" vegetation (ME1)
  - Litter is a threat to ecosystem health (ME2)
  - Mention of pollution and/or deforestation (ME3)
  - Water bodies are a "normal" colour if they are healthy (ME4)

Inquiry Task Rubric used to analyze the unit design:

- Authenticity
- Academic Rigour
- Assessment
- Beyond the School
- Appropriate Use of Technology
- Active Exploration
- Connecting with Expertise
- Elaborated Communication

(Galileo Educational Network, 2000-2008)

Collaboration and group work in face-to-face or online environments. At the highest level, the following are the criteria used to assess the collaboration:

- Evidence of collaborative environment pushing thinking and work forward (F)
- Evidence from collaborative environment of leadership that builds group cohesion and effectiveness (L)
- Evidence from collaborative environment of making connections that build on and extend ideas (C)

(Galileo Educational Network, 2007-2008)

Technology-enriched learning environments and deepening understanding. At the highest level, these are the criteria used to analyze the data:

- Technology is used in a purposeful manner that demonstrates an appreciation of new ways of thinking and doing. The technology is essential in accomplishing the task.
- The study requires students to determine which technologies are most appropriate to the task.
- The study requires students to conduct research, share information, make decisions, solve problems, create meaning and communicate with various audiences inside and outside the classroom.
- Students, parents and the larger community have ongoing, online access to the study as it develops.
- The study requires sophisticated use of multimedia/hypermedia software, video, videoconferencing, simulation, dynamic geometry, databases and/or programming.

(Galileo Educational Network, 2000-2008)

The teaching effectiveness in this unit was assessed in many criteria of the *Teaching Effectiveness Framework* (Friesen, 2009)

- Design is focused on Building Understanding
- Design is Informed by Disciplinary Knowledge
- Work is Authentic
- Work Fosters Deep Understanding
- Assessment is Comprehensive
- Clear Criteria are Established
- Students are Self-Directed
- Students' Relationship to the Work

- Teachers' Relationship with the Students
- Students' Relationships with Each Other
- Teaching is a Scholarship

APPENDIX B

Alberta Program of Studies (1996):

Analysis of curriculum content related to ecological concepts, field study processes and human impacts on the environment before students reach Grade 7

B.1. Alberta Program of Studies (1996): Analysis of curriculum content related to ecological concepts, field study processes and human impacts on the environment before students reach Grade 7

	Ecological Concepts	*Field Study Processes*	*Understanding of how humans impact the environment*
Grade 1	Seasonal Changes The interactions among different parts of the environment, and the recurrence of change as part of a cycle, are important science ideas that are introduced in this topic. (p. B.3) Needs of Plants and Animals How different animals meet their needs. (p. B.4)	Seasonal Changes Record observable seasonal changes over a period of time. (p. B.3) Needs of Plant and Animals By studying a variety of living things, students become familiar with similarities and differences and develop skills for describing and classifying what they see. (p. B.3)	Needs of Plants and Animals Students also learn about their own responsibility in caring for living things. (p. B.4)
Grade 2	Small Crawling and Flying Creatures Identify each animal's role within the food chain. To meet this expectation, students should be able to identify the animals as plant eaters, animal eaters or decomposers and identify other animals that may use them as a food source. (p. B10) Describe the relationships of these animals to other living and nonliving things in their habitat, and to people. (p. B.10)	Small Crawling and Flying Creatures Compare and contrast small animals that are found in the local environment. These animals should include at least three invertebrates. (p. B.10)	Exploring liquids Recognize human responsibilities for maintaining clean supplies of water, and identify actions that are taken to ensure that water supplies are safe. (p. B.8) Small Crawling and Flying Creatures Describe conditions for the care of a small animal, and demonstrate responsible care in maintaining the animal for a few days or weeks. (p. B.10)
Grade 3	Animal Life Cycles students learn about the changes in needs of the young as they grow and develop and about the changing relationship between these animals and their environment. (p. B.15) Demonstrate awareness that animals require different habitats in order to meet their basic needs of food, water, shelter and space. (p. B.16)	Animal Life Cycles Classify a variety of animals, based on observable characteristics Observe and describe the growth and development of at least one living animal. (p. B.15)	Animal Life Cycles Recognize that habitat preservation can help maintain animal populations, and identify ways that student actions can assist habitat preservation. (p. B.16)
Grade 4	Waste in Our World In studying natural systems,	Plant Growth and Changes observing plant growth within the	Waste in Our World They learn that

	Ecological Concepts	*Field Study Processes*	*Understanding of how humans impact the environment*
	students learn that all plants, animals and other living things are made up of materials that are recycled through the environment again and again. (p. B.19) Plant Growth and Changes Recognize that a variety of plant communities can be found within the local area and that differences in plant communities are related to variations in the amount of light, water and other conditions. (p. B. 22)	community. (p. B.22)	personal action in reducing, reusing and recycling materials can help decrease the waste we accumulate. (p. B.19)
Grade 5	Wetland Ecosystems Recognize and describe one or more examples of wetland ecosystems found in the local area; Understand that a wetland ecosystem involves interactions between living and nonliving things, both in and around the water. Understand and appreciate that all animals and plants, not just the large ones, have an important role in a wetland community. Identify the roles of different organisms in the food web of a pond Draw diagrams of food chains and food webs, and interpret such diagrams.	Wetland Ecosystems Through classroom studies, and studies in the field, students learn about organisms that live in, on and around wetlands and about adaptations that suit pond organisms to their environment. Through observation and research, students learn about the interactions among wetland organisms and about the role of each organism as part of a food web. (p. B. 27)	Weather Watch Recognize that human actions can affect climate, and identify human actions that have been linked to the greenhouse effect. (p. B. 27) Wetland Ecosystems Identify human actions that can threaten the abundance or survival of living things in wetland ecosystems; e.g., adding pollutants, changing the flow of water, trapping or hunting pond wildlife. Identify individual and group actions that can be taken to preserve and enhance wetland habitats.(p. B.28)
Grade 6	Trees and Forests Students learn about trees as individual plants and as part of a forest ecosystem. (p. B.33) Describe the role of trees in nutrient cycles and in the production of oxygen. (p. B.33)	Evidence and Investigation Through these studies, students learn to pose questions, devise investigations, recognize patterns and discrepancies, and think logically about what they have observed. (p. B.33)	Trees and Forests Identify reasons why trees and forests are valued. (p. B.33) Identify human actions that enhance or threaten the existence of forests. Identify an issue regarding forest use, identify different perspectives on that issue, and identify actions that might be taken. (p. B.34)

APPENDIX C

Lesson Plan for Interactions and Ecosystems Unit

C.1. Lesson Plan for Interactions and Ecosystems Unit

INTERACTIONS AND ECOSYSTEM LESSON PLAN

Preliminary Activity

Time Allotted: Approx. 1 hour

1. Is the natural area a healthy ecosystem? Draw pictures and describe what if you think the natural area is healthy. What can you remember from your trips there? (Do activity on own. Hand in when complete. No laptops/textbooks: use memory and own thoughts)
2. After students have handed in work, ask them what they came up with. Begin mind mapping with them on the board their ideas (but try not to prompt them too much).
3. Tell the students that a naturalist will be visiting the class to begin the process of helping them determine if the natural area is healthy or not. Tell them they will be setting up their own studies in the natural area to determine if it is a healthy ecosystem. They will see if their assumptions about the natural area are on track with the experts already very familiar with the area.

Conservation Biologist working in the natural area: Guest Speaker

Speaker will focus on:

- General information about the natural area as an ecosystem
- What they know about potential impacts on the area from humans?
- How do they know? How do they study it?

After the speaker leaves:

1. Brainstorm with the students all the possible impacts they could study
2. Each group will decide which one they will focus on.
3. Students need to be reminded that they will only visit the natural area 2 times to do their study. What can they reasonably study in two visits?
4. They will have to come up with their proposal for their research methods. The will be expected to document their study digitally to gather evidence and explain what they did.
5. Groups will be expected to bring their outline to the class for critique and post it on a Google Doc for critique as well. Specific groups will be responsible for providing critique to other specific groups on the Google Doc.

Scientific Panel

1. Students have already received feedback on the Google Doc.
2. Once done receiving feedback, they will fine tune ideas, and get materials ready.

First Field Study

1. Students will be responsible documenting study with digital cameras and to gather evidence.
2. When they get back to school, they need to have time to save photos and begin analysis. They can post their preliminary findings to the Google Docs.

Class Work

1. Students are analyzing, planning for the next trip (what will they focus on?)

Second Field Study

1. Next field trip: students need cameras again.
2. When back, analyzing getting stuff off cameras. Posting findings to Google Docs.

Last Week

1. Analyzing, coming to conclusions, answering focusing question. Preparing a presentation for June 7^{th}.

APPENDIX D

Template used by students to develop their tests on Google Docs.

D.1. Template used by students to develop their tests on Google Docs.

Natural Area: Human Impacts

Focusing Questions: How has the [natural area] been affected by changes? Is the [natural area] changed?

EXPERIMENTAL PLANNING

Topic: Describe specifically what change you are testing. (e.g. "We are studying the impact of invasive caragana shrubs on native bird populations.")

Testable Hypothesis: What do you predict you will find out? (e.g. " We expect that there will be a greater diversity of birds in a plot of Saskatoon bushes when compared with a plot of caraganna."

Quantitative Measurement: What will you measure to prove (or disprove) your hypothesis? You need a specific measurement (numbers), not just observations. (e.g. we will count the number of each type of bird seen on the two different shrubs over the span of 20 minutes. We will repeat the testing 3 times.)

COMPARISON STUDY SITES

Controlling Variables: Describe specifically the impacted and non-impacted sites you will be comparing. How will ensure that the abiotic and biotic components are the same between the two sites (control your variables)? Variables that might be relevant to consider: sunlight, water, exposure, noise, size of area, time spent in observation, other?
Explain the steps you will do to compare the impacted/ non-impacted sites. Be precise and clear. Another person who is not in your group should be able to duplicate your study with your outlined steps.

DATA GATHERING

How will you record your findings? Indicate how you will record your findings (chart? table?) Build your chart / table so you are ready. Make sure you take digital photos as well to supplement your quantitative data.

APPENDIX E

Anecdotal Evidence of Coding of Pre and Post Unit Interviews for each student

E.1. Anecdotal Evidence of Coding of Pre and Post Unit Interviews for each student

Student A

Student A: Pre-Unit Analysis: During the pre-interview, the responses this student gave to the images shown demonstrate some of the key characteristics used to code this student's preliminary understandings: i) a focus on what animals need from the ecosystem and not what plants might need (Code ND1), ii) seeing plants as one entity and not necessarily recognizing that there is a great diversity of plants (Code DD2b), iii) using a single parameter (such as appearance alone) to assess ecosystem health (Code TD2), and iv) not seeing death as a normal part of ecosystems (Code AD3). After being shown an image of forest, and then a picture of a cleared forest, the student states:

> This looks healthy because all the trees are green and it's a habitat for animals. And this [referring to the second picture] looks bad because they cut everything.
>
> (Student A, Pre-Interview, p. 16 of transcript)

Student A often mentions ecosystems as homes for animals, but does not mention ecosystems as a habitat for plants as well (Code ND1). Plants appear to be "in service" of providing a home for animals, but not important in their own right:

> Well sometimes when we're creating land we're taking over animal's places where they live so we're taking that away from them and clear cutting their areas.
>
> (Student A, Pre-Interview, p. 16 of transcript)

Analysis of the pre-unit concept map demonstrated that the student understood that plants and trees might be a part of the ecosystem, but not a complete understanding of the succession of a forest or an individual plant (either seasonally or more long term). It seemed like the image the student had of a healthy ecosystem was static and there was no understanding of how a healthy ecosystem might change over time. For example, the student states:

> Plants and trees exist in the environment. The leaves are usually green and not falling off. The trees have lived for a long time. The branches on the tree have bark and have not fallen off.
>
> (Student A, pre-unit concept map)

When asked how the student would study if the ecosystem was healthy or unhealthy during the pre-interview, the student says, "Maybe take samples of the water…see what kind of area it's in and what kind of animals are supposed to live there." Later on, "Well, samples of trees and stuff and see how old they are." (Student A, Pre-Interview, p. 14 of transcript)

The student is considering more than one possible way of looking at the ecosystem, but the assessment seems limited, and not based on testing hypothesis or complete experimentation to prove or disprove initial ideas. It is unsure how the age of the trees is connected to ecosystem health? The student's thoughts on what animals should live there and then checking to see if this was in fact the case seems to be pushing towards a more elaborate understanding of application and transfer skills. However, it seems that the student is unsure of what exactly to look for when checking for ecosystem health.

At first, it appeared that the student understood the importance of living and dead things in an ecosystem, but after closer analysis it seems like this is more a memorized piece of information rather than a deep understanding. When asked how they could describe the word ecosystem, the student says, “I’d probably say it’s a mixture of living and dead things like trees and animals.” (Student A, Pre-Interview, p. 13). It is unsure how “trees and animals” are examples of living and dead things. The student does not mention things such as soil, nutrients or moisture at any time during the interview. Later on during the pre-unit interview, the student makes it apparent that dead things are a sign of unhealthy ecosystems. ”I would probably look at the water colour and see if there’s living animals and if there’s plants are they alive or dead.” (Student A, Pre-Interview, p. 13).

<u>Student A: Post-Unit Analysis:</u> Upon completion of the unit, the student has moved to a deeper understanding of diversity and mentions abiotic and biotic in their description of ecosystems as well as the importance of diversity and specifically the importance of different ages of species. Student A still mentions dead plants as an indicator of health and has not quite moved to see succession or death as a natural part of an ecosystem. (Student A, Post-Unit Interview)

This student was also much more articulate in the post-interview data at explaining the cause and effects of specific human impacts on the ecosystem (understanding of scale). This was also seen in the post-unit concept map analysis:

"Illegal pathways are getting rid of vegetation" and "Caragana doesn't allow plants to grow around it." (Student A, Post-Concept Map)

Student B

Student B Pre-Unit Analysis: It was difficult to code this student's initial ideas about ecosystems. It appears that the student seems to see ecosystems as a home and is articulating that it is difficult to determine the size of an ecosystem:

> Because from space it looks all green but when you get close the colors start to change. So I would like, well, it would be different from a globe it would be more like real [asked to clarify what they mean] Well, I would probably say well you're always in an ecosystem because ecosystems aren't one thing they're a bunch of different things like a house or garden.
>
> (Student B, Pre-Interview, P. 13)

From this student, we see evidence that they consider the image of a forest an example of a healthy ecosystem, and do not seem to see that other ecosystems such as grasslands, arctic ecosystems or other can also be healthy. The following passage was coded RD3, TD2, and AD3. The student was asked what they would look for to determine if an ecosystem was healthy or not:

> Well, if it had like a bunch of cars and like oil spills and stuff it wouldn't be a healthy area but if it had like green grass and like lots of trees.
>
> (Student B, Pre-Interview, P. 13)

The image of a healthy ecosystem having to be "green" persists in this student's analysis of the images he is shown later in the interview. When shown a picture of a lawn with a few well-placed shrubs and a brick pathway, the student indicates that the ecosystem would be healthy if you removed the brick pathway because the grass was green. The student fails to recognize diversity as a key indicator of ecosystem health.

This student placed a lot of emphasis on the impact of cars on the environment (mentions hybrid cars, biking instead of driving, car tracks in natural areas) but understanding seems to shift back in forth between understanding the scale of impacts. For example, the student mentions smoking as having an impact on ecosystems as well as throwing garbage on the street.

Student B: Post-Unit Analysis: In the post-unit analysis, we can see that Student B's definition of ecosystem has evolved. At the beginning of the interview analysis, Student B was given a DE2 code for mentioning both plants and animals in definition, but also a RD3 code:

> A place with lots of vegetation where animals live, or humans…Well there is two kinds of ecosystems. There is a healthy and a bad. And a healthy ecosystem has lots of plants, vegetation, people – well not any pollution but little pollution. And then there is unhealthy ecosystems which are pretty much like cut down trees, no animals, little plant life, and lots pollution.
>
> (Student B, Post-Interview, p.10)

During the post-unit interview, we could see the beginning of a developing understanding of the importance of diversity and how to develop a test to check for ecosystem health. The following passage was Coded TE2, AE1, DE2:

> INTERVIEWER: So say you come across a natural area, what would you do or what would you study to determine if it was healthy or unhealthy?
>
> RESPONDENT: I would see if there is lots of animals. I would test the soil to see if it was easy to dig up or really hard and beat down. I would see the people are there and the plant life, if there is lots of plants or if there is like a couple of plants but they've been planted by humans. [0:27:04.3]
>
> INTERVIEWER: And what do you mean by 'lots'?
>
> RESPONDENT: Like a forest where there is a tree and a whole bunch of shrubs. And there's grass but not a lot like (inaudible at 0:27:26.4).
>
> INTERVIEWER: So like a lot of different kinds, is what you mean?
>
> RESPONDENT: Yeah.
>
> INTERVIEWER: So diversity. Is that what you mean?
>
> RESPONDENT: Yeah.
> (Student B, Post-Interview, p.11)

But by the end of the interview it was felt that the student still had difficulty applying the concepts learned to new contexts (Code TD1). When asked about the image with a garden and a pathway going through it, the student indicated they thought it was healthy. When questioned further about the diversity of plant life there, the student mentioned it was still diverse despite there only being lawn grass and a few of the same species of shrubs. It seems this student has a difficult time differentiating between a manicured garden and a natural area. (p.13 of post interview transcript)

In the post-unit analysis, this student was showing a lack of complete understanding of human impacts on ecosystems particularly in reference to the scale of impacts (coded RD3, RD1):

> INTERVIEWER: And how do you think that humans have a positive or a good impact on ecosystems?
>
> RESPONDENT: I think we have a good impact on ecosystems because if there's a tree that it on top of like, on (inaudible at 0:28:04.9) we'd probably move the tree so it could be cut out. And say there's a bunch of – like the oil spill in the Gulf of Mexico, humans are trying to clean that up. [0:28:31.2]
> (Student B, Post-Interview, p.12)

Student B demonstrated evidence that they are starting to question more deeply what they are seeing (Code DE2), but not quite at a fully developed into a stage where they hypothesize and then consider experimentation (Code TE3). When asked to reflect on one image, the student says:

> It looks like there is lots of vegetation, but they are all big trees so you don't know if there is other ones underneath. So I'm just assuming that they'd be healthy.
>
> (Student B, Post-Interview, p.13)

Student C

Student C: Pre-Unit Analysis: From the pre-unit analysis, Student C seemed to have a more elaborate understanding of ecosystems and the interconnections in ecosystems. This student made a point of highlighting the difference between human and natural environments (Coded DE2, NE1):

STUDENT 10: I would say ecosystem is like kind of environment.

INTERVIEWER: Okay.

STUDENT 10: And then it's like the way everything works in it so it's like a system kind of.

INTERVIEWER: Oh, okay.

STUDENT 10: Yeah, I would just kind of make it like it's the way that things work in the environment.

INTERVIEWER: Okay. And how would you define environment to somebody?

STUDENT 10: I would say environment is like where everything kind of lives like plants and animals and then environment yeah it's where and there are different environments for like different things.

INTERVIEWER: Okay. Anything else?

STUDENT 10: Well, there's like natural environments so there's like plants and animals and stuff and then there's like human made environments with like buildings and everything.
(Student C, Pre- Interview, p.19 of transcript)

The student seems to have an understanding that moisture is an important part of the ecosystem, but seems to think that winter is an unhealthy time of the ecosystem (does not understand the seasonal succession of ecosystems). Although the student mentioned at the beginning of the interview that there are "different environments for different things" the student seems to see healthy environments as only green and lush. I wondered about his understanding of ecosystems that were not green and lush (grasslands, arctic ecosystems, desserts). The following was coded AE1, AD3, RD2, ND2:

INTERVIEWER: - how would you if you're looking at this natural area, how would you tell if that natural area was healthy?

STUDENT 10: Well, if everything was like, if it was summer and everything was like green and moist then it would seem healthy but if everything was like crunchy and kind of weird color like reddish and like all droopy it probably wouldn't be very healthy. But if everything was like colorful and pretty and like wet and stuff it would probably be healthy.

INTERVIEWER: Okay. Okay, now let's say the opposite, how would you, and you kind of described this -

STUDENT 10: Yes.

INTERVIEWER: - how would you describe it if it was unhealthy?

STUDENT 10: It would probably be like the plants and stuff would probably be crunch and if there are animals they would probably be like looking like really bad, in bad shape, and it would be kind of the plants would be off-colored probably and they would just be drooping. [0:29:08]
(Student C, Pre- Interview, p.20 of transcript)

Student C highlights what others demonstrate as well, that students seem to see summer as a healthy time of year, where as winter is an unhealthy time for an ecosystem.

This student seems to have a deeper theoretical understanding of the bigger picture, or has thought more about the larger implications of urban sprawl and habitat loss, resource use, and humans "thinking they are the dominant species" (Coded RE3). They also seems to consider more variables and dives more deeply into the analysis of the images (Coded TE2):

INTERVIEWER: Okay, good. What about Number Two?

STUDENT 10: It is being inhabited by humans so there's like brick and stuff there and the plants and grass look to be healthy except they're probably like growing in green houses and grown for that and being fertilized and have maybe possibly like things that are bad for the earth in them to make them look green. So it looks healthy but it may not be as healthy as it looks.
(Student C, Pre- Interview, p.25 of transcript)

<u>Post-Unit Analysis:</u> In the post unit analysis, the student demonstrates an even more elaborate understanding of ecosystems, particularly having a deeper understanding of the importance of biodiversity to ecosystem health:

> RESPONDENT: I think an ecosystem is kind of like a pyramid where there is everything relies on everything else. So there is the things that rely on the least, and then as it goes up everything is reliant on the thing before it, and without one thing in it, it would crash.
>
> INTERVIEWER: Good. And how would you tell if an ecosystem is healthy?
>
> RESPONDENT: I think a healthy ecosystem wouldn't have impact from humans in it. And I would think that it has a lot of natural species and not a lot of invasive species in it. And it is not impacted by humans. There is lots of diversity in it, in age and species. [0:39:17.5]
>
> INTERVIEWER: And how would you tell if an ecosystem is unhealthy?
>
> RESPONDENT: I think if there is lots of human impact, it would be unhealthy. Or if there is all invasive species taking over. Or if it is all one age. Or if there is no diversity in it, it would be unhealthy because it could be wiped out easily then.
>
> INTERVIEWER: And why is something that doesn't have a lot of diversity can be wiped out easily?
>
> RESPONDENT: If it is an age thing, if all of them are the same age once they die it will be unhealthy because it will take a long time for the new ones to grow back in and reform it. And if there is not diversity in the plants – if one disease comes and takes over that plant then the entire thing could die because it will all come from the plant that got the disease. [0:40:12.3]
> (Student C, Post- Interview, p.14 of transcript)

The student seems to have a deep understanding of human impacts on ecosystems but flips back and forth between small and large scale impacts as if they are one. (Coded RE3, RD1)

> RESPONDENT: Well I think that humans can help with ecosystems because if the ecosystem is naturally crashing or going down, the humans can do things to help it to stay up and running well. But the ecosystem couldn't do on its own. [0:41:10.6]

INTERVIEWER: And how do you think humans have a negative or a bad impact on ecosystems?

RESPONDENT: They can disrupt them and make major changes into them. And they can harm the earth with it. So with cement and stuff, putting it down. And noise and going through, it could change a lot of behavior of animals, and how they go to the plants and find food and everything about them, it could completely change a lot of that.

INTERVIEWER: And why do you think humans impact ecosystems in the way that they do?

RESPONDENT: I think sometimes because of the growing population they impact them because they just want to keep growing out and out because there is more people. And some people like to be in the trees and stuff, but they don't realize that they are impacting it. They just like being in that type of environment. [0:42:16.7]

(Student C, Post- Interview, p.15 of transcript)

This student demonstrates how some students have trouble distinguishing between an impact that could lead to an unhealthy ecosystem (an inability to recover from the impact) and a small impact that could lead to a small isolated change that the ecosystem could recover from. This distinction is important in developing a more holistic perspective of ecosystems.

Student D

Pre- Unit Data Analysis: When asked how they would describe the word ecosystem, this student replied, "stuff to do with nature" but had no other words to elaborate on her understanding of this concept. When asked how they would study a natural area to determine if it was healthy or not, the student indicated that they would go to Google, the Internet and some books, and look up "how is this healthy?" (Student D, pre-interview transcript, p. 17)

This student mentioned that humans impact the environment by cutting down trees and polluting the air and when asked to assess the ecosystem's health in the four images, they used "alive and dead-looking or green" as their only parameters.

Post-Unit Data Analysis: For this student, the idea of living plants "green looking" versus "dead-looking" as an indication of ecosystem health persists, even despite reflecting on their own study (AD3). Despite the fact that their specific study did not focus on living and dead plants, when they reflect back on it, they mention living and dead plants as part of the study. The interviewer had to probe the student more deeply to get them to see beyond death as the only way to study the health of an ecosystem:

> RESPONDENT: I'd tell them that a healthy ecosystem would be diverse. So there'd be lots of plants. There would be a lot of living things. And there wouldn't be any pathways or … just, it wouldn't be disturbed.
>
> INTERVIEWER: And how can you tell if an ecosystem is healthy? You've kind of answered that a little bit already, but what would you do to determine. Or how could you tell if you came across a natural area, if it was a healthy ecosystem? [0:01:02.4]
>
> RESPONDENT: Well it probably wouldn't be dead. There wouldn't be a little people there. There wouldn't be benches or pathways, or garbage. So probably everything would be natural.
>
> INTERVIEWER: And what do you mean when you say, 'Natural'?
>
> RESPONDENT: Nothing has been disturbed. Everything is healthy, and there's no benches and stuff.
>
> INTERVIEWER: Okay good. And how would you be able to tell – and you've kind of answered this – how would you be able to tell if the ecosystem is unhealthy?

RESPONDENT: If it is dead and been disturbed?

INTERVIEWER: And let's say that you wanted to study an ecosystem to determine if it was healthier and healthy. What would you do?

RESPONDENT: Probably some of the tests that we did, that our class did.

INTERVIEWER: Can you describe some of the kind of testing that you did?[0:02:16.6]

RESPONDENT: Uhh… this is hard. I don't know.

INTERVIEWER: I think, so you kind of came across that ecosystem that make you zone in to test (ph)

RESPONDENT: Maybe like which plants – like how many plants that are dead. Yeah.

INTERVIEWER: And what was the study that you guys did, your group again?

RESPONDENT: Our test was how many, like how many, the number of plants around native species and invasive species.

INTERVIEWER: And so what did you find out in your results?

RESPONDENT: We found out that there are more plants around native species than invasive species.

INTERVIEWER: Okay. So there is more diversity.

RESPONDENT: Yeah. [0:03:15.7]

INTERVIEWER: And did you find around the invasive species that there were a lot of dead plants? Or did you find that there just wasn't as many diversity of plants?

RESPONDENT: There were more.. it depends. There were a couple of plants around it, but it just depends on the radius. If it near the plant then it is just grass and just dandelions.

INTERVIEWER: And that was it.

RESPONDENT: Yeah.

INTERVIEWER: Whereas around the native species, what did you find?

RESPONDENT: We found around trees and there were more plants around it.

Similar to some of the other students, this student demonstrates a lack of understanding of how humans can help ecosystems or human impacts on ecosystems, also lacks a clear understanding of what a natural ecosystem is versus a garden. When asked how we can help ecosystems, the student says:

> Well we could probably plant some more trees and stuff. We may like, if the weather is not raining or anything we'd probably just water the plants." (Student D, post-unit interview, p.3)

Student E

Pre-Unit Analysis: Student E was quite strong from the start. They had a deeper understanding of connections as being important in ecosystems, as well as mentioning soil in their descriptions. Not many students mentioned abiotic components as being an important part of ecosystems. However, as you can see from the transcript, the mention of soil was in reference to a lack of vegetation and an indication of an unhealthy area (Code AD3):

> RESPONDENT: An ecosystem is like how everything is connected to each other like living things. Like a forest all the animals and the trees are connected because they need each to survive and stuff.
>
> INTERVIEWER: Anything else? I know that's kind of a tricky question. Yeah.
>
> RESPONDENT: I don't think so.

INTERVIEWER: Good. Let's say you went for a walk and you came across a natural area like a ravine or something like that. How would you tell if that natural area was healthy? What would you look for? [0:01:04]

RESPONDENT: Like vegetation. If there's soil so it's dead and stuff; maybe signs of wildlife.

INTERVIEWER: Anything else?

RESPONDENT: No signs of humans like concrete, or bricks, or anything like that.

Despite this student's more elaborate understanding in the other pre-unit work, this student had no ideas about how to study an ecosystem. When the student was asked what they would do to actually study is an area was healthy or unhealthy by studying in the actual environment, the student had no ideas nor felt comfortable to even attempt a guess or possibility for how they would approach such a study.

Post-Unit Data Analysis: From the post-unit data, we can see that the idea of death as an indicator of health persists, despite an acknowledgement of the importance of diversity:

INTERVIEWER: What about Number 3?

RESPONDENT: It looks healthy, I guess it is green. But it doesn't seem like there are a lot of different species, it is just the same tree. I don't know. But it looks pretty alive and healthy.
(Student E, Post-Unit Interview transcript, p. 10)

We can also see from this student's responses that their understanding of the scale of human impacts is difficult for them to interpret. Will the impact cause a small reversible change, or a major disturbance in the ecosystem? This student shows that they have difficulty wrestling with this concept:

> INTERVIEWER: And then the opposite of that, how do we have a negative or a bad impact on ecosystems?
>
> RESPONDENT: Whenever we go leaving trails. Sometimes we're in the park and we'll decide to pick the plants because they look pretty or something and then that does not have a good effect. We can pollute the air with our cars. [0:18:10.0]
> (Student E, Post Interview, P. 8)

Student F

Pre-Unit Analysis: Student F was the first student to mention ideas related to developing understanding of species population size. The ideas ended up being coded as developing and not quite elaborate as this was one of the only parameters they listed for determining ecosystem health, but it was interesting that no other student mentioned the numbers of animals as part of their thinking:

> INTERVIEWER: No, okay. And let's say that aside from just looking at the ecosystem you wanted to actually study that ecosystem to determine if it was healthy or unhealthy. So what would you do to study it more than just eyeballing it and looking at it?
>
> RESPONDENT: Well I would see how many animals normally visit that location because the more animals the healthier the ecosystem tends to be.
> (Student F, Pre-Interview, p. 9 of transcript)
>
> Student F also made mention of how the media impacts our perceptions of ecosystems:
> By watching the media like listening to Al Gore or David Suzuki say deciding whether or not it's as bad as they say it is.
> (Student F, Pre-Unit Transcript, p. 11)

Post-Unit Analysis: In Student E's work on the post-unit concept map, they demonstrated that although they noticed potential impacts, they took an overall more holistic look at the ecosystem in determining health. This shows a deeper understanding of concept of scale (RE1):

> As you can see in my drawing the [natural area] is mostly healthy. There is some garbage and illegal trails but there is a lot of different animals and plants.
> (Student F, Post-Unit Concept Map)

This student also forced me to reexamine my coding rubric, as the student very clearly articulated how people can help ecosystems by clearing out infected pine beetle trees and re-introducing species if there is "not enough". This leads me to believe that the student is developing an understanding of population dynamics, and forced me to develop a code to highlight this deeper understanding of how humans can have positive, not just negative, impacts on the environment. This new code ended up being an extension of section RD3. This thinking, articulated by the teacher, is exactly the type of work that conservation biologists engage in.

Student G

<u>Pre-Unit Data Analysis:</u> Student G demonstrated how many of the students wrestled with the second image they were shown during the interviews. The image is of a manicured lawn, with a brick pathway going through it. There is no diversity in plant species, just lawn grass and the same shrub placed systematically around the pathway. The student struggled with whether or not it was a healthy ecosystem, as it is "very green", but obviously not very diverse. Student G:

INTERVIEWER: Okay. How about Number Two?

STUDENT 7: Number Two is hard to tell because it looks like humans did it, it doesn't look natural.

INTERVIEWER: Okay.

STUDENT 7: But like it looks like they used a lot of fertilizer and stuff.

INTERVIEWER: Okay.

STUDENT 7: But it still looks pretty.
(Student G, Pre-Interview Transcript, p. 7)

This student also shows how the student have learned an analogy of the ecosystem behaving as a cycle with one thing connected to the other, but their interpretation of how this analogy works in different contexts is limited. For example, this student says:

INTERVIEWER: And so first things, can you tell me like say you wanted to describe the word ecosystem to someone who is younger then you like in Grade 2 or Grade 4 or whatever, it's kind of a tricky word, the word ecosystem, so what – how would you tell someone what an ecosystem is?

STUDENT 7: I say it was like a life, how things link to each other.

INTERVIEWER: Okay. Anything else?

STUDENT 7: It's kind of like a circle like it will (inaudible at (0:00:31), it's like a circle it all links together.

INTERVIEWER: Okay. Okay cool anything else?

STUDENT 7: And like (inaudible at 0:00:43) animals kind of live off each other, like.

INTERVIEWER: Okay. Anything else?

STUDENT 7: No, I don't think so.

INTERVIEWER: Okay (inaudible at (0:00:57), okay.

STUDENT 7: Like a fox would eat a robin and then robin eats the grass or whatever and then the, yeah.
(Student G, Pre- Interview Transcript, p.1)

Post-Unit Analysis: By the end of the post-unit interview, this student has a more elaborate definition of ecosystem including things like "a network of living things" that run together, and the word "connected". The student mentions that healthy ecosystems have diverse wildlife and plants, have "lots of plant species", and goes on to extend this further by mentioning decomposers.

This student's analysis of the second image (the lawn with the brick pathway) has changed as well. This time, the student says it looks very impacted and is all the same, and that "all that is there is grass". (Student G, Post-Unit Interview) This student has developed a deeper understanding of diversity and is able to transfer the understanding to new contexts.

APPENDIX F

Anecdotal Evidence of Collaboration

F.1. ANECDOTAL EVIDENCE OF COLLABORATION

Evidence the collaborative environment pushing thought and work forward (Level 4)

The student editors looking at another group's work focused much of their attention as to whether or not the group developed a fair test. The suggestions of the student editors on the Google Docs sometimes led to changes in the experimental design and more precise experimental methods. This can be illustrated in the following way:

One student in the group reflects that the measurement instruments developed for their test might not be accurate enough to draw reliable conclusions. He says, "I think there should be a forth step like after me [we?] record the data we will check if it is right or something like that. But I am sure it will be right." The group then goes back and revises their experimental methods to indicate, "Spend more time at each site and make more precise plant counts." (Google Doc Group 1, May 2010, p.6-7).

During the scientific panel discussions, students were also questioned on the accuracy of their testing methods and the reliability of their results based on their planned measurement tools. The teacher became a part of the panel and had equal opportunity during the discussion to provide feedback to each group member. Her question regarding how the students planned to measure the radius around the shrub they were testing was an effective one to encourage the group, as well as other groups, to consider the importance of quantitative measurements in their field studies. (Scientific Panel Discussion Group 1, May 2010, 05:02)

Student groups participated in two rounds of testing for their comparison study. Following the first round of testing, peer feedback was given to each group on their progress and specifically how they could modify their second round of testing to get more accurate results. During this feedback session, I noted a chain of one suggestion made by a student that kept reoccurring during the collaborative feedback. One student suggests to the presenting group during discussion that they should spend a longer time period at their test site to get a more accurate count of the squirrel species they are studying. A few minutes later, she repeats the recommendation after some more discussion. A few minutes after that, another student in her peer feedback group also recommends a longer time period at the test site. (Group 2 feedback in videotaped dialogue, May 2010)

When I asked the students about their collaborative efforts in the post-unit interviews, the students did mention times when peer feedback helped move their work forward. Often times, the suggestions they remembered were very procedurally based, and not necessarily centered on broadening or deepening their thinking. For example, when asked about how different groups were helpful, one student stated:

> …because the first time we tried, we were just wandering around to see if we could find a different kind of shade but we realized that we didn't find anything. So that other group just told us to stay there and maybe have a bigger radius. And we were told take pictures of a wider area in general.
>
> (Student D Post-unit interviews, June 2010, p. 4 of transcript)

This student articulated how the collaborative work led to procedural changes. Another student also stated how having their peer feedback offered new insights into their procedural thinking:

> Yeah because the other group would be able to sometimes see things that you wouldn't think of. Or see things that you didn't see when making your procedures and you could do the same for them. So it would help you make your study better than it was.
>
> (Student C Post-Unit Interviews, June 2010, p. 16 of transcript)

It was intriguing to me that when one student talked about their group's work, they considered all the individual group member's thinking as one. If you notice in the following statement, the student says, "*we* realized" (not *I* realized) and then describes how the whole group changed their thinking, as if the group operated as one in making more procedural scientifically accurate decisions:

> There is like if one of the groups that was there they were at a birdfeeder and they were looking for birds and squirrels there. And we had birds at ours so *we* were going to switch but then *we* realized *we* can't because it has to be in the same spot. So *we* just counted the squirrel and *we* just counted the birds that were there.
>
> (Student B in Post-unit interviews, June 2010, p. 13 of transcript)

Evidence of "uses a variety of collaborative environments to keep in touch with group members and to build knowledge" (Level 3)

Some peer editors made suggestions about overlooked background information necessary for the studies. One student commented how another group noticed they were missing some information about caragana that they had not yet discovered in their preliminary research. Another student commented how the peer editors help put them back on track and indicated that they were missing information that would help them with their study. (Student Post-Unit Interviews, June 2010). Both of the above comments are evidence of how the collaborative environment helped build their knowledge. It is not evident of the collaboration causing a shift in thinking, and so remains at a level 3.

One student did mention during the post-unit interviews that the scientific panel and final presentations had an impact on their learning:

> Yeah. When we were doing the feedback between the different groups, they gave us some suggestions to help improve our study. And when I was watching the projects I also learned about what they were doing. (Student E Post-Unit interviews, June 2010, p. 9 of transcript)

Peer feedback also helped with the group's accuracy:

> It was just kind of advice about maybe make your study longer, or pick a better area. Nothing really had a huge impact on our study, but it just helped it be a bit more accurate.

(Student C Post-Unit Interviews, June 2010, p. 16 of transcript)

The teacher mentioned in her post-unit interview that the groups managed themselves to be accountable for their learning. She explained how she provided a basic structure of deadlines but that the group's themselves organized accomplishing the tasks:

> INTERVIEWER: Did you notice that they seemed to be more accountable – how did you notice their accountability? Was there a lot of checking in with you during this, or was it more …
>
> TEACHER: Not really. I put the dates up on the board for when they had to have things done by, and they were pretty good about getting them done by the date. I think having the other group checking in on them, and then through each other. Not letting someone slip through and not get their stuff done. And there were times when there were groups staying in at recess to get things done. But they were doing that on their own, they weren't under direct instruction.
> (Teacher Post-Unit Interview, June 2010, p. 7 of transcript)

Evidence in the collaborative environment of leadership that builds group cohesion and effectiveness. (Level 4)

There is overlap in this section of how the self-management of the group enabled the members to be more cohesive and effective, and how the appropriate use of technology enabled the groups to be cohesive and effective. The implications of technology will be discussed in the next section. I will attempt to look at evidence of how the group's relationships with each other and leadership within the group enabled them to be cohesive and effective in this section.

Within the Google Docs and face-to-face collaborative work, it was apparent that the groups were self-organizing to accomplish their tasks. For example, during the background research portion of their work, each group member contributed different information to gather as much relevant information as they could about their topic on the Google Docs. Within the Google Docs, new information builds on the other members' contributions and there is little repetition of facts. Some form of leadership must have existed within the group to divide up the workload and tasks that needed to be accomplished. In the scientific panel discussion, each group led the discussion to receive feedback from their classmates. The self-managed group assigned each member specific tasks for the scientific panel. Through their leadership of the panel discussion, the group receives the specific feedback they need to move their study forward. This is apparent in the video footage with each group member speaking at various points during the discussion. At a glance from the video footage, there are no group members who appear disengaged or unsure of what their role is or the group's direction. All group members seem to be invested in the group's work.

One student specifically mentioned another student in the group who "seemed to know a lot." (Student E Post-Unit Transcripts, June 2010, p. 18) This student was singled out as a leader who was able to help the group put together an effective presentation. It is apparent that the leadership of this one particular student was seen as valuable.

Evidence of students' use of the collaborative environment to make connections and build on and extend each other's ideas. (Level 4)

The best example I found of students building on ideas on the Google Docs was a series of questions and comments made by the student editors that seems demonstrate how one idea is taken up and explored further by the students. The online conversation begins with one student editor asking:

> The changes seem like they will help out the testing a lot. It seems like you will still have troubles finding a good site without a bird feeder, though. What will you do if you can't find any?
>
> (Google Doc Group 2, March 2010, p. 8)

Later, another student editor builds in this thinking by asking:

> What will your group do if no squirrels come? Do you think your test is accurate if only a couple of squirrels come?
>
> (Google Doc Group 2, March 2010, p. 9)

Further on, another student editor asks:

> What if the same squirrel comes a lot?
>
> (Google Doc Group 2, March 2010, p. 9)

Based on the first student editor's thoughts about the location for their study, the other student editors continue to build on the idea about the accuracy of their testing. This kind of questioning seems to go deeper beyond more procedural recommendations to the validity of data and how accurate their analysis might be when the group starts trying to form conclusions based on their data. It seems like the initial idea forces the other students to consider the investigation more deeply and inspires deeper more meaningful questions from the others. The questioning builds on the ideas put forth from the first question. The questions posed by the student editors are challenging. How did the group take up these challenging questions? Are challenging questions in online collaborative environments easily ignored if the group does not know what to do with them? Was this line of questioning helpful in formulating the group's conclusions?

I reviewed the group's final presentation and looked for evidence of this thinking emerging in their conclusions. The group did have a low number of squirrels observed at each site that they compared (feeder area versus no-feeder area). They did comment that because of the low numbers, the reliability of their tests were questionable, and suggested that they needed more time and more frequent visits to their test site to get more accurate results. They also suggested that they needed to find locations that were further away from pathways because they felt human disturbance may have also impacted their results. Despite this, the group still concluded that feeders needed to be removed from the natural area and that the squirrels visited them more often than the other areas because it was easier for them. (Student Final Presentation Videotape, June 2010) It was intriguing to see how despite an articulated understanding of the reliability of their data, the group still jumped to a conclusion based on their small amounts of data.

Another example of this kind of big picture questioning occurred when a student editor challenged a group to think about clarifying their hypothesis. He states:

> You have a good idea for quantitative measurements. Your hypothesis makes sense, but you may want to say why you think that there will be more plants around a Saskatoon bush. An example could be: I think that there will be more plants around a Saskatoon bush because...You say that the caragana can grow in poor soil, and it messes up the eco system, so you clearly state that caragana is a bad plant for this eco system.
>
> (Google Doc Group 1, May 2010, p. 7)

This student editor posed a challenging question to the group that was intriguing to me. The naturalist from the area had spent quite a considerable time discussing with the students about how invasive plants create conditions that make it unfavorable for other plants to grow. What about the opposite situation? How do native plants create favorable conditions for numerous different plants to grow together in one area? This question, although seemingly obvious at first (one could say that the conditions are what an invasive plant is not) was quite a deep question that could lead to a deeper understanding of how native plants help facilitate the conditions that enable numerous plants and animals to live together. The group that this student editor questioned did not modify their hypothesis based on this question, nor does it seem that they specifically addressed his question.

In this case, the questioning directed at this group around this topic continued during the scientific panel. The teacher asked the group to consider as a sub-question whether or not invasive plants grew under invasive shrubs, and if native plants grew under native shrubs. (Scientific panel discussions, May 2010) This was an interesting question, very similar to the one posed initially by the student editor in the google docs. I wondered if the group considered this in their testing, and whether or not they considered why this may or may not be true. If they considered the question, their understanding of invasive plants and their impacts on ecosystems would most likely increase dramatically. What are the ideal conditions (soil acidity, moisture content, nutrients, other?) to encourage plant growth in a natural area? Did the group take up their teacher's question in a meaningful way?

I examined the final presentation of this group again. The group presented their data, which included counting the plants that were growing under the invasive species (caragana) and under a non-invasive species (wolf willow). Their data showed more plants and more diversity under the non-invasive species. They did mention that there was invasive grass under the caragana and 5 different flower species under the native species. This did address their teacher's question in some ways. In their conclusion, the group stated that: "caragana can kill plants". (Student Final Presentation Videotape, June 2010) The group did not probe deeper into soil conditions under each plant and did not consider testing the ground for more information about why there was a difference in data underneath each type of plant. I am sure that time constraints and other factors influenced how much testing the group could take on, and when the teacher suggested the sub-question there was not enough time during the panel discussions to discuss how the group might take up the question in a meaningful way. It would have been interesting to question these students on what they thought the soil conditions would be like under each species. I was intrigued that this initial idea, posed on the google docs and again during the scientific panel questioning, was not really taken up pursued further by the group other than in a procedural counting of species.

The teacher articulated moments during the discussions where it was the students who, unprompted, made a deeper connection to ethics and their field study, and how their own understanding of the study became connected more deeply to their everyday lives. It exemplified clearly how the students were starting to recognize the deeper implications of their learning and how their actions had an impact on the environment:

> INTERVIEWER: Were there things that popped up in the class discussions that helped them to think about things differently? Do you remember particular kids saying something that shot off the discussions in a different direction?
>
> TEACHER: Well the whole conversation about ethics was kid-driven. It wasn't anything that I even thought of bringing up… and it is a pretty good discussion of the parts of science and the boundaries that science has to live within in terms of the ethics and the morals behind following the guidelines and rules of a certain area…And we discovered that it is a big grey area. So things like that came up, and they were really interesting. [0:23:30.3]
>
> (Teacher Post-Unit Interview, June 2010, p. 8 of transcript)

In my discussions with the teacher, she mentioned that in some cases she felt the collaborative nature of the room might have allowed certain misconceptions to remain unchallenged. In this case, the teacher felt there was a tendency for students to over-generalize one of the human impacts as indicators of a completely unhealthy ecosystem. She felt the students would jump to conclusions quite quickly based on a small piece of evidence. During the post-unit interview with the teacher, she states:

> …I have a feeling some of the kids were coming away thinking that the [natural area] is not healthy because of their localized study. So as, I think they can make generalizations very easily and say, because there were birdfeeders, it is not a healthy ecosystem. When in reality that is a very

> small component of the ecosystem. That probably isn't having as negative a consequence as they think, based on their study.
>
> So there were like, 'These are the pathways, yes. They are contributing to erosion and invasive species, but in the grand picture of that entire ecosystem, it is not really affecting wildlife movement.' It is not…Like I think they were really quick to jump to – because we said it is something that was negative, that this is an unhealthy ecosystem.
> (Teacher Post-Unit Interview, June 2010, p. 4 of transcript)

She goes on to further articulate the how misconceptions might get perpetuated:

> I think it depends on who is providing that feedback. Because there are kids that will just perpetuate misconceptions to each other. You need to be careful. And it takes a high degree of monitoring. I probably wasn't monitoring as closely as I should have been to catch all of those. But I think that they could kind of self-perpetuate misconceptions potentially, if someone doesn't interject and say, 'Actually why don't you think about this.' And I think that happened orally when they were doing their practice presentations, and even after the presentations, there were kids who were asking questions that were looking at some of those misconceptions.
> (Teacher Post-Unit Interview, June 2010, p.5 of transcript)

This hunch that the teacher has that the students might be jumping to conclusions was intriguing for me to explore. When I looked back at the 7 student's post-unit concept maps, all of them articulated both healthy and unhealthy elements in the natural area under investigation. Despite this the impression that the teacher had that students might be jumping to conclusions, none of them seemed to be completely tunneling their conclusions into one direction and were in fact considering many points of view.

Evidence of Level 2 and 1 Collaboration

During the post-unit interview with the teacher, she did mention that on occasion she felt that the collaborative nature of the field study resulted in some off task behavior at times, and that in some groups, some members might have contributed more to the study than other group members. Interestingly, the off task behavior seemed to occur more indoors than when the students were at the study site. Overall, the teacher seemed to express excitement about the overall engagement of the students in their work. When asked about the teacher's own learning and her students' in the post-unit reflection interview, the teacher said:

> INTERVIEWER: Do you think that your own thinking has changed in any way?
>
> TEACHER: Well I know more about the [natural area] than I knew before I started this. I didn't know about all those illegal trails. I had no idea that they were there and that we weren't supposed to be on them. So perhaps going down there now will change the way I present how we interact in that space, as a class. Just knowing that now.
>
> I just really loved seeing them down there and really engaged in their work. There were small groups that were super-focused for the hour and a half that they were there, on what they needed to accomplish. And there wasn't any goofing around. There was no behavior issues to deal with. They were respectful of the area they were in, and worked really well together. So I think it just reinforced in me the need to do that. To work with my students. [0:24:37.2]
>
> INTERVIEWER: And do you think the, having the purpose and the intention behind why they were there, and the…
>
> TEACHER: Oh absolutely. It was a serious endeavor.
>
> INTERVIEWER: If you had just taken them on a hike down there you may have seen different things.
>
> TEACHER: Oh yeah. Totally.
>
> (Teacher Post-Unit Transcript, p. 8-9)